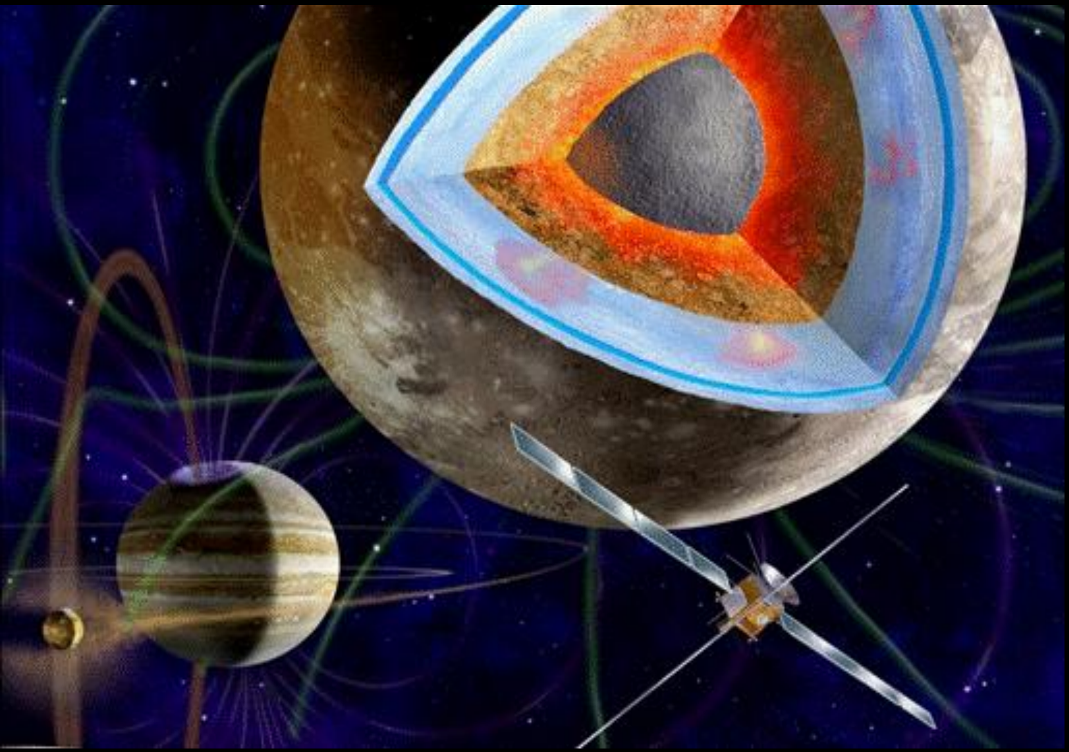
Astrobiology aspects in the JUICE mission



JUICE Science Themes

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

This talk

- *Overview of over-arching questions*
- *Deep oceans at Europa and Ganymede*
- *Mission Design*
- *Planetary protection*
- *What is next?*

JUICE concept

- *European-led mission to the Jovian system*
- *First L-class mission of the Cosmic Vision Programme*
- *3.5 years in-system*
- *First orbiter of an icy moon*

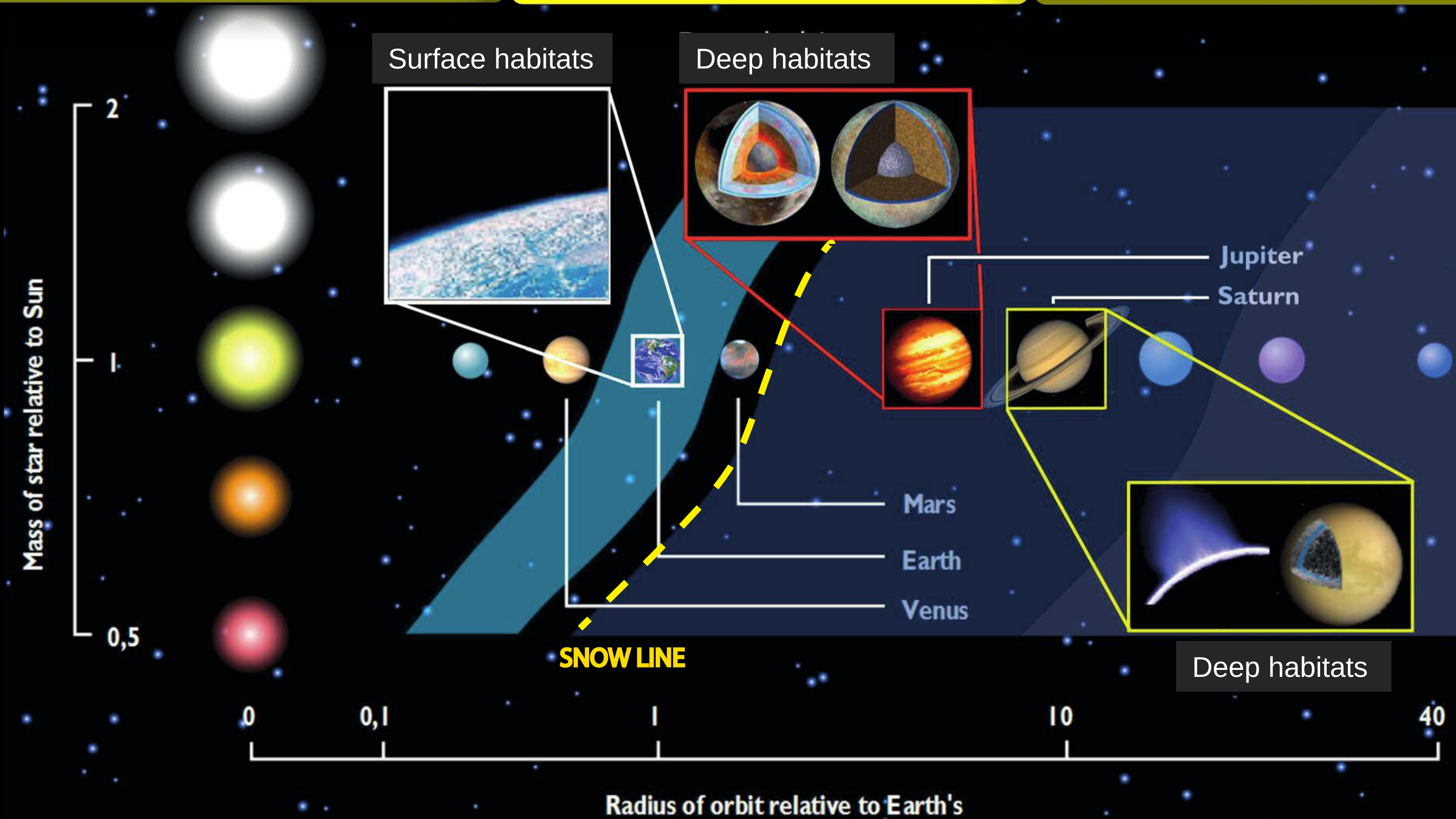
Astrobiology aspects in the JUICE mission

JUICE is not a mission dedicated to astrobiology …

Exploration of the habitable zone: Ganymede, Europa, and Callisto	
Characterise Ganymede as a planetary object and possible habitat	Characterise the extent of the ocean and its relation to the deeper interior
	Characterise the ice shell
	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
Explore Europa's recently active zones	Determine the composition of the non-ice material, especially as related to habitability
	Look for liquid water under the most active sites
	Study the recently active processes
Study Callisto as a remnant of the early jovian system	Characterise the outer shells, including the ocean
	Determine the composition of the non-ice material
	Study the past activity
Explore the Jupiter system as an archetype for gas giants	
Characterise the Jovian atmosphere	Characterise the atmospheric dynamics and circulation
	Characterise the atmospheric composition and chemistry
	Characterise the atmospheric vertical structure
Explore the Jovian magnetosphere	Characterise the magnetosphere as a fast magnetic rotator
	Characterise the magnetosphere as a giant accelerator
	Understand the moons as sources and sinks of magnetospheric plasma
Study the Jovian satellite and ring systems	Study Io's activity and surface composition
	Study the main characteristics of rings and small satellites

Overview of over-arching questions

Waterworlds and giant planets | **Habitable worlds** | Astrophysics Connection



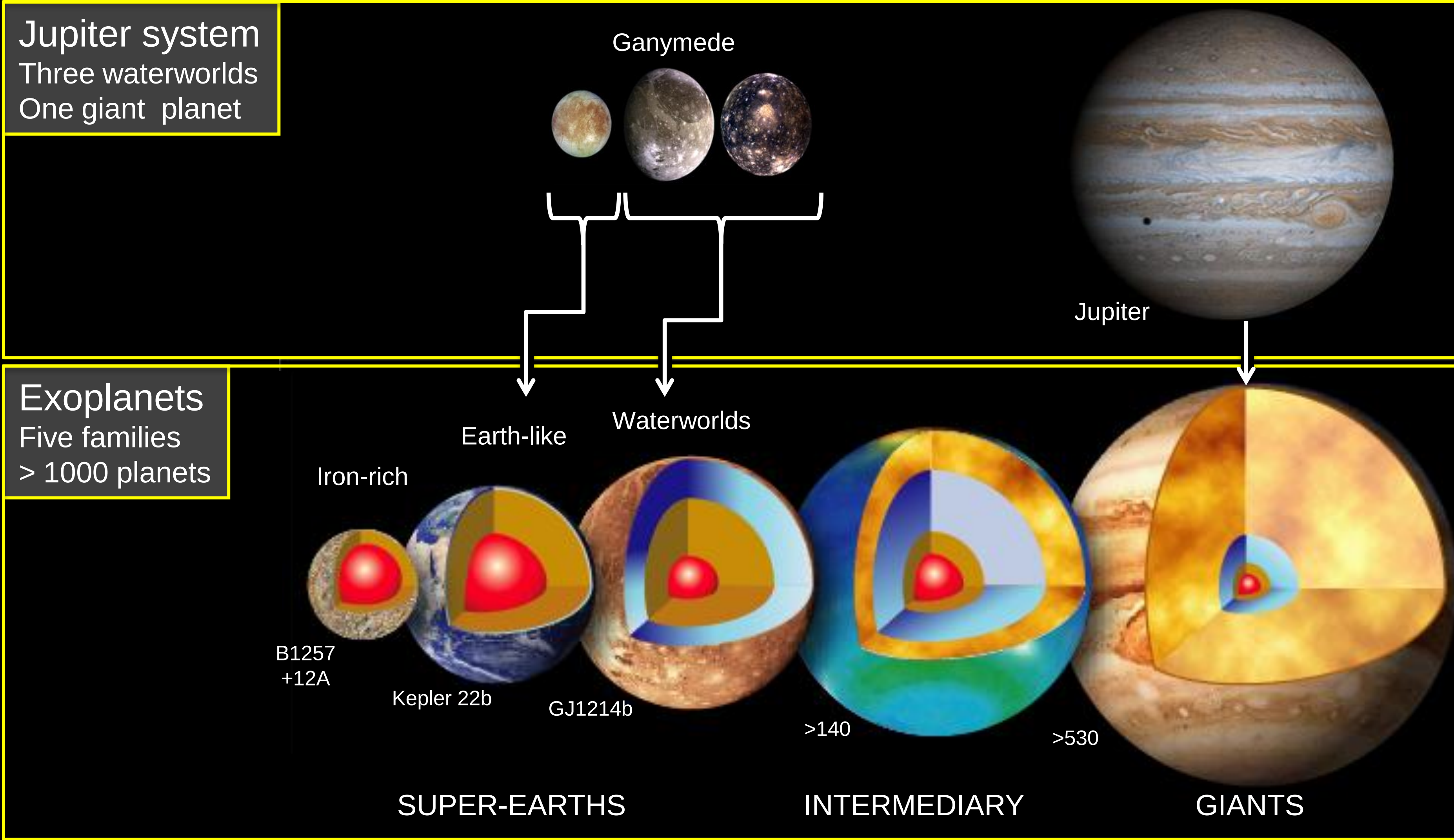
Cosmic Vision: The quest for evidence of life in the Solar System must begin with an understanding of what makes a planet habitable

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

From the Jovian system to extrasolar planetary systems **JUICE**

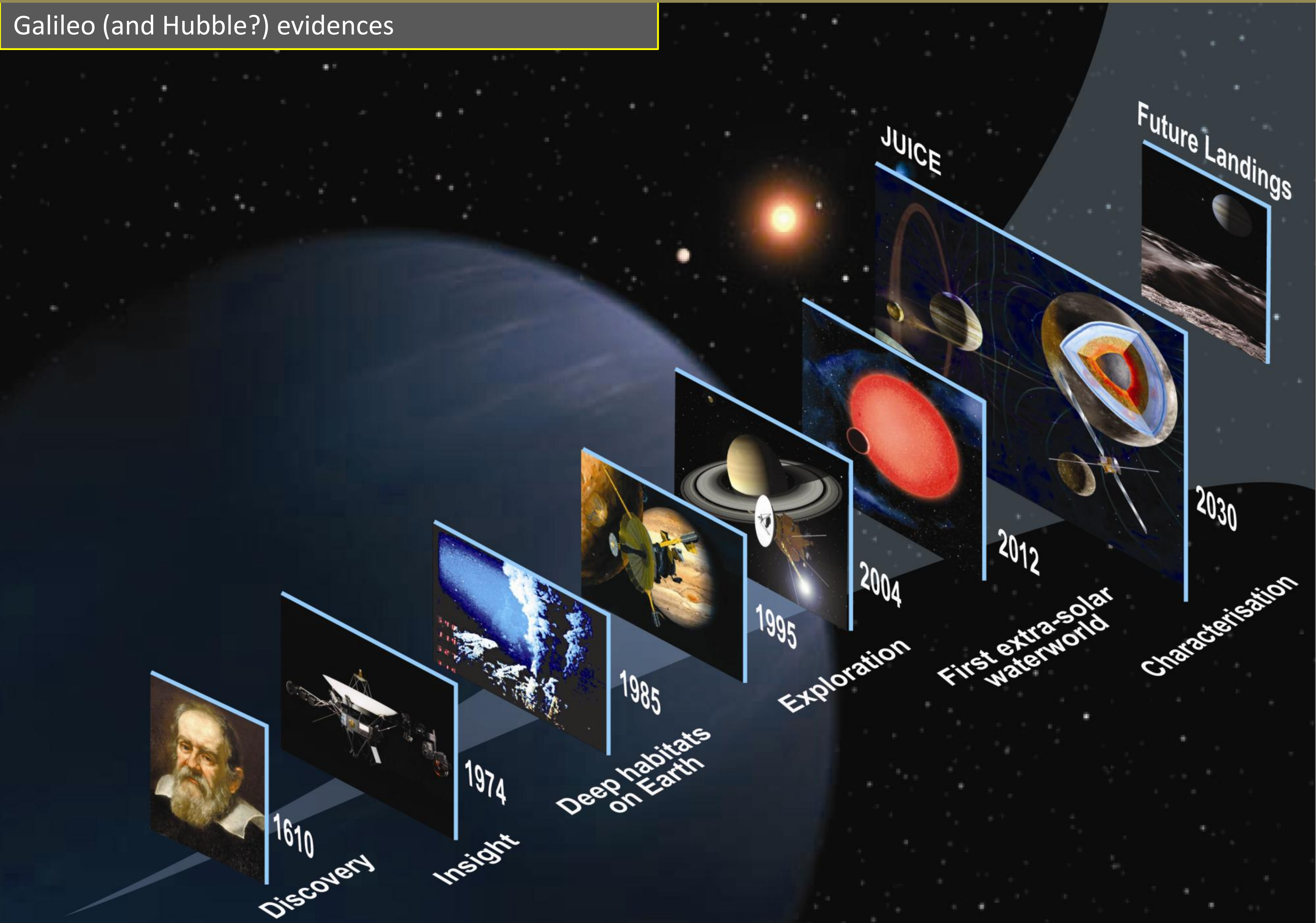
Waterworlds and giant planets | Habitable worlds | Astrophysics Connection

At Ganymede, JUICE will characterise an entire family of exoplanets: the waterworlds.
At Jupiter, JUICE will further explore an archetype for giant exoplanets.



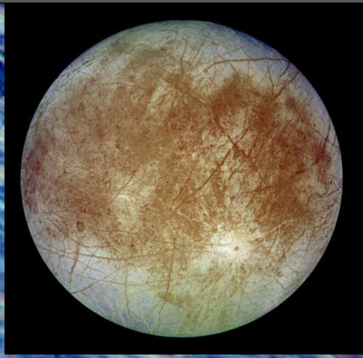
The ocean worlds

Galileo (and Hubble?) evidences

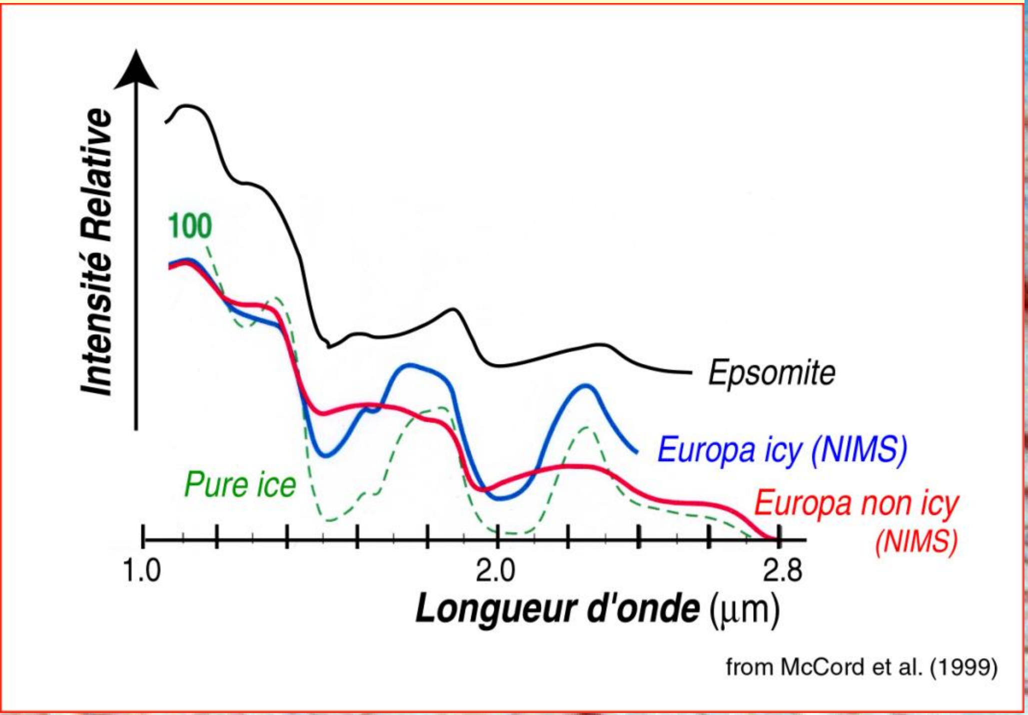


Science objectives at Europa strongly related to astrobiology – ocean characteristics

Complex chemistry



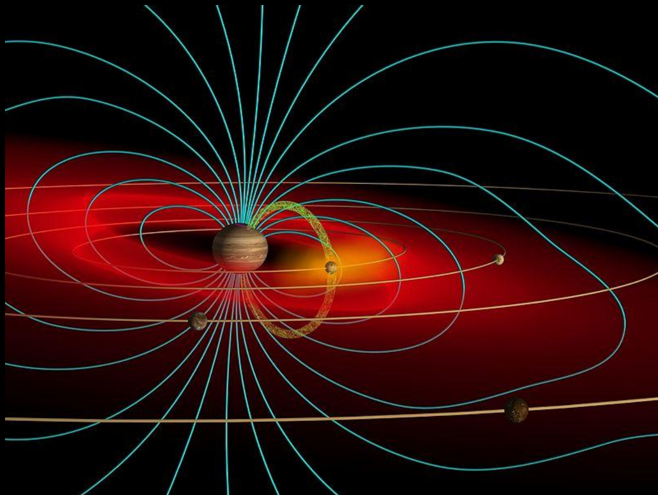
The composition of ices

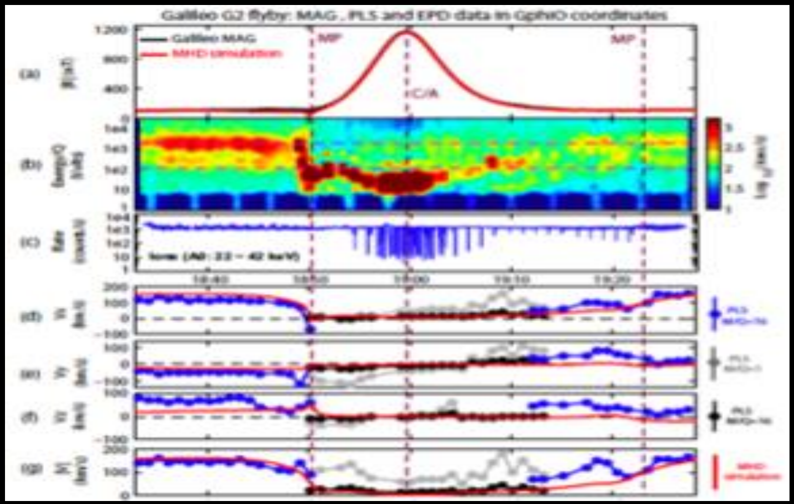


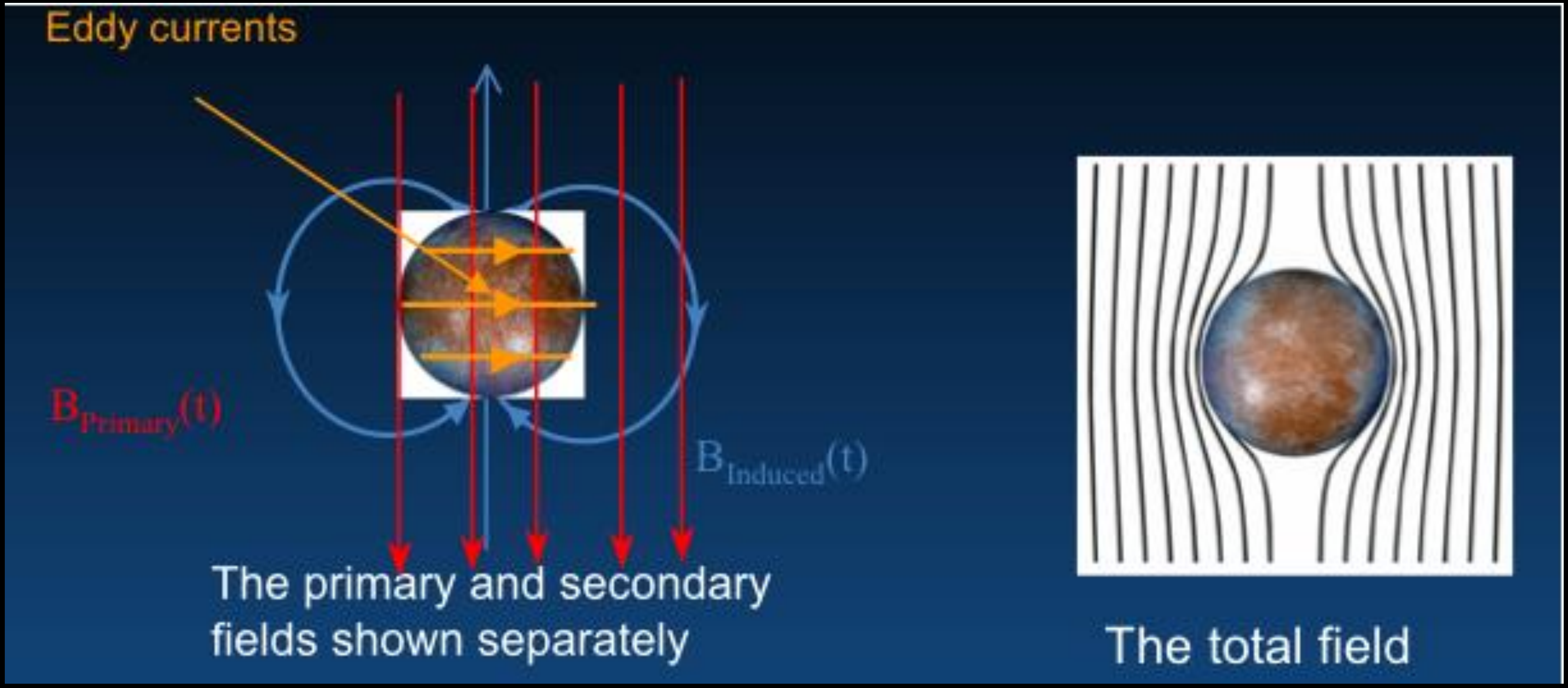
from McCord et al. (1999)

Science objectives at Europa strongly related to astrobiology – ocean characteristics

Europa – detection of an induced magnetic field







The context

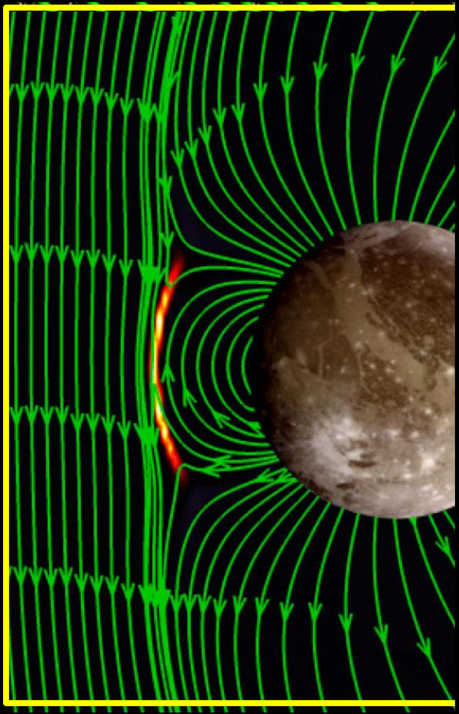
Icy worlds – detection of a plume in the South pole ?

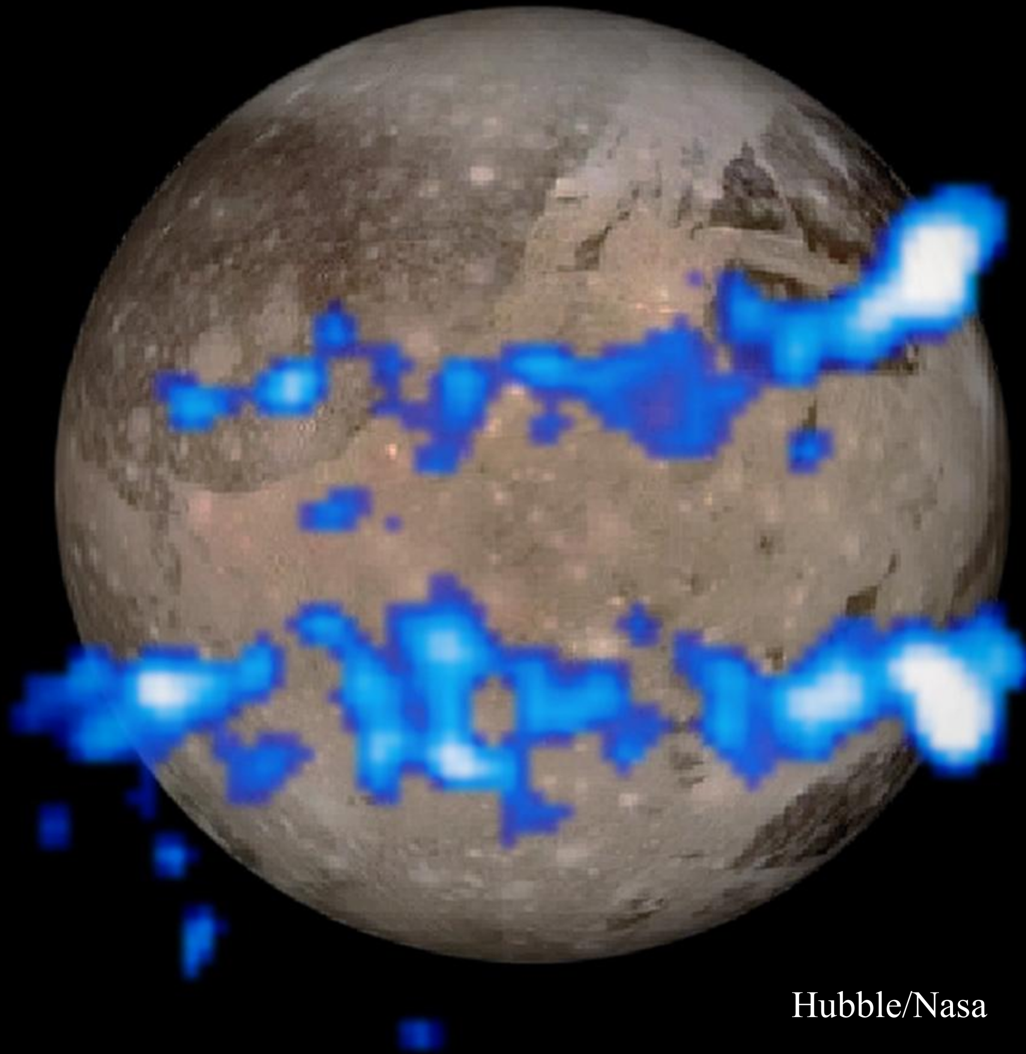
Detection with Hubble
End of 2013
Never observed since then

Galileo evidences

Induced magnetic field

Observed but not chara



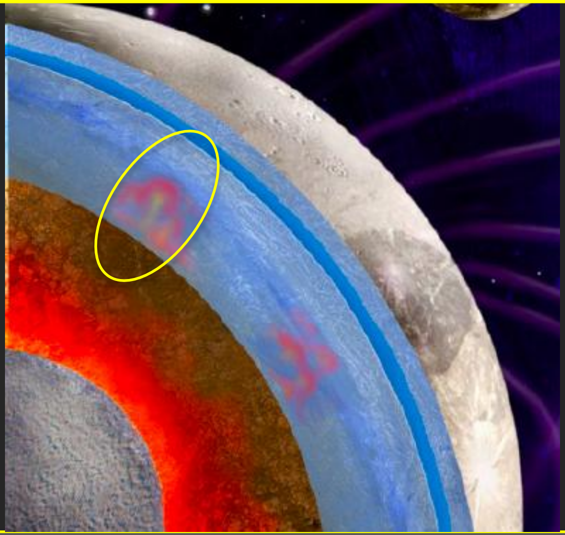


Hubble/Nasa

From liquid domains to habitable worlds

JUICE

Waterworlds: If habitable, the liquid layers are trapped between two icy layers

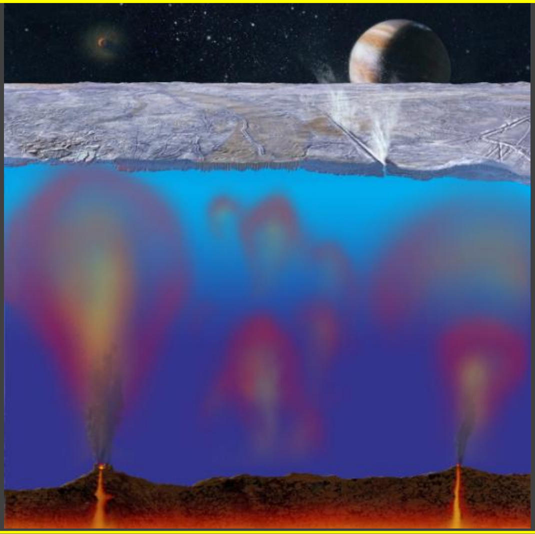


Occurrence:
Largest moons, hot ice giants, ocean-planets…
Most common habitat in the universe ?

Key question:
Are these waterworlds habitable ?

What JUICE will do:
Via characterisation of Ganymede, will constrain the likelihood of habitability in the universe

Europa-like: If habitable, the liquid layers may be in contact with silicates as on Earth



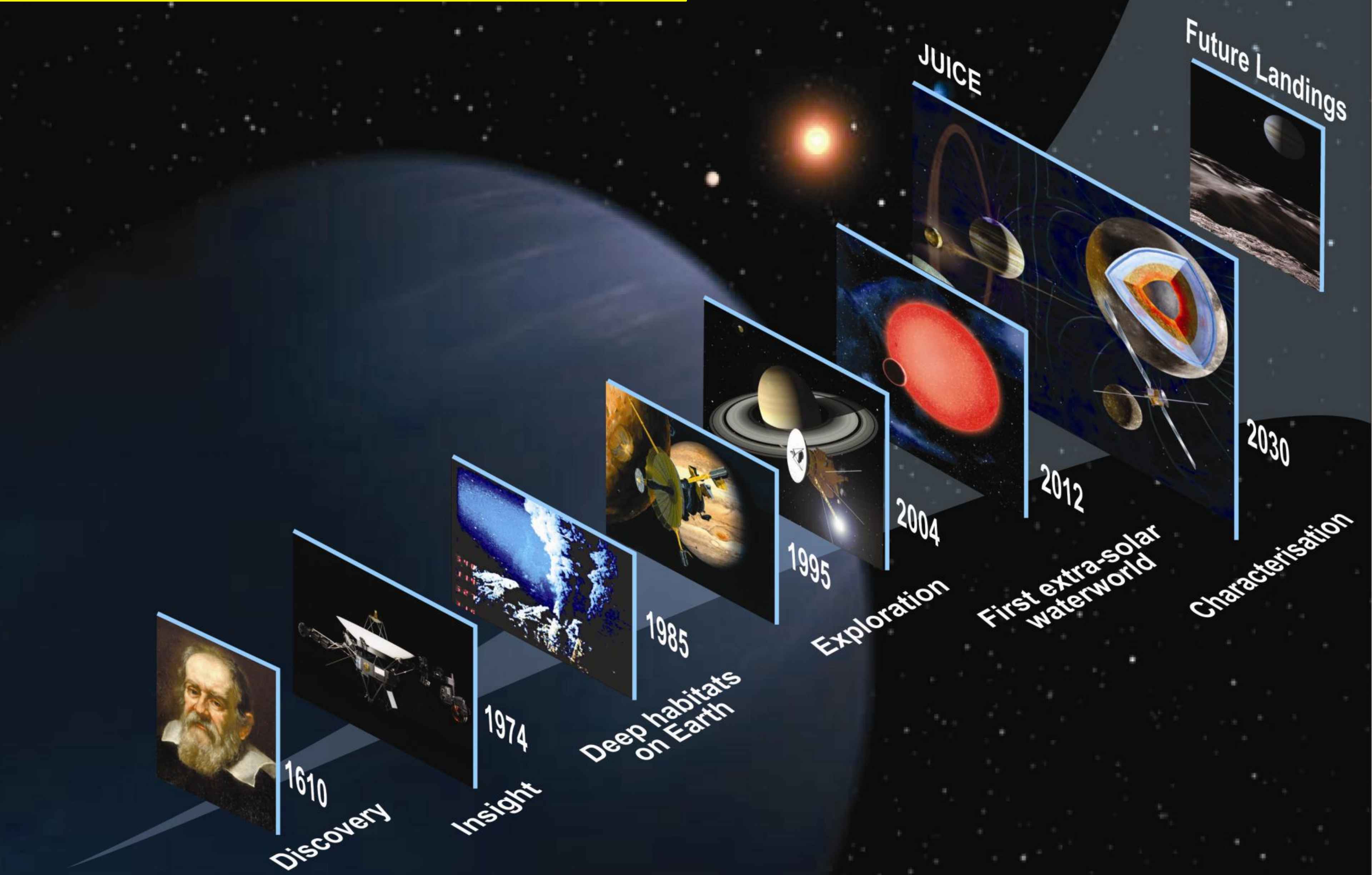
Occurrence:
Europa, Enceladus
Only possible for very small bodies

Key question:
How are the surface active areas related to potential deep habitats?

What JUICE will do:
Pave the way for future landing on Europa
Better understand the likelihood of deep local habitats

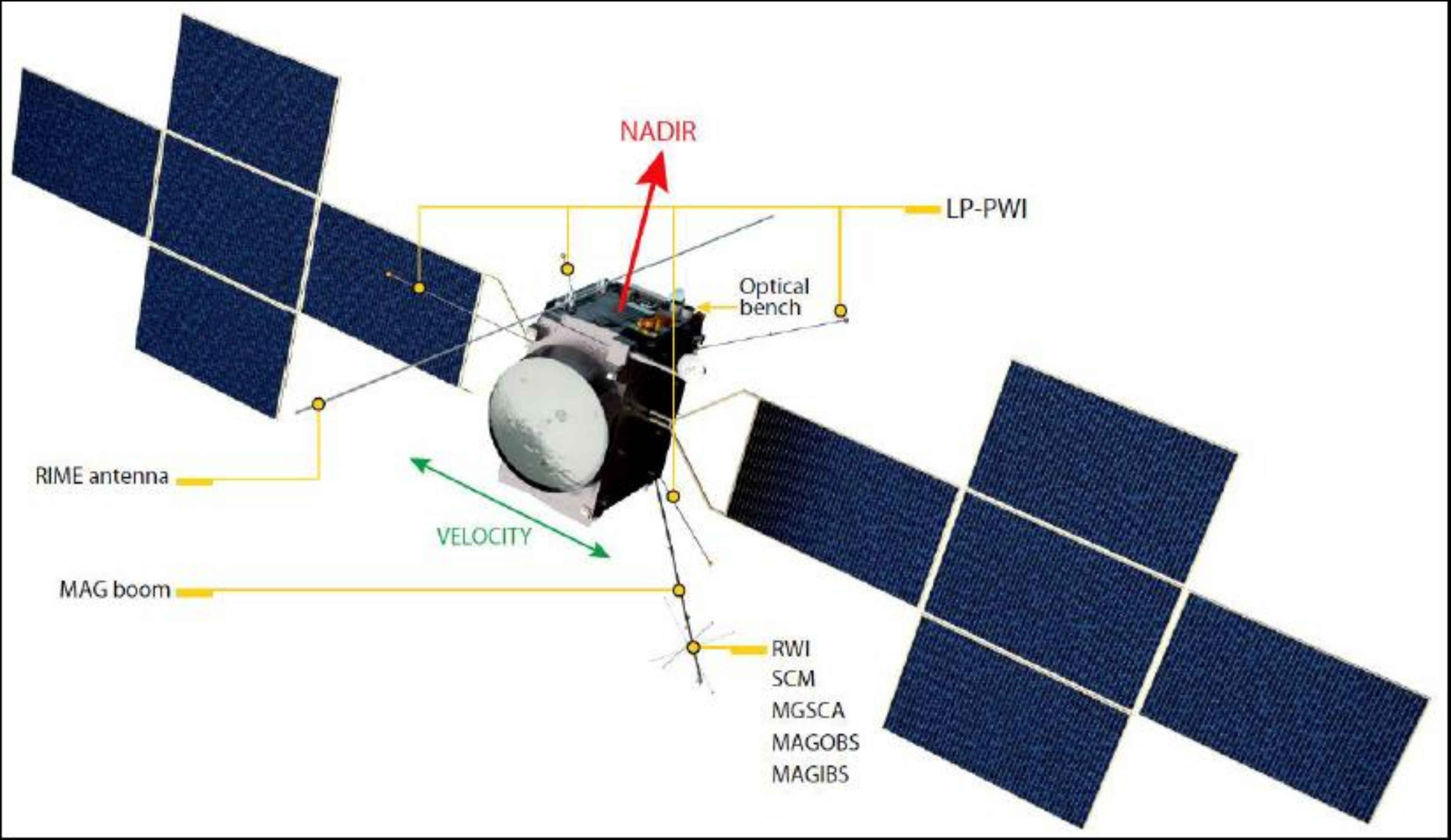
Mission design

Time to progress from exploration to characterisation of habitable worlds



Mission design

Spacecraft Design



Spacecraft Design

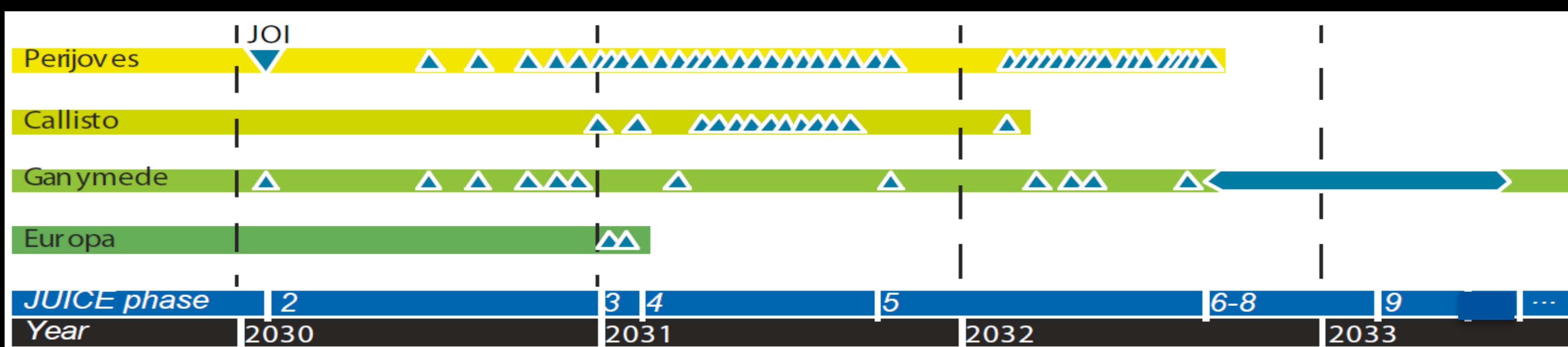
- Prime industrial Contractor: Airbus Defence & Space (Toulouse, France), selected in July 2015
- Spacecraft:
  - 3-axis stabilised
  - Mass:
    - Launch mass: 5264 kg
    - Instruments: 219 kg
    - Propellant: 2857 kg
  - Solar array 97 m^2 (~850 W at Jupiter)
  - Fixed High Gain Antenna (X, Ka Bands)
  - Steerable Medium Gain Antenna (X, Ka Bands)
  - Data Volume > 1.4 Gb per day

Mission profile

JUICE

Launch	06.2022
1. Interplanetary Transfer	7.6 years
Jupiter Orbit Insertion	01.2030
2. Jupiter equatorial phase #1	~11 mon
3. Two Europa flybys	36 days
4. Jupiter high-latitude phase including Callisto flybys	~6 mon
5. Jupiter equatorial phase #2	~11 mon

Ganymede phases	
6. Elliptic #1	30 days
7. High altitude (5000 km)	90 days
8. Elliptic #2	30 days
9. Circular (500 km)	130 days
Total mission duration in the Jovian system	> 3 years



Mission design

Science Payload

Acronym	PI	LFA	Instrument type
Remote Sensing Suite			
JANUS	P. Palumbo, R. Jaumann	Italy, Germany	Narrow Angle Camera
MAJIS	Y. Langevin, G. Piccioni	France, Italy	Vis-near-IR imaging spectrometer
UVS	R. Gladstone	USA	UV spectrograph
SWI	P. Hartogh	Germany	Sub-mm wave instrument
Geophysical Experiments			
GALA	H. Hussmann	Germany	Laser Altimeter
RIME	L. Bruzzone, J. Plaut	Italy, USA	Ice Penetrating Radar
3GM	L. Iess, D.J. Stevenson, Y. Kaspi	Italy, USA, Israel	Radio science experiment
Particles and Fields Investigations			
PEP	S. Barabash, P. Brandt, P. Wurz	Sweden, USA, Switzerland	Plasma Environmental Package
RPWI	J.-E. Wahlund, B. Cecconi	Sweden, France	Radio & Plasma Wave Instrument
JMAG	M. Dougherty	UK	Magnetometer

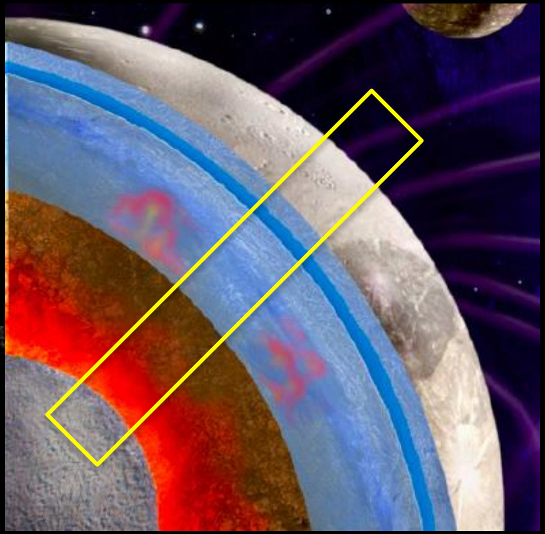
Ocean worlds

Three large icy moons to explore

Ganymede

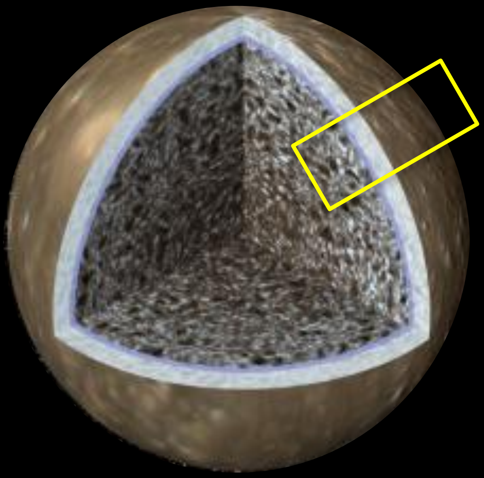
- Largest satellite in the solar system
- A deep ocean
- Internal dynamo and an induced magnetic field – unique
- Richest crater morphologies

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



Callisto

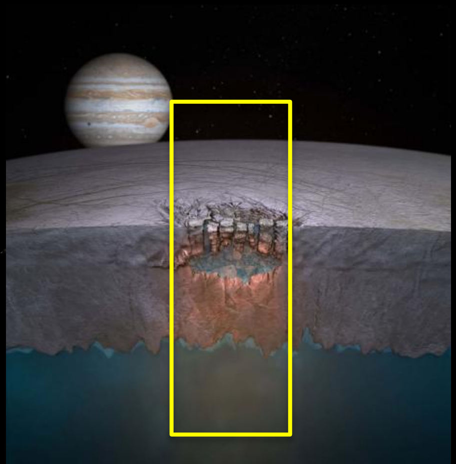
- Best place to study the impactor history
- Differentiation – still an enigma
- Only known example of non active but ocean-bearing world
- The witness of early ages



Europa

- A deep ocean
- An active world?

- Best example of liquid environment in contact with silicates

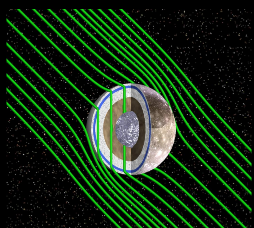


Explore Europa recently active zones

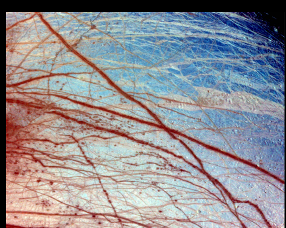
Flyby strategy:

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

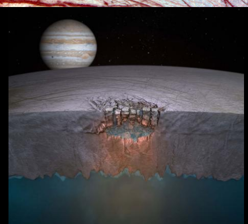
Will result in :



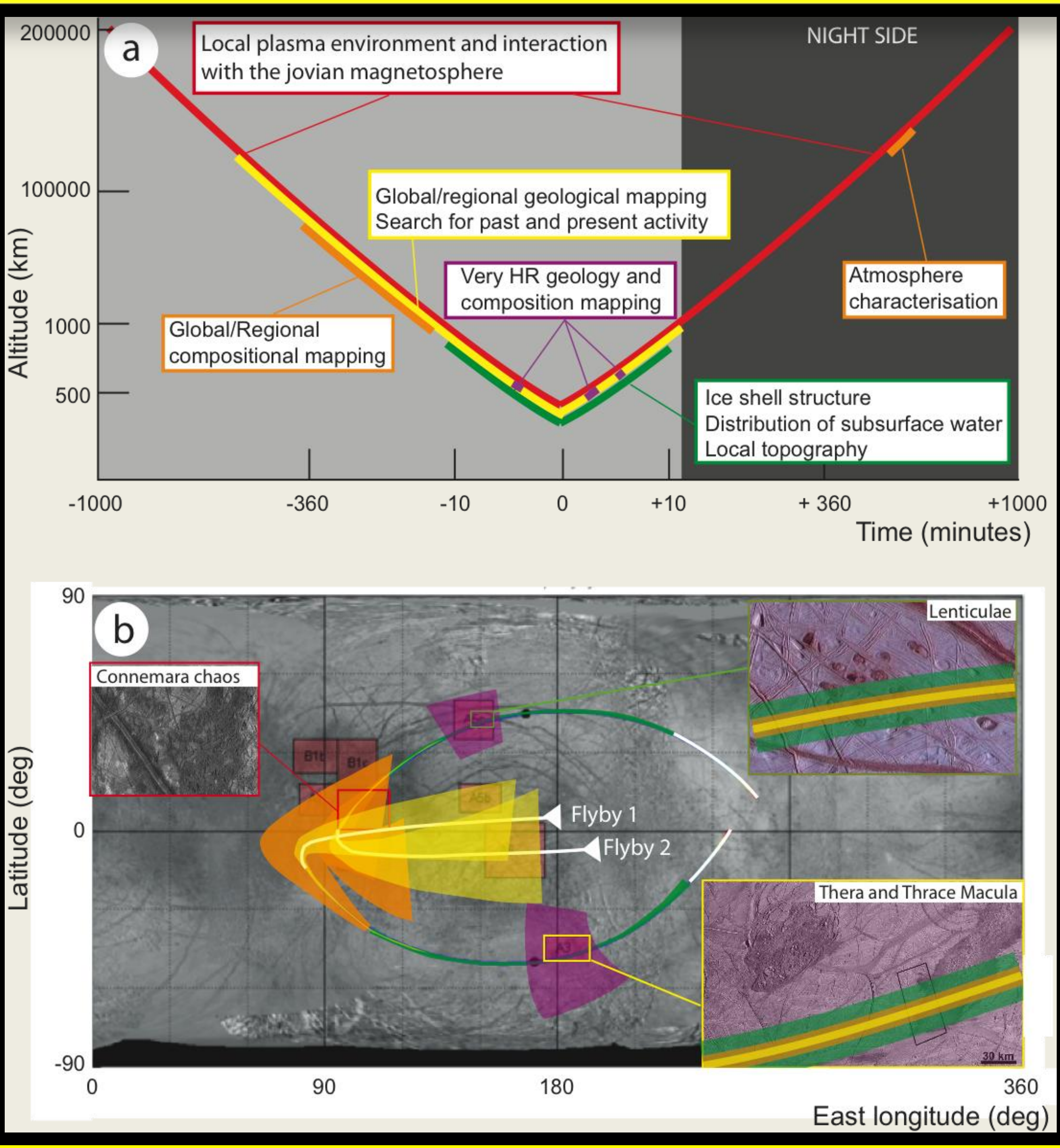
Characterisation of induced field



Composition and geology of areas of high interest



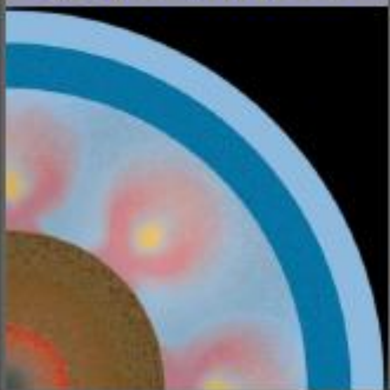
First subsurface exploration of recently active regions



Europa				
Year	2030	2031	2032	2033

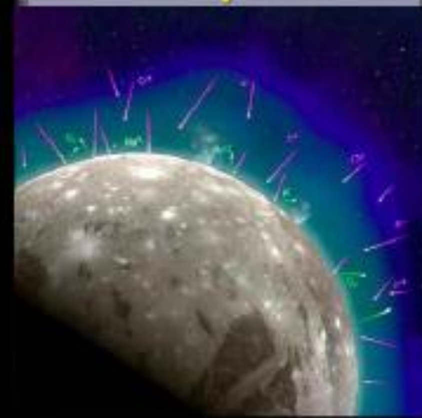
Ganymede: planetary object and potential habitat

Ice shell, ocean, deeper interiors

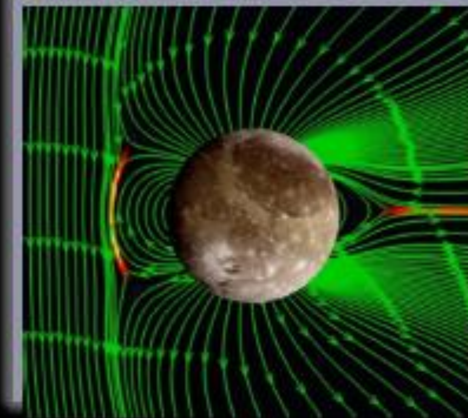


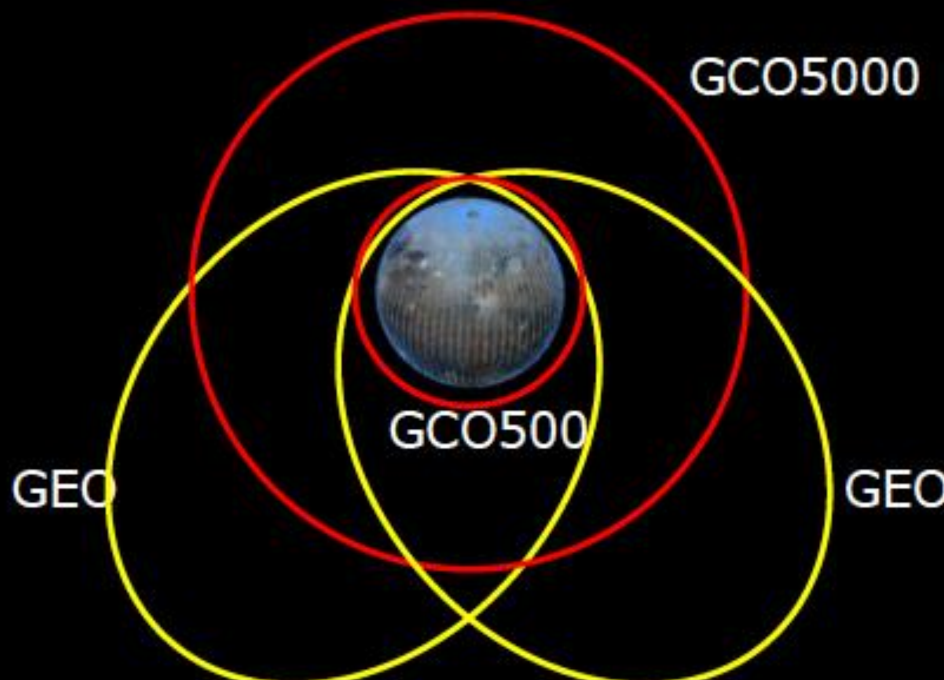
Geology, surface composition

Atmosphere, ionosphere



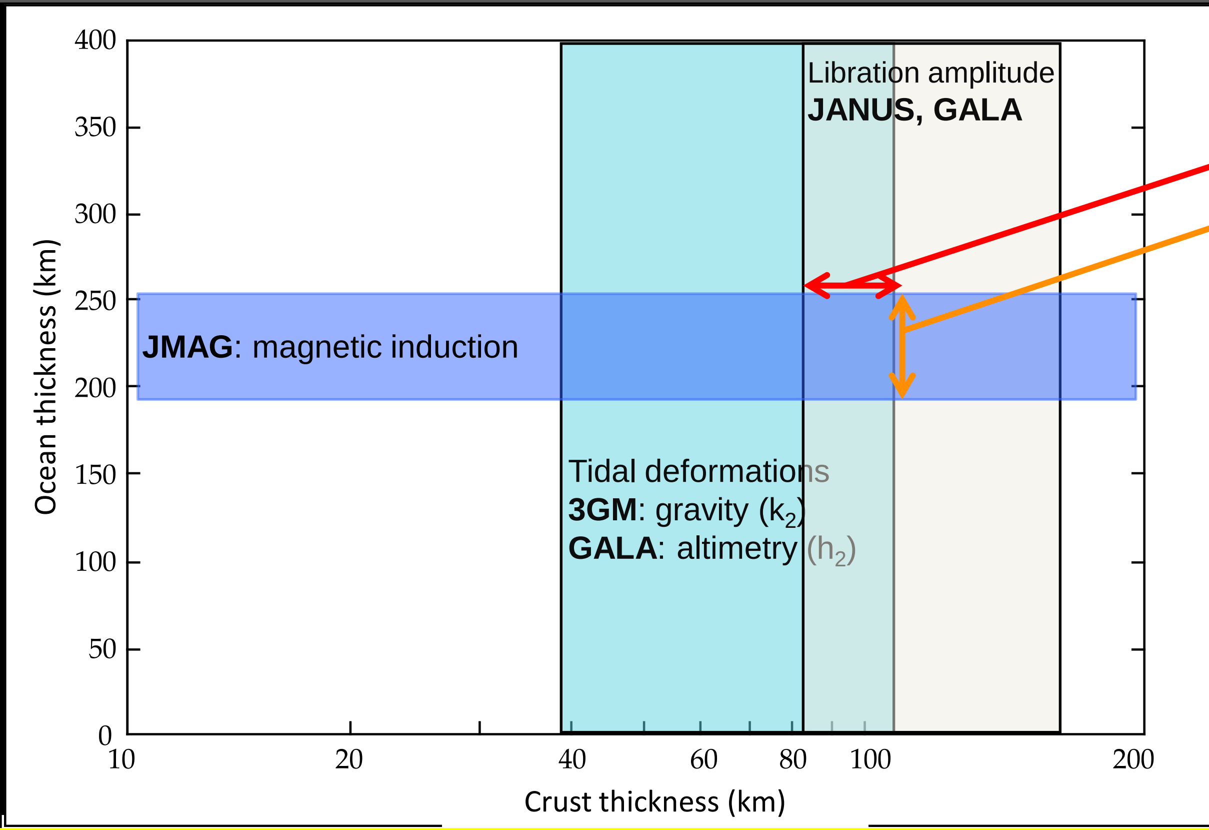
Magnetosphere, plasma environment



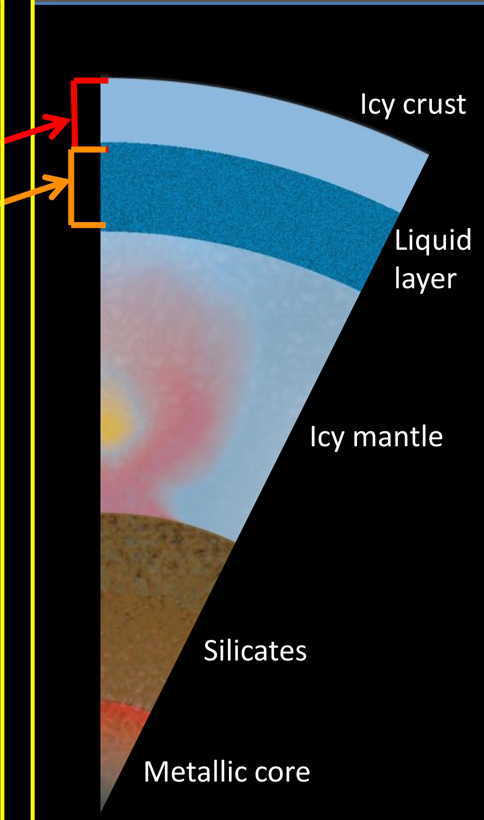


Astrobiology at Ganymede - characteristics of the ocean layer

1. Ganymede’s ocean and icy crust



Internal structure



JUICE measurements

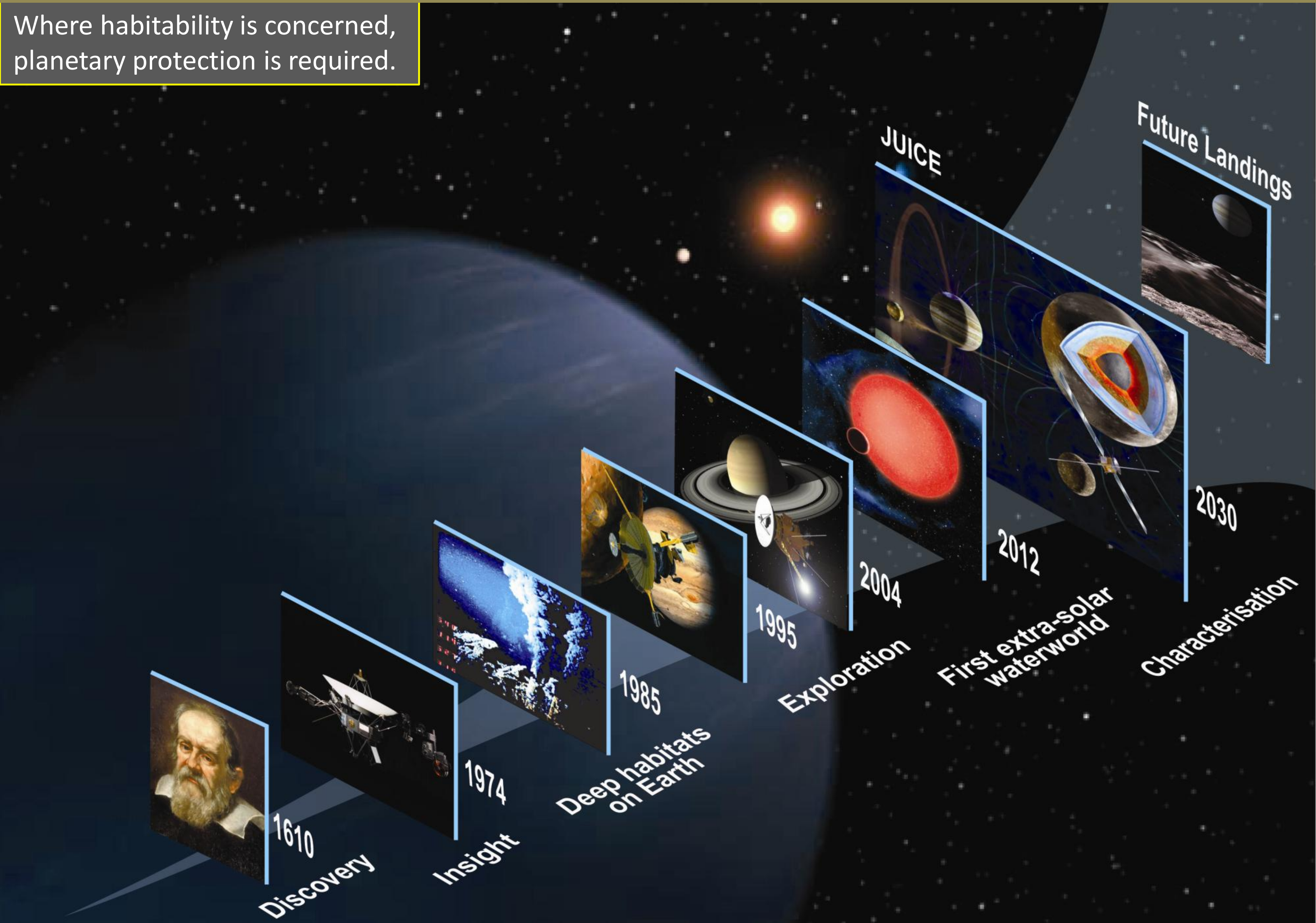
- Surface deformations
- Libration characteristics
- Magnetic induction

Instrument Packages

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

Planetary protection

Where habitability is concerned, planetary protection is required.



JUICE and astrobiology (wrt mission constraints)

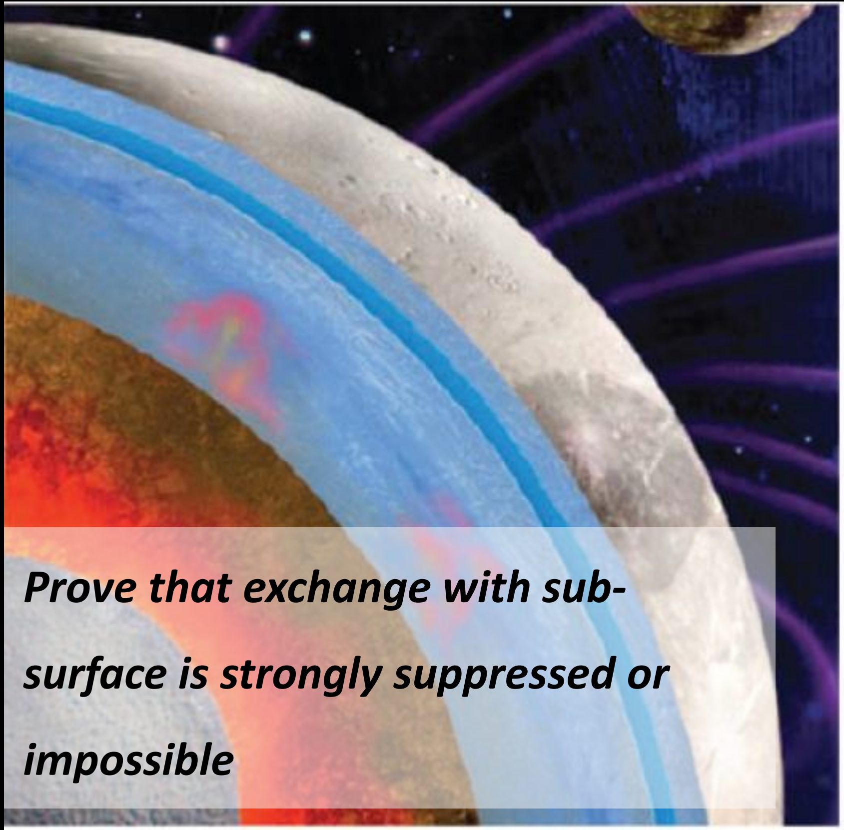
The planetary protection issue

Planetary Protection Mission Categories

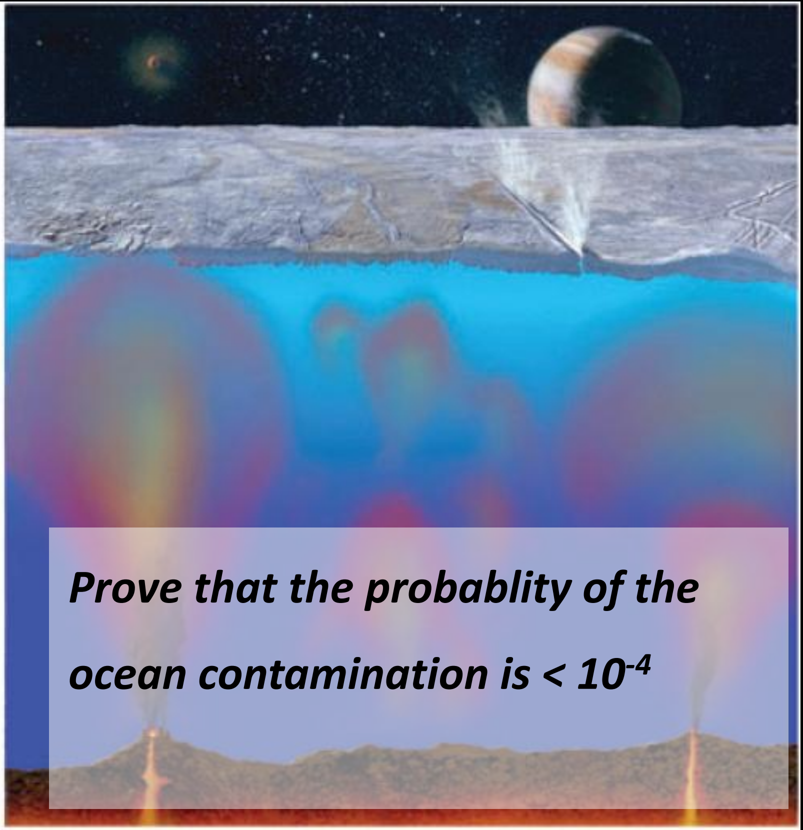
PLANET PRIORITIES		MISSION TYPE	MISSION CATEGORY
A	Not of direct interest for understanding the process of chemical evolution. No protection of such planets is warranted.	Any	I
B	Of **significant interest relative to the process of chemical evolution**, but only a **remote chance that contamination** by spacecraft could compromise future exploration. Documentation is required.	Any	II
C	Of **significant interest relative to the process of chemical evolution and the origin of life** or for which scientific opinion provides a **significant chance of contamination** which could compromise a future biological experiment. Substantial documentation and mitigation is required.	Flyby, Orbiter	III
		Lander, Probe	IV
All	Any Solar System Body	Earth-Return	V

Planetary protection issues for JUICE

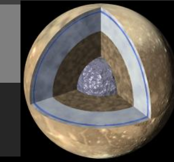
Ganymede class II*



Europa – class III



Ganymede: Exchange processes from space to habitable zones



Summary and conclusion

Layer (from top to bottom)	**Minimal Thickness**	**Downward migration process**	**Time duration (years)**	**Comments**
Regolith	First centimeters of the crust	Diffusion	a few years	Impact is the only way to introduce microorganisms into the regolith in a short time scale.
		Impact	<< 1 year	
icy crust (stagnant lid) and upper thermal boundary layer	From a few kilometers to a few tens of kilometers	Diffusion	Several millions of years	No way envisaged to go through the lid in a short time scale. Geologic evidences demonstrate that the faults cannot propagate through the total thickness of the crust because it is too thick.
		Tectonism	<< 1 year but extremely unlikely through the entire lid	
Convecting layer	From a few kilometers to a few tens of kilometers	convective transport up to a few m/yr along a descending cold plume.	a few thousand years	Duration estimate is based on a very conservative approach regarding the vigour of convection.
Lower thermal boundary layer	A few hundred meters	Almost impossible - Diffusion could be envisaged	a few thousand years at least if diffusion is feasible	Upwards thermal buoyancy impedes downwards migration.
		Fractures	<< 1 year	No evidences that such fractures exist

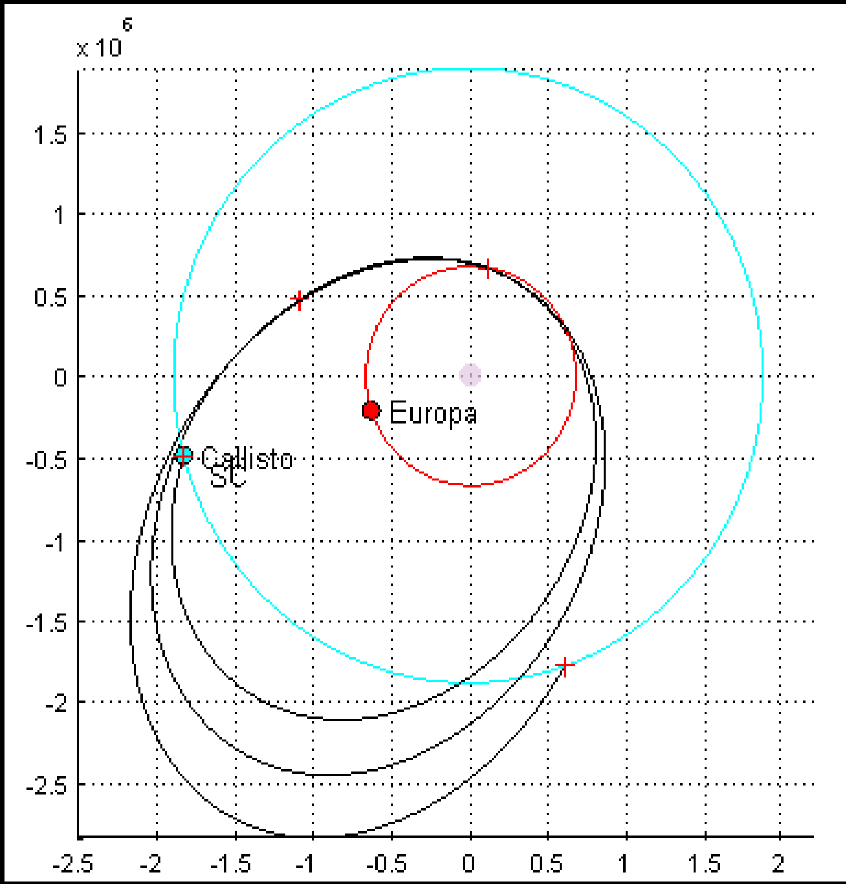
COSPAR's categorisation (II*) – our suggestion is that it should be class II:

Ganymede is of significant interest relative to the process of chemical evolution and the origin of life, and there is only a **remote** chance that contamination by a spacecraft could compromise future investigations.

Astrobiology,2014, Review on exchange processes on Ganymede in view of its planetary protection categorisation
Grasset, E.J. Bunce, A. Coustenis, M.K. Dougherty, C. Erd, H. Hussmann, R. Jaumann, O. Prieto-Ballesteros

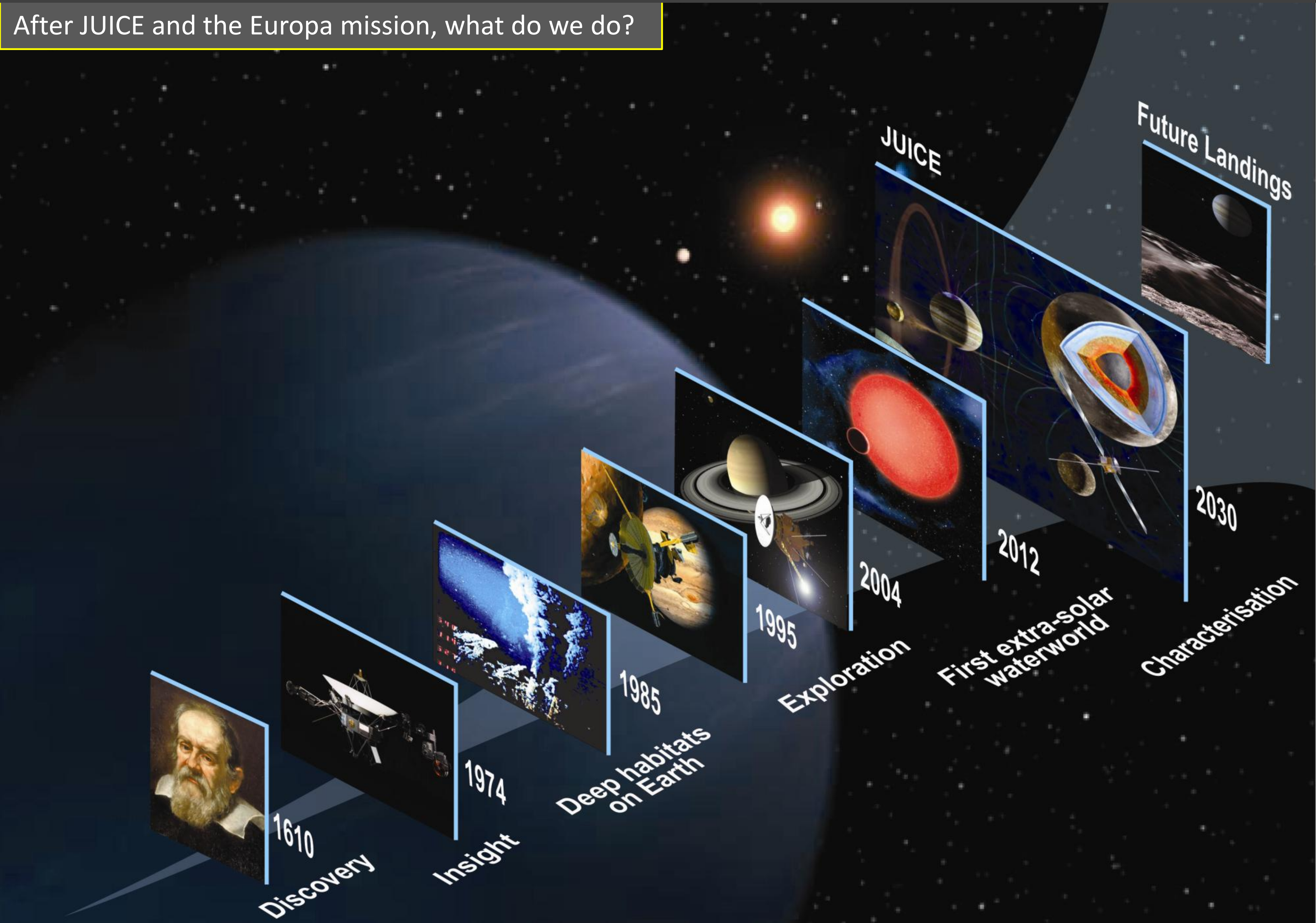
Europa Reference Scenario

- 36 day fly-by period from leaving Callisto until return to Callisto
- 2 Europa fly-bys
  - First 10 days after leaving Callisto
  - Second 14 days after the first
- Callisto GA 12 days after Europa
- S/c velocity relative to Europa: 4.5 km/s



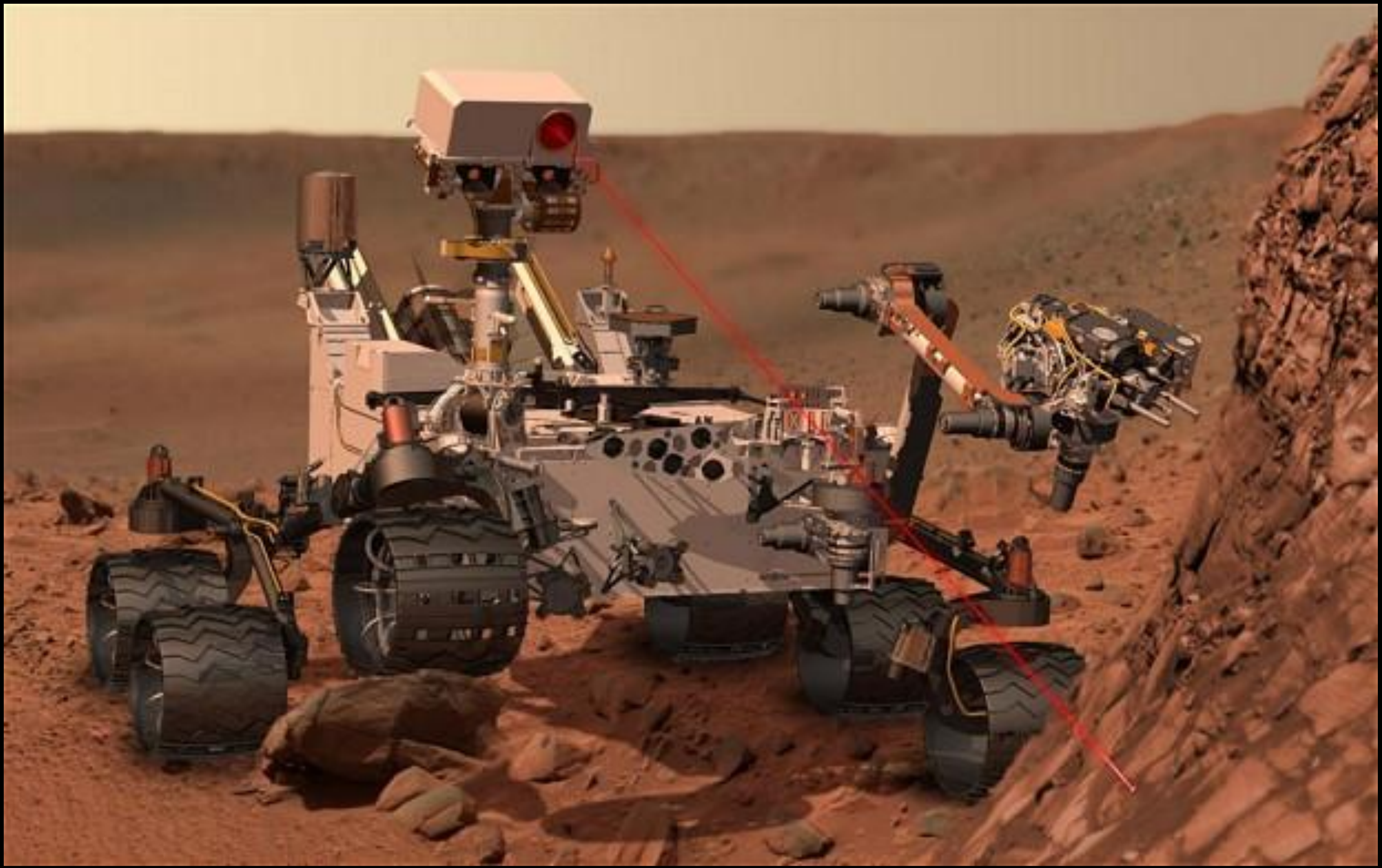
What is next for astrobiology in the outer solar system?

After JUICE and the Europa mission, what do we do?



What's next?

To do astrobiology on a planet/moon, there is a need for big rovers



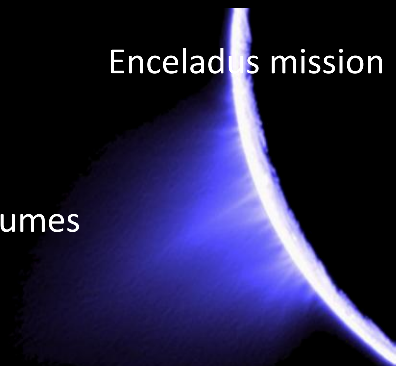
What's next?

No roadmap so far for astrobiology in the outer solar system

Astrobiology
Suburface
investigations

Astrobiology
Surface
investigations

Titan mission



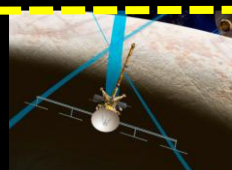
Enceladus mission

Astrobiology
Sample return

Europa touchdown?
Plume activity?

Enceladus plumes

Characterisation of the habitable domains

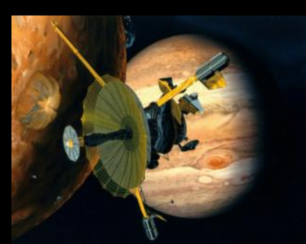


Europa flybys

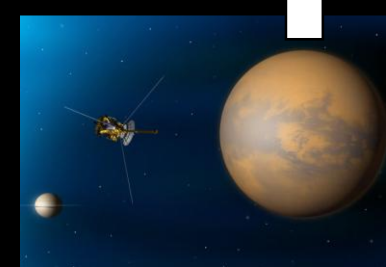
JUICE

New mission ??

Exploration
Evidences for
habitability



Galileo



Cassini