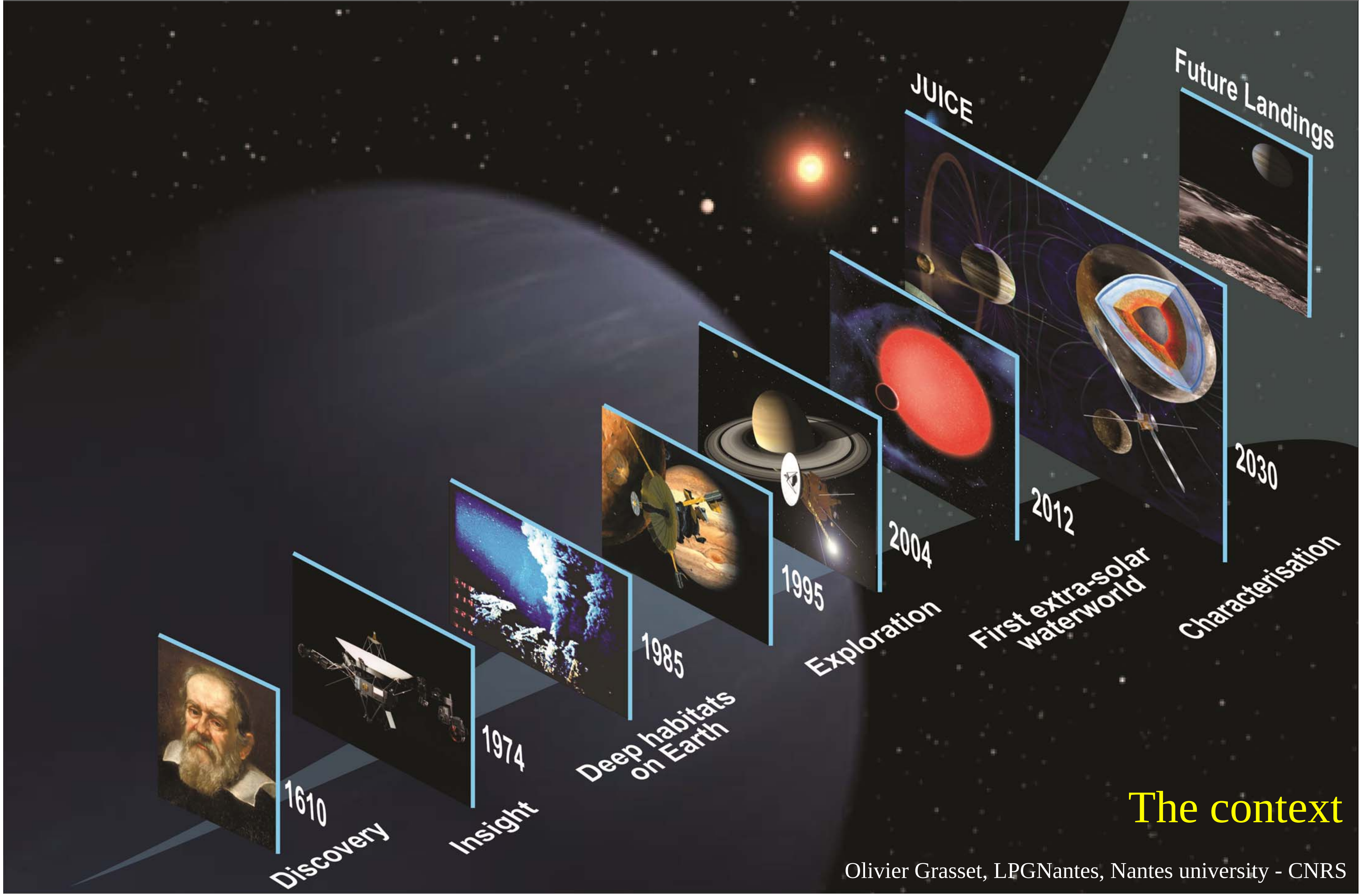
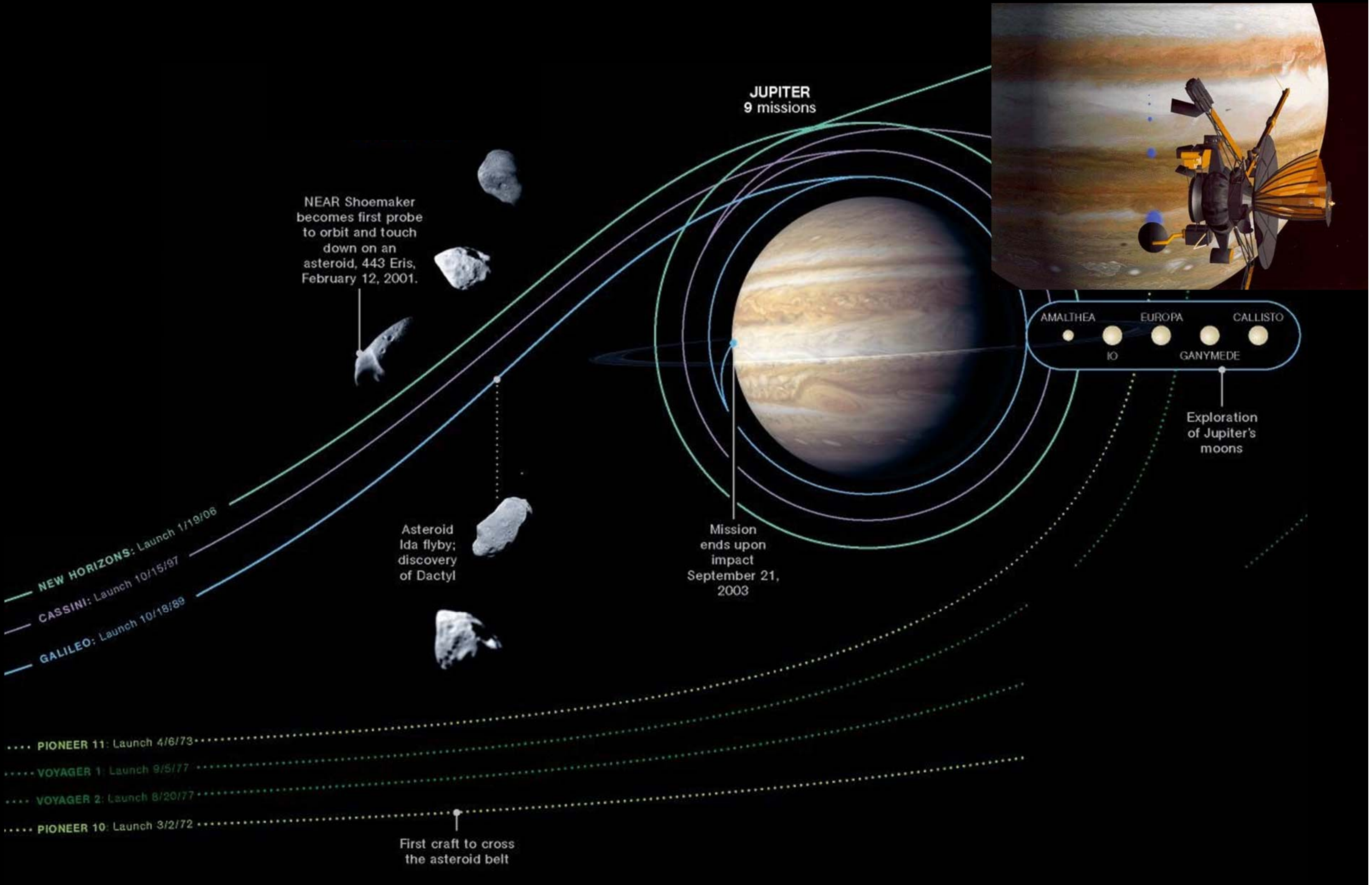
Habitabilité des lunes de Jupiter:
des premières évidences aux futures explorations



Olivier Grasset, LPGNantes, Nantes university - CNRS

Previous missions

A few flybys and an orbiter (Galileo)



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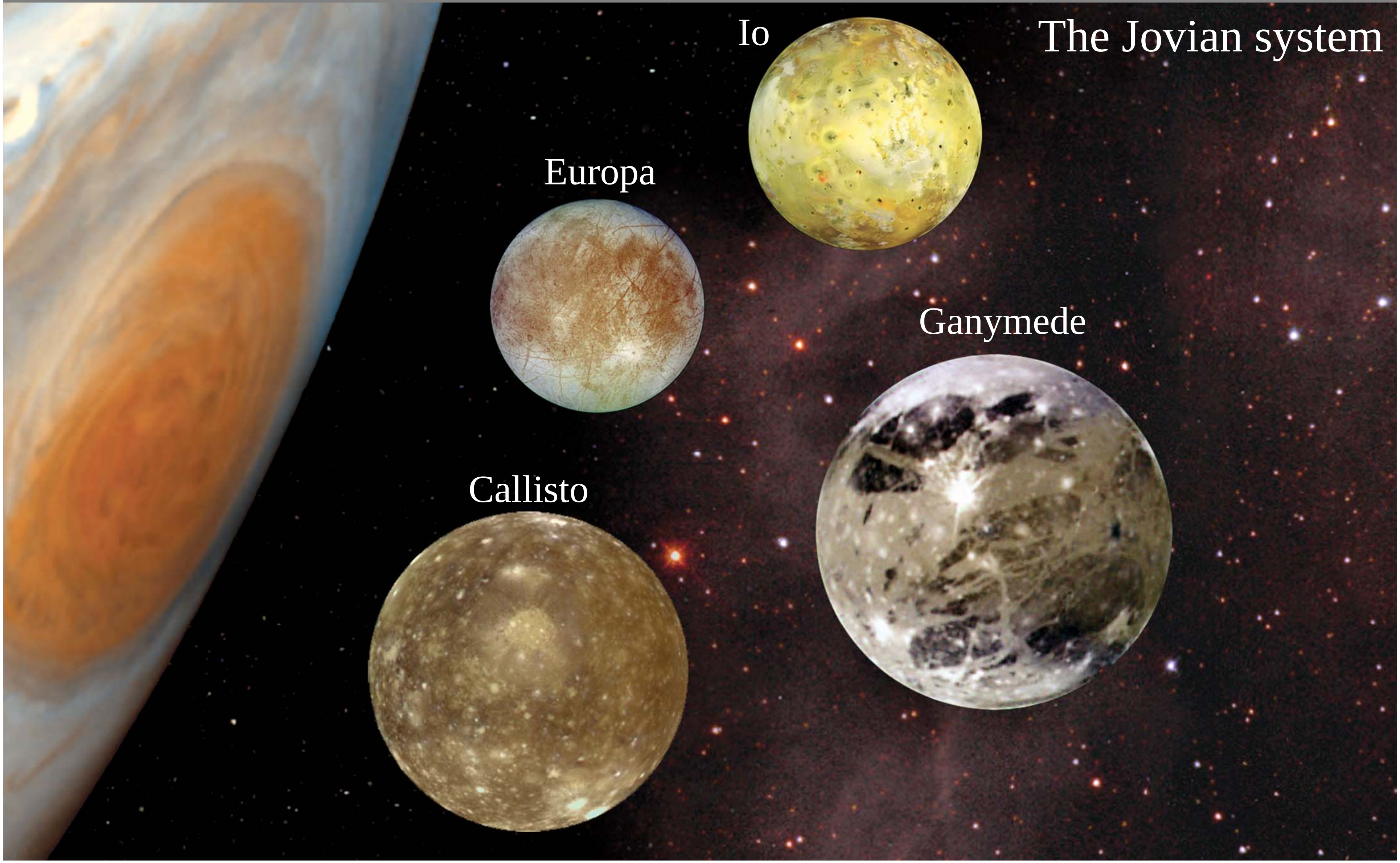
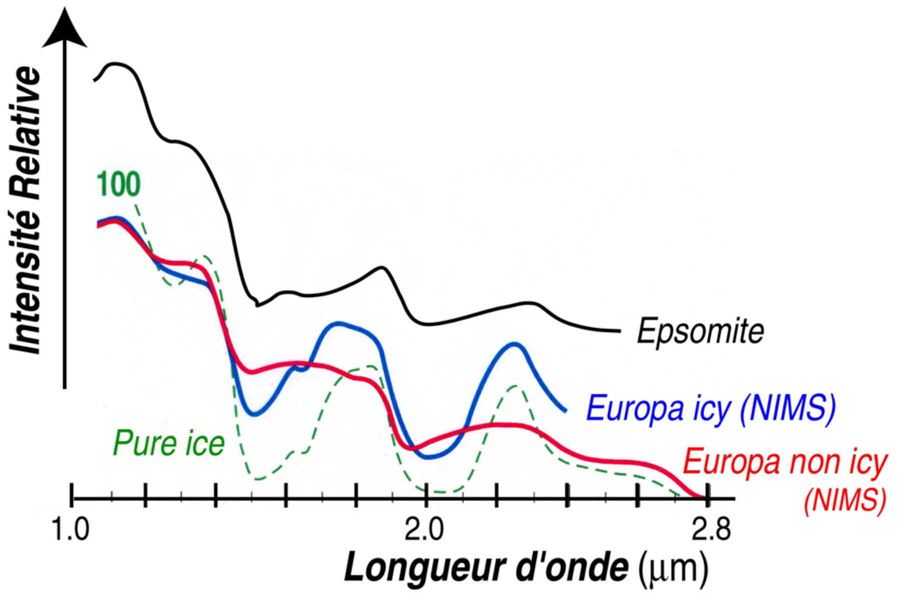
The planetary bodies that we will explore…

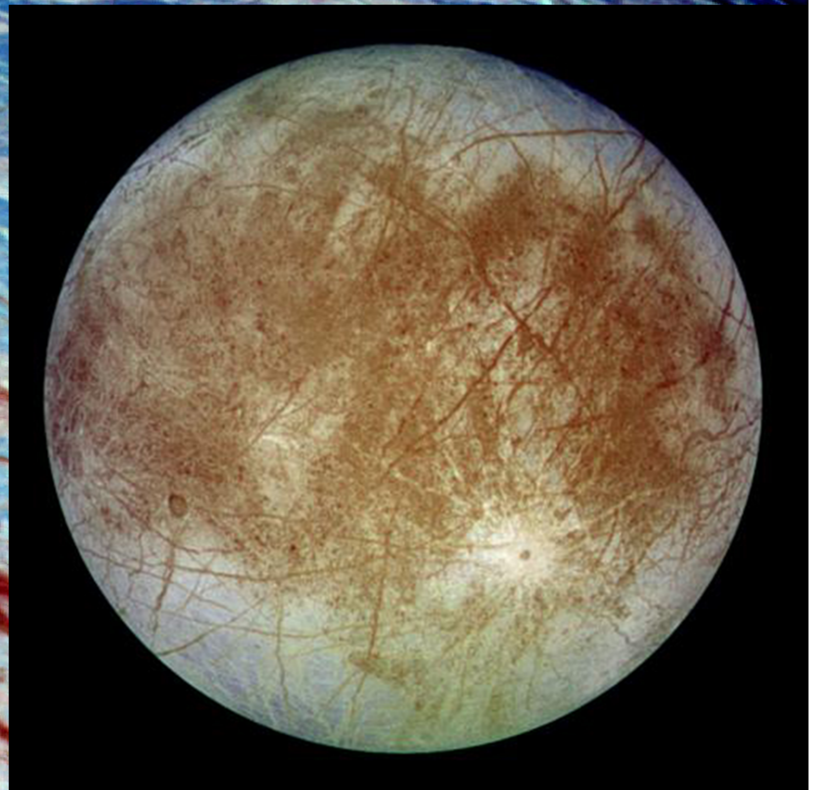


Chemical evidences

The composition of ices

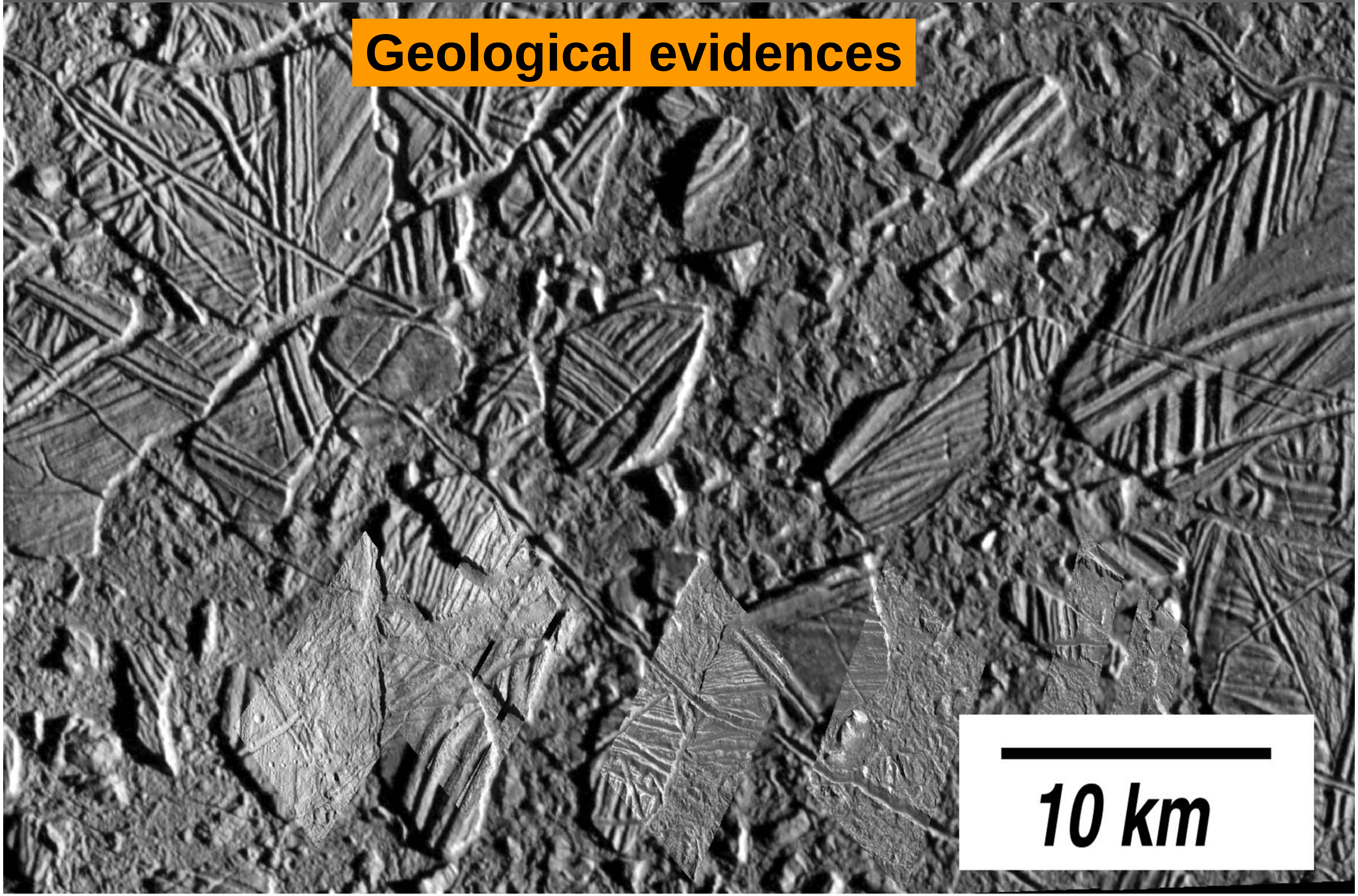


from McCord et al. (1999)



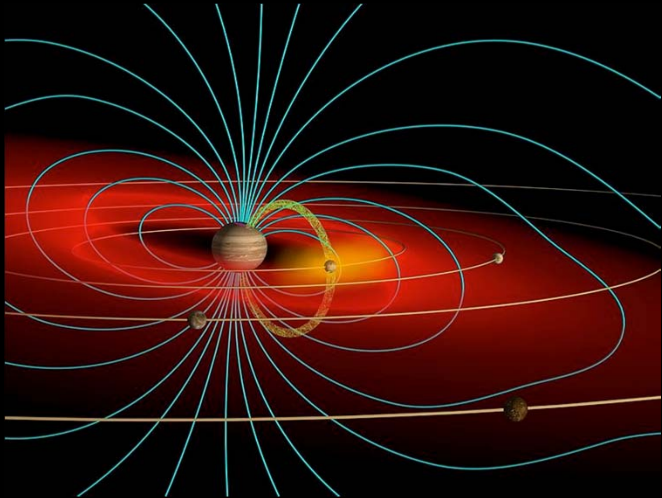
The context

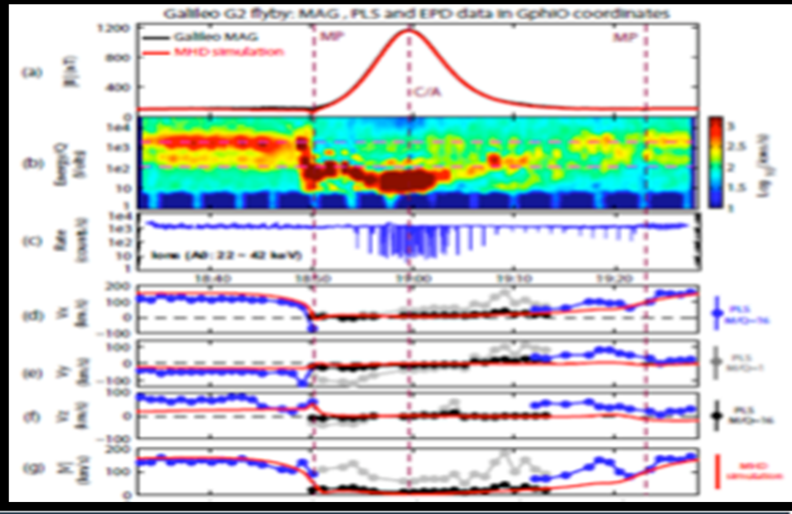
Evidences of possible habitability

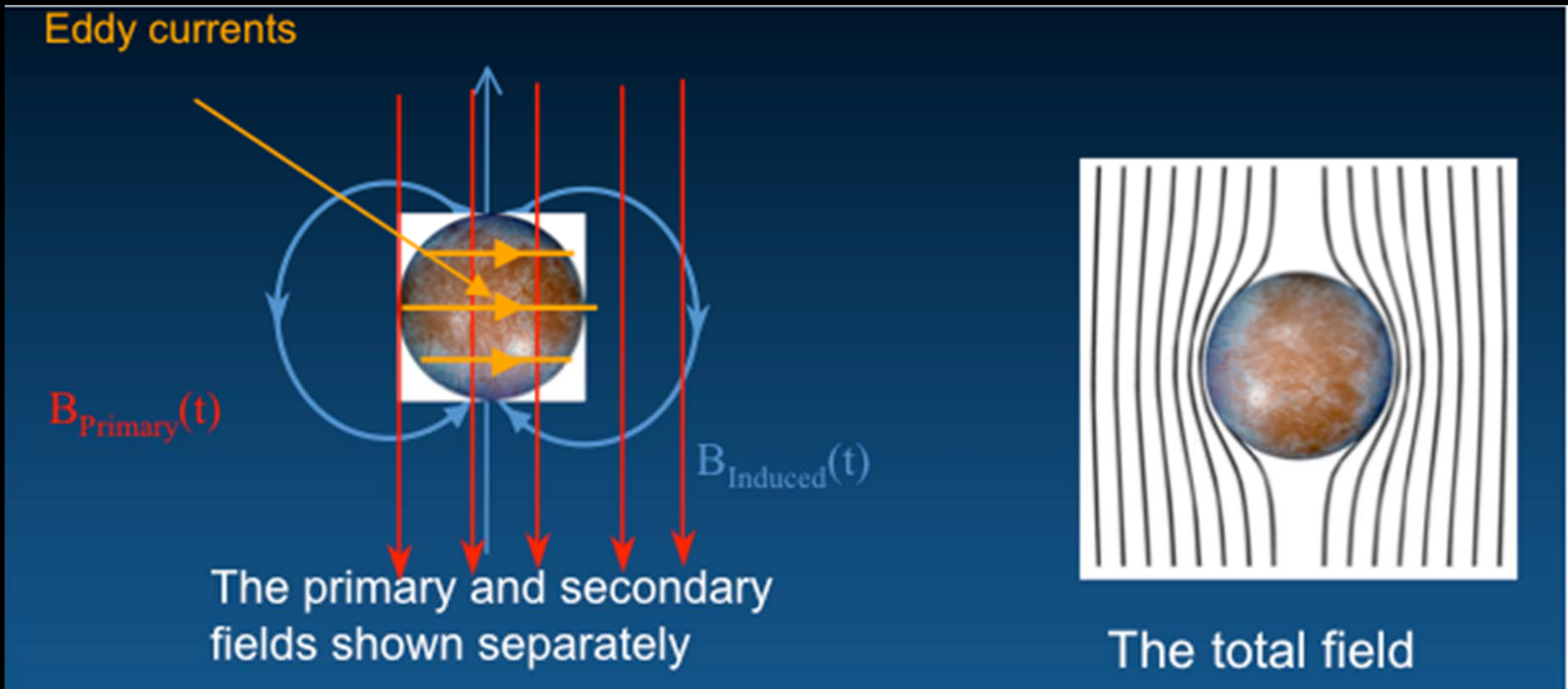


The context

Icy worlds – detection of an induced magnetic field

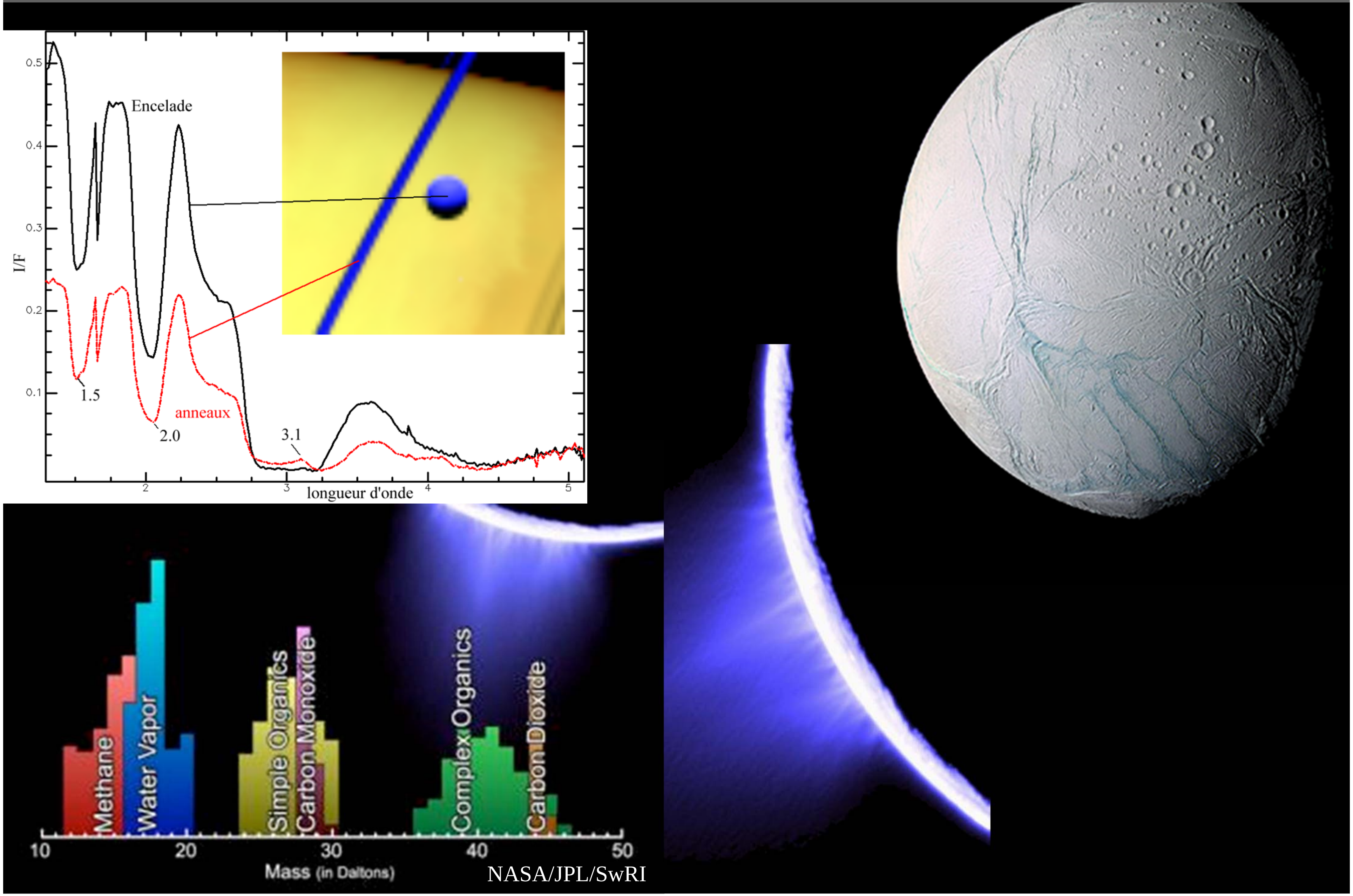






The context

Evidences of possible habitability – Cassini evidences at Enceladus



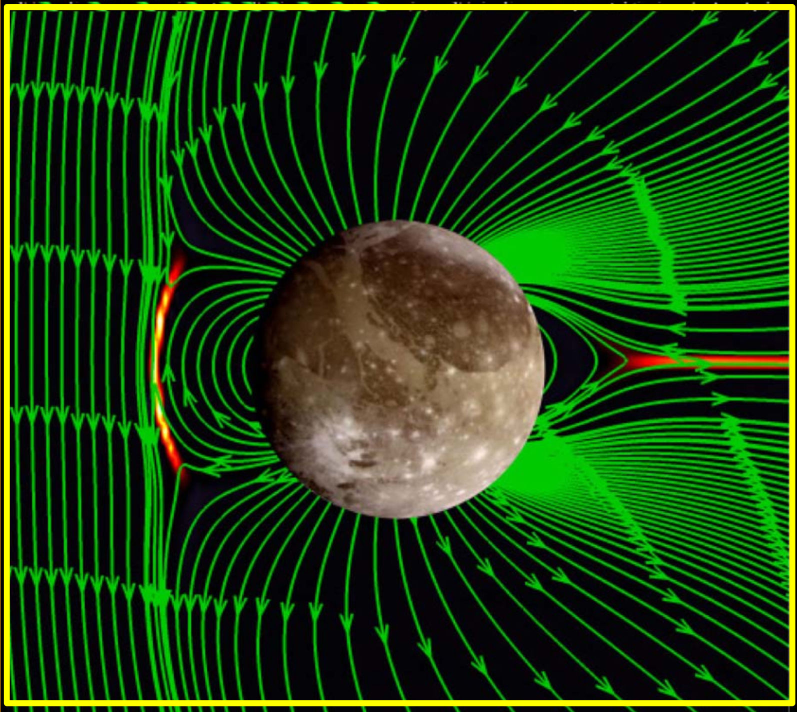
The context

Evidences of possible habitability – Ganymede and Callisto

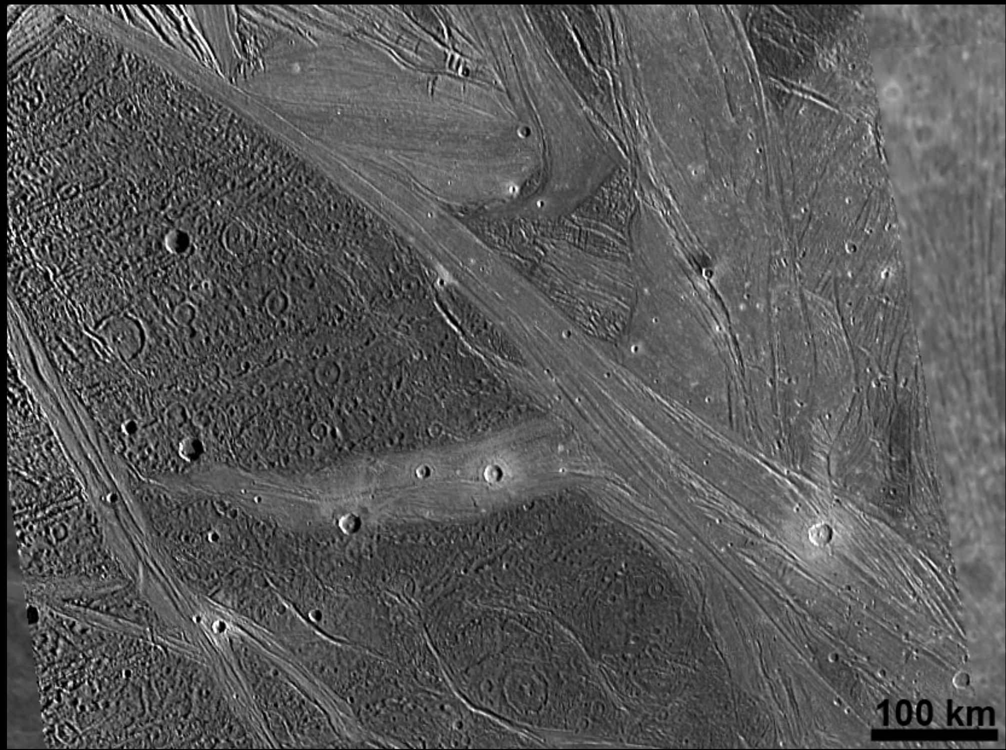
Galileo evidences

Induced magnetic field

Observed but not characterised



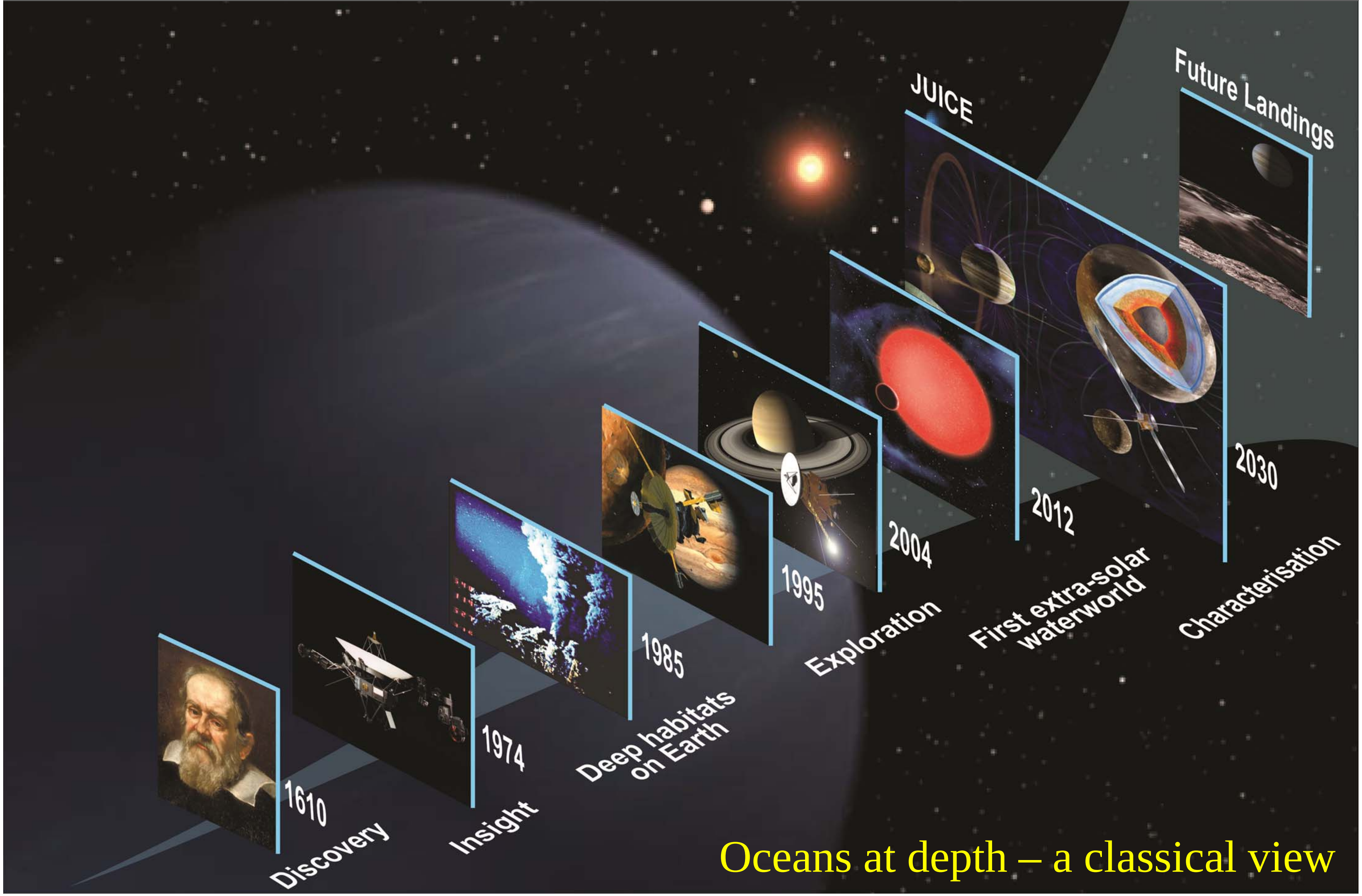
Geologic activity



Questions

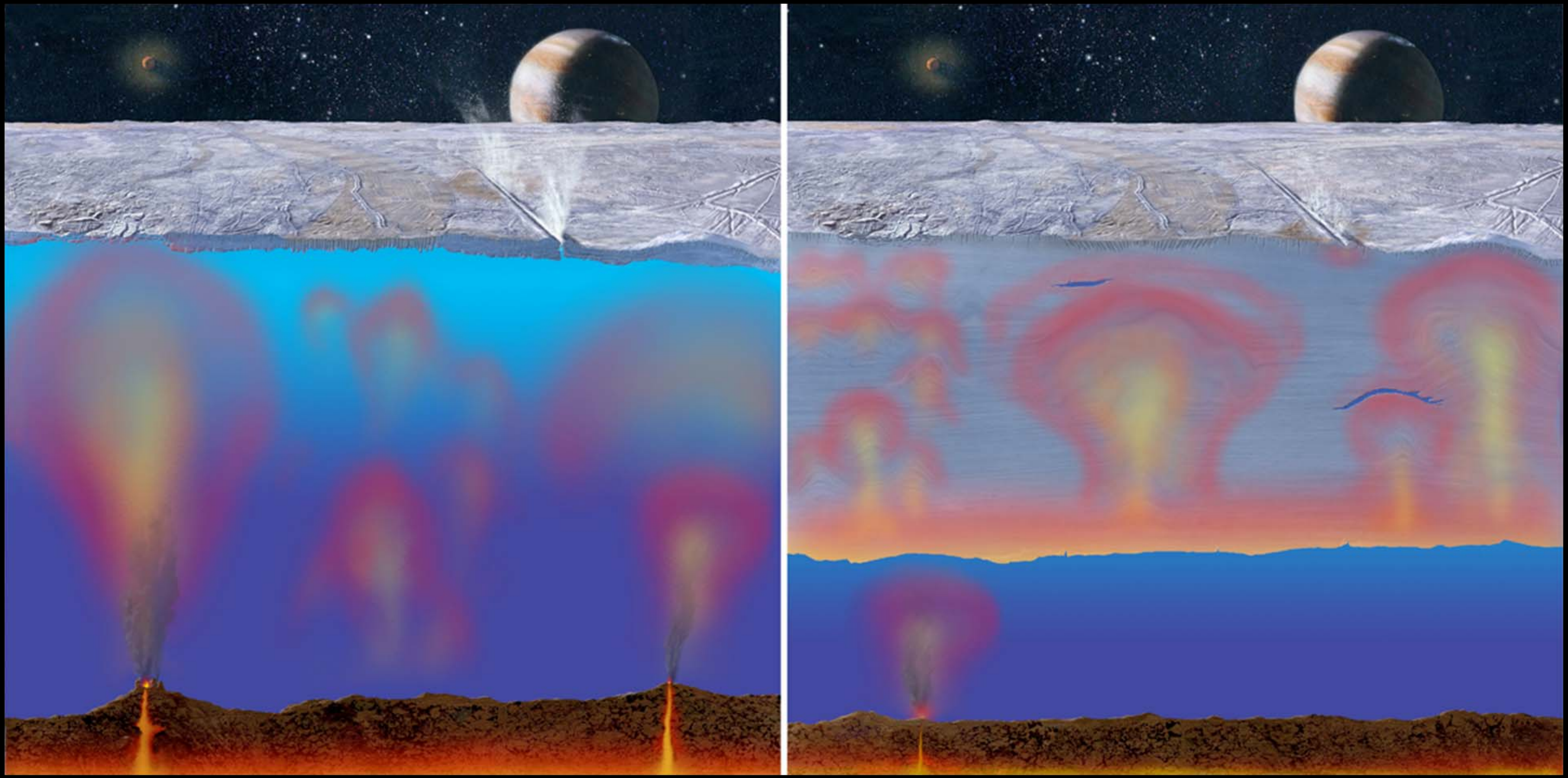
- ✧ Which depth?
- ✧ Which size?
- ✧ What is its composition?

Habitabilité des lunes de Jupiter:
des premières évidences aux futures explorations



Oceans at shallow depth

How deep are the oceans? We still don't know…



Europa

Evidences are not sufficient to solve this issue

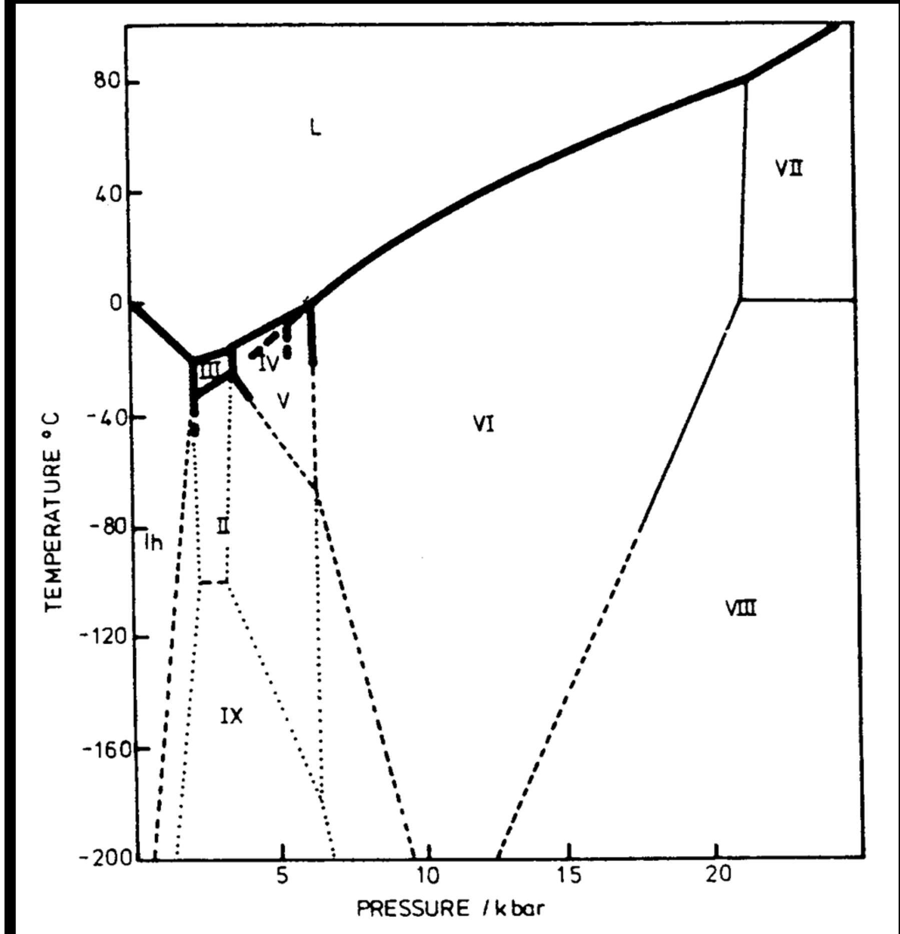
Globally thin crust: pros – magnetic field?, geologic features, current activity

cons – thermal equilibrium?, geologic features

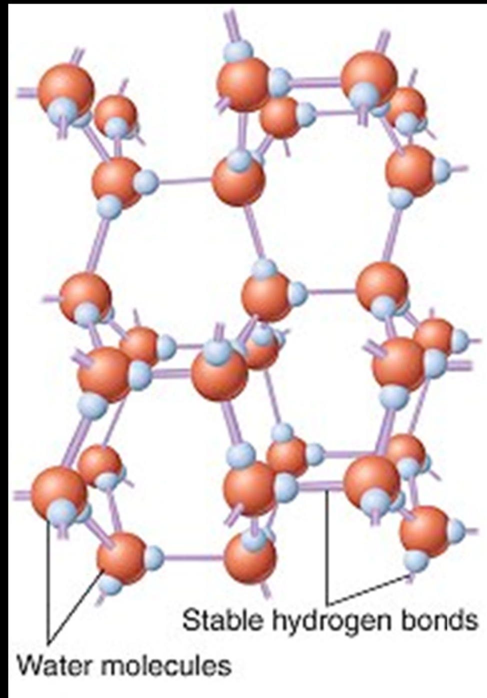
A new space mission is needed

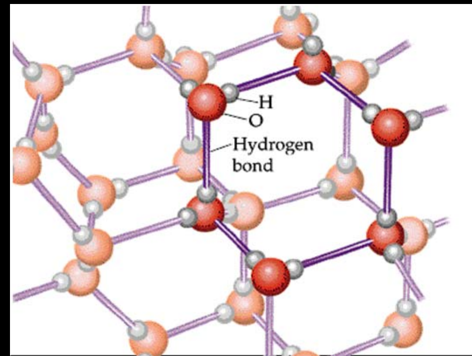
Very deep oceans

Giant Icy worlds – the high pressure phase diagram of water



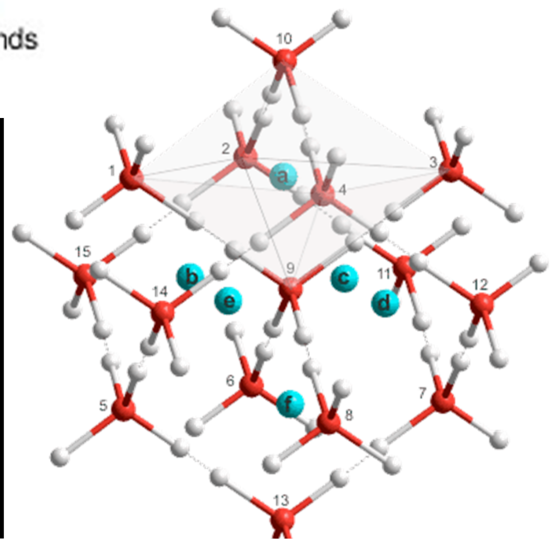
Ice V





Ice Ih

Ice VII

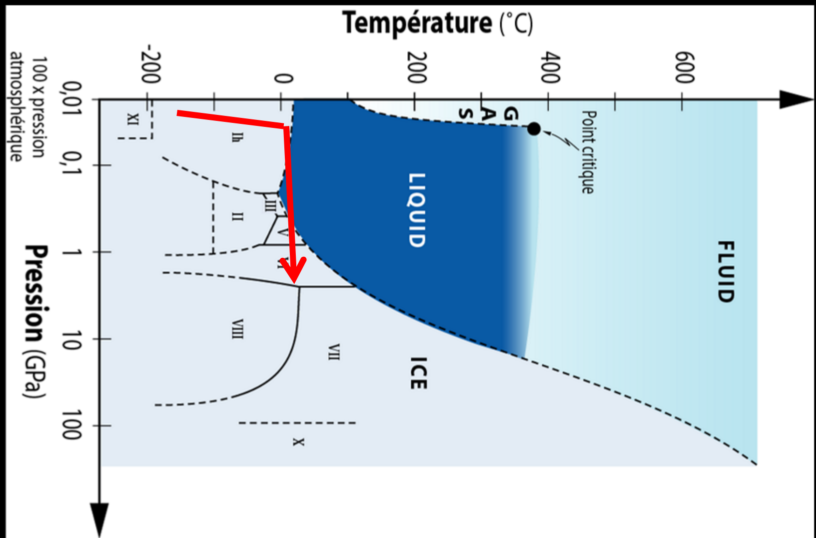


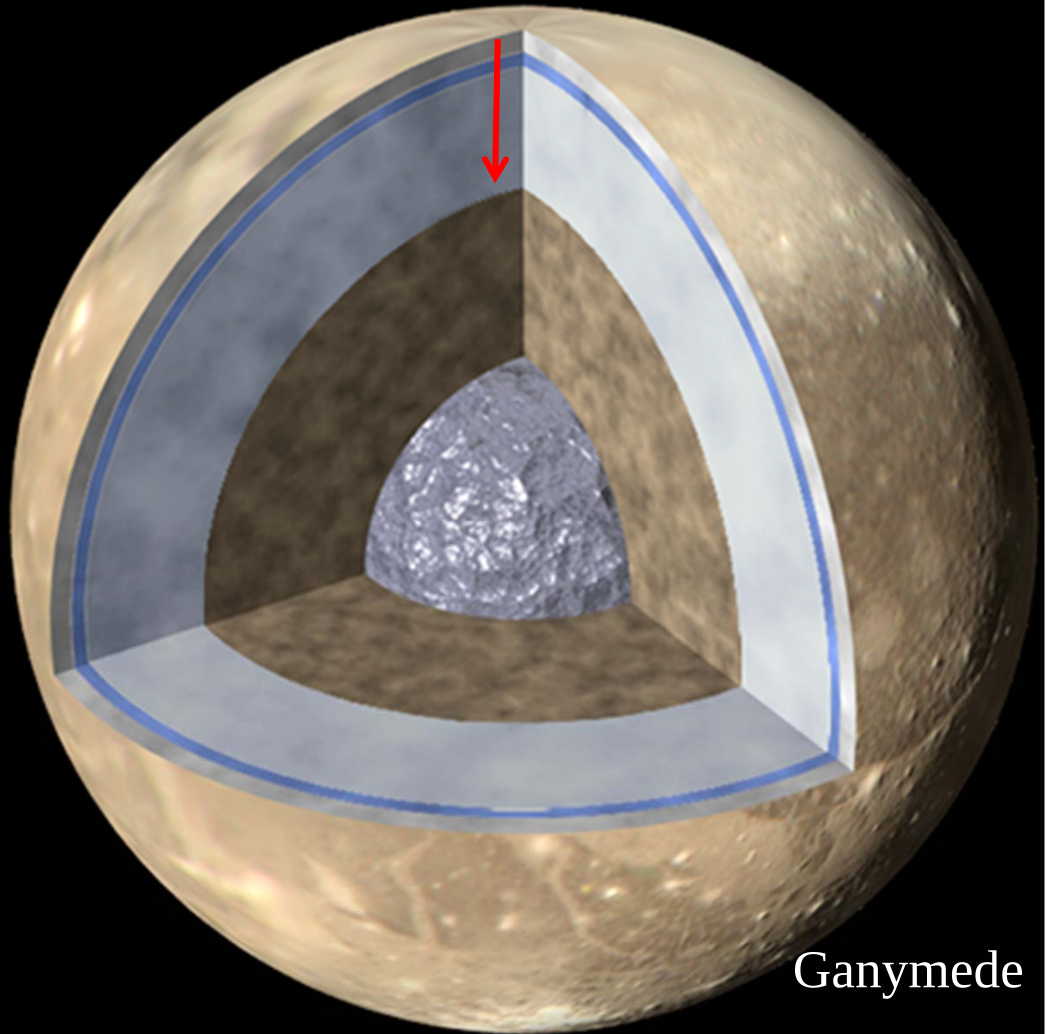
H_2O Well-known since 1912 (Bridgman)

Modern experiments (for planetology) devoted to complex mixtures.

Very deep oceans

Icy worlds – evidences of a liquid ocean

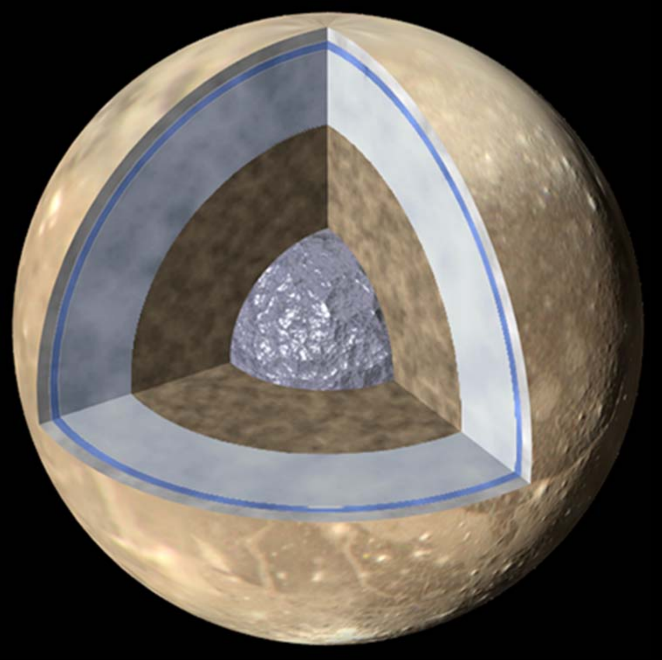




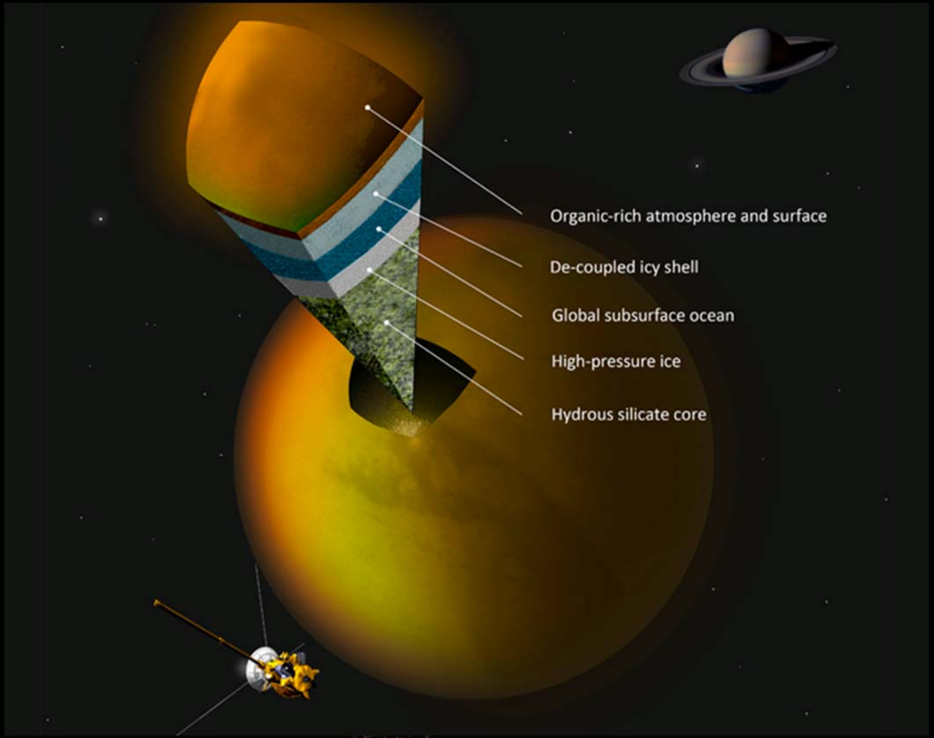
Ganymede

Very deep oceans

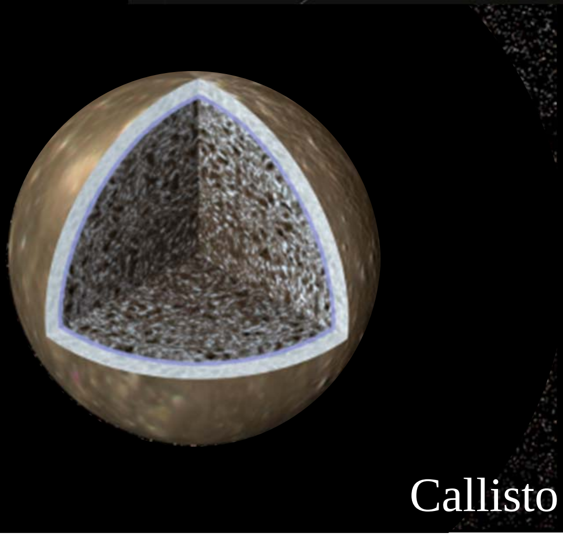
The known examples in the Solar System



Ganymede



Titan



Callisto

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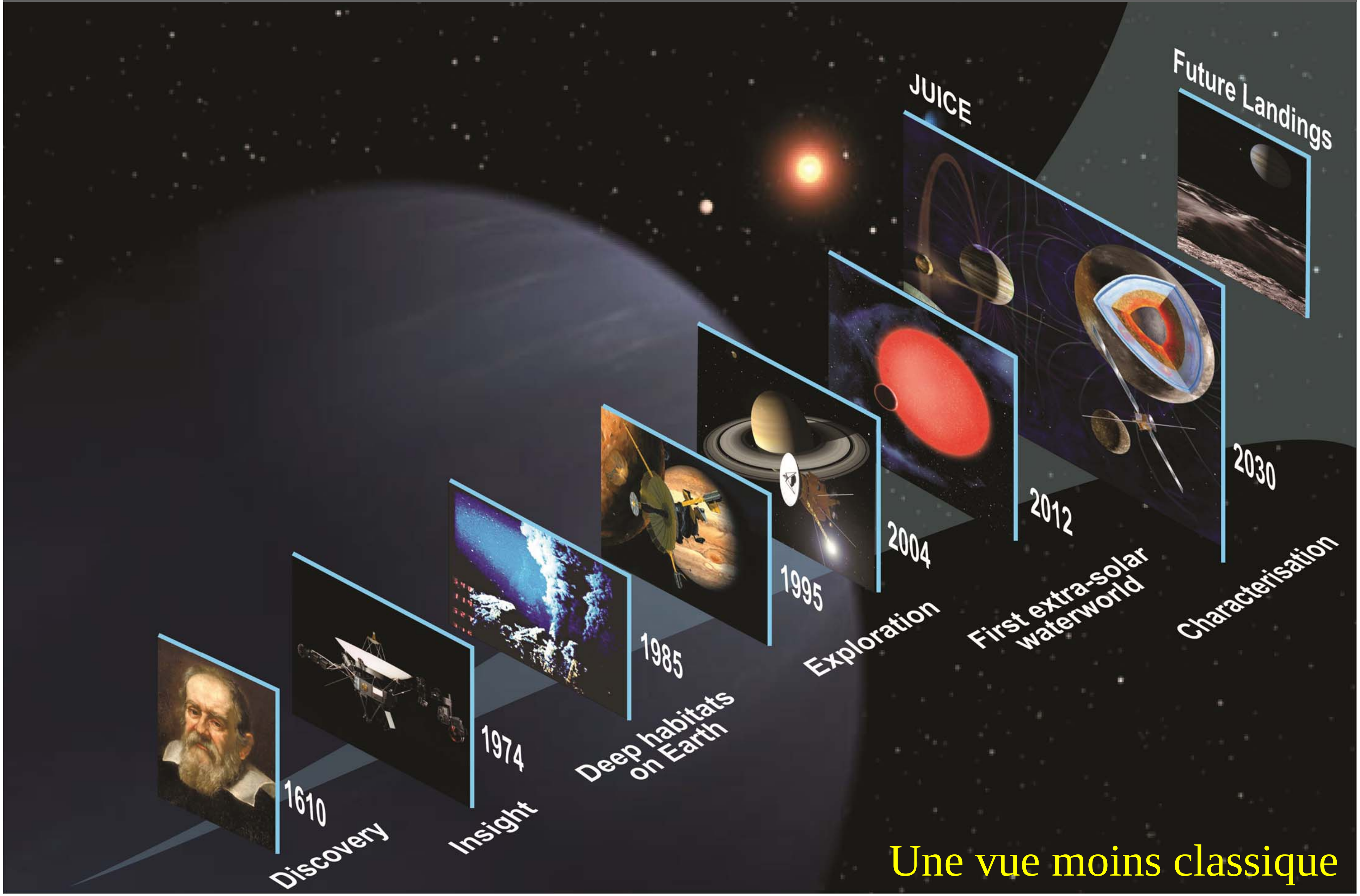
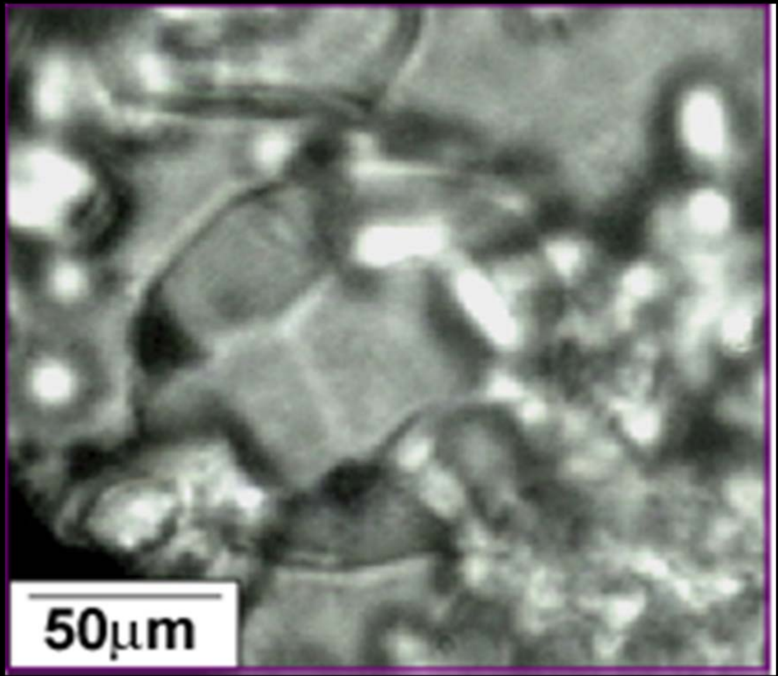
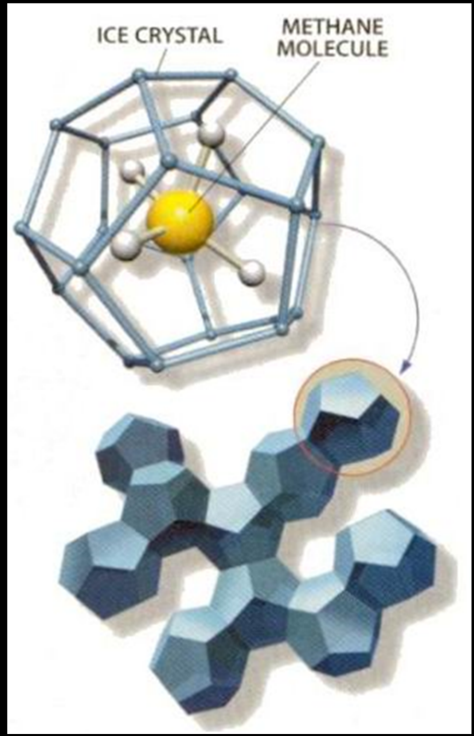


Oceans at shallow depth

Le problème de la composition

Clathrate hydrates : the burning ice.

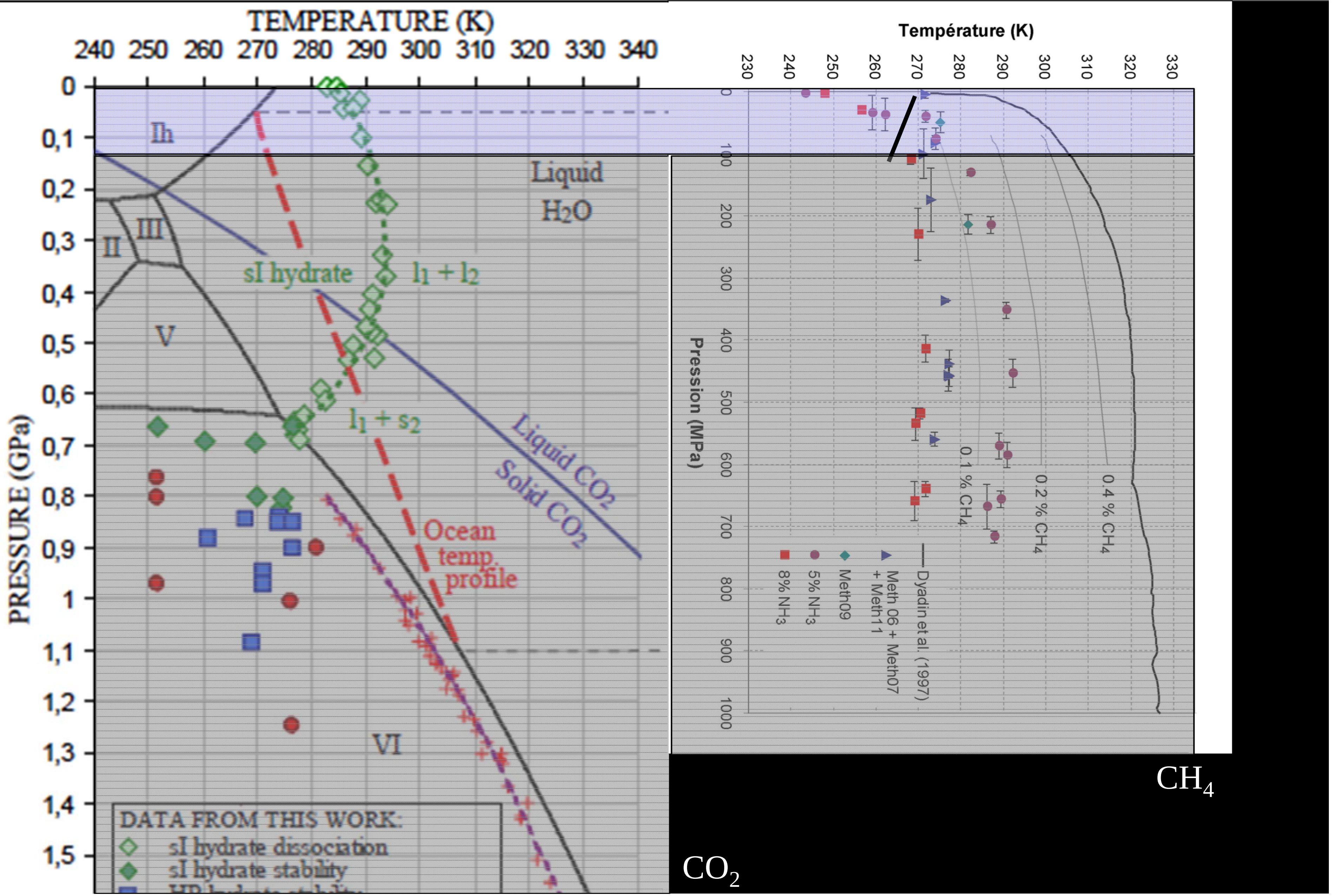




Known since the 50's (oil engineers)
Envisaged in icy moons since early 90s (not sure about this…)
More recently, Prieto-Ballesteros (2005), and Vance et al. envisage to find them in abundance in Europa's crust
But how does that work in depth?

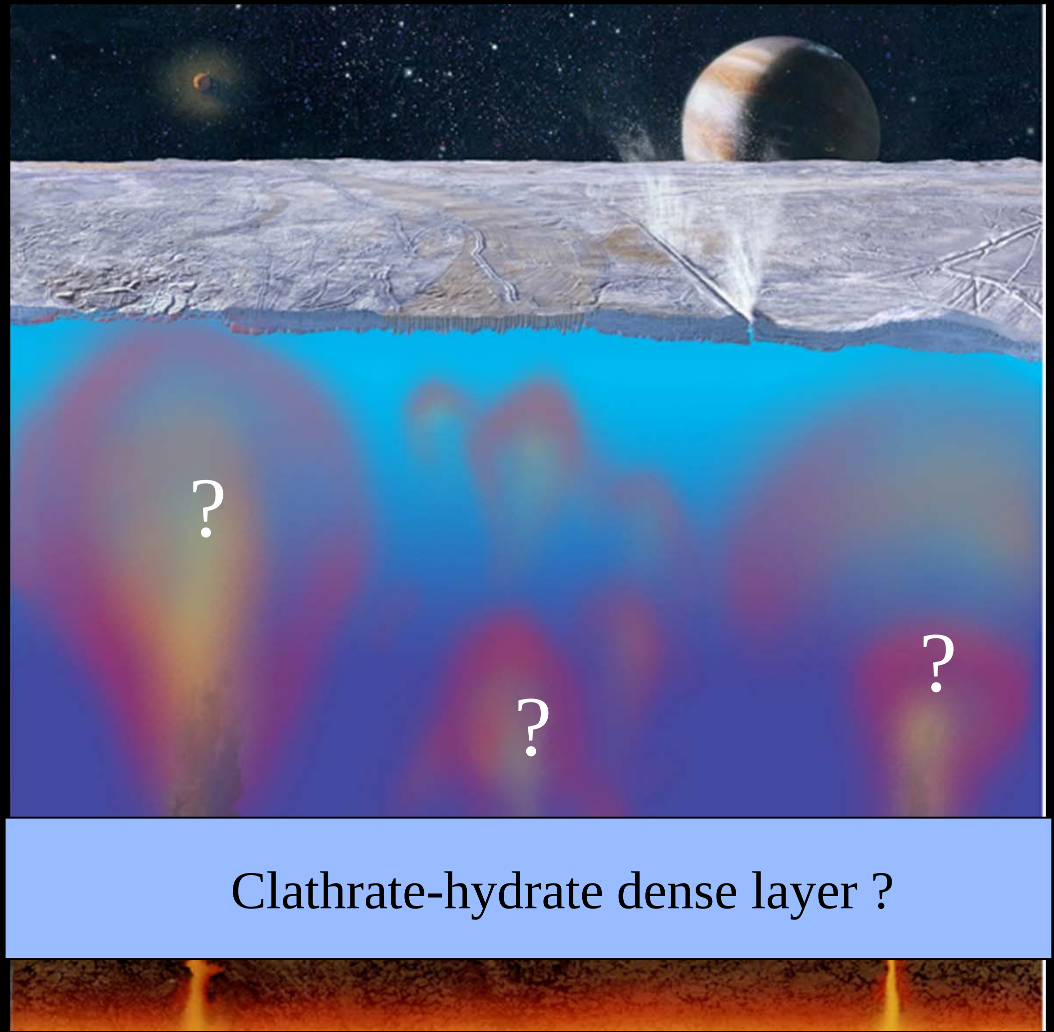
Oceans at shallow depth

Contact of the ocean with silicates - is that certain?



Oceans at shallow depth

Contact of the ocean with silicates - is that certain?

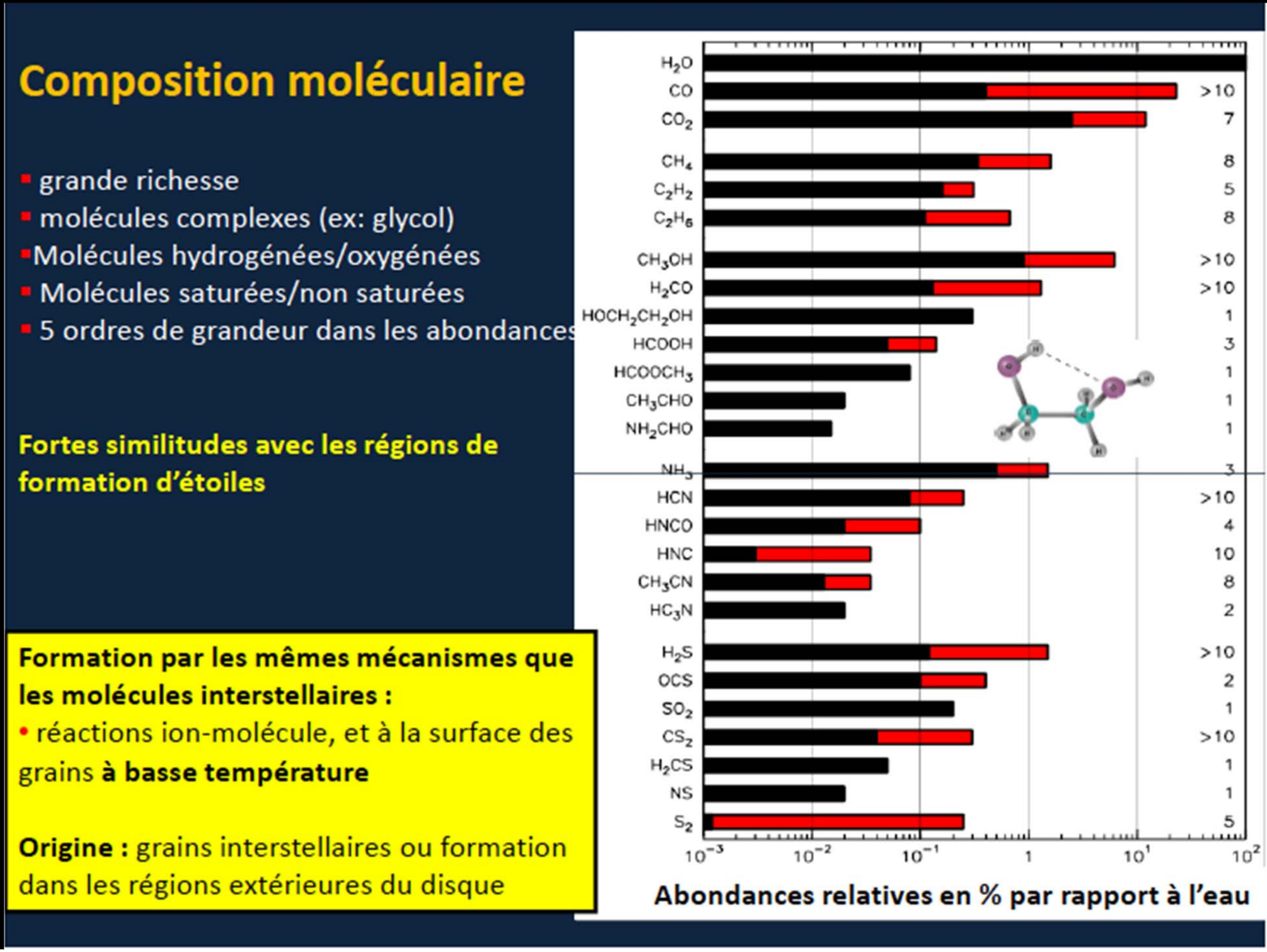


At last, the total amount of volatiles and salts fixes the thickness of the deep layer.

But why is that so important? A problem for **SPONCH**.

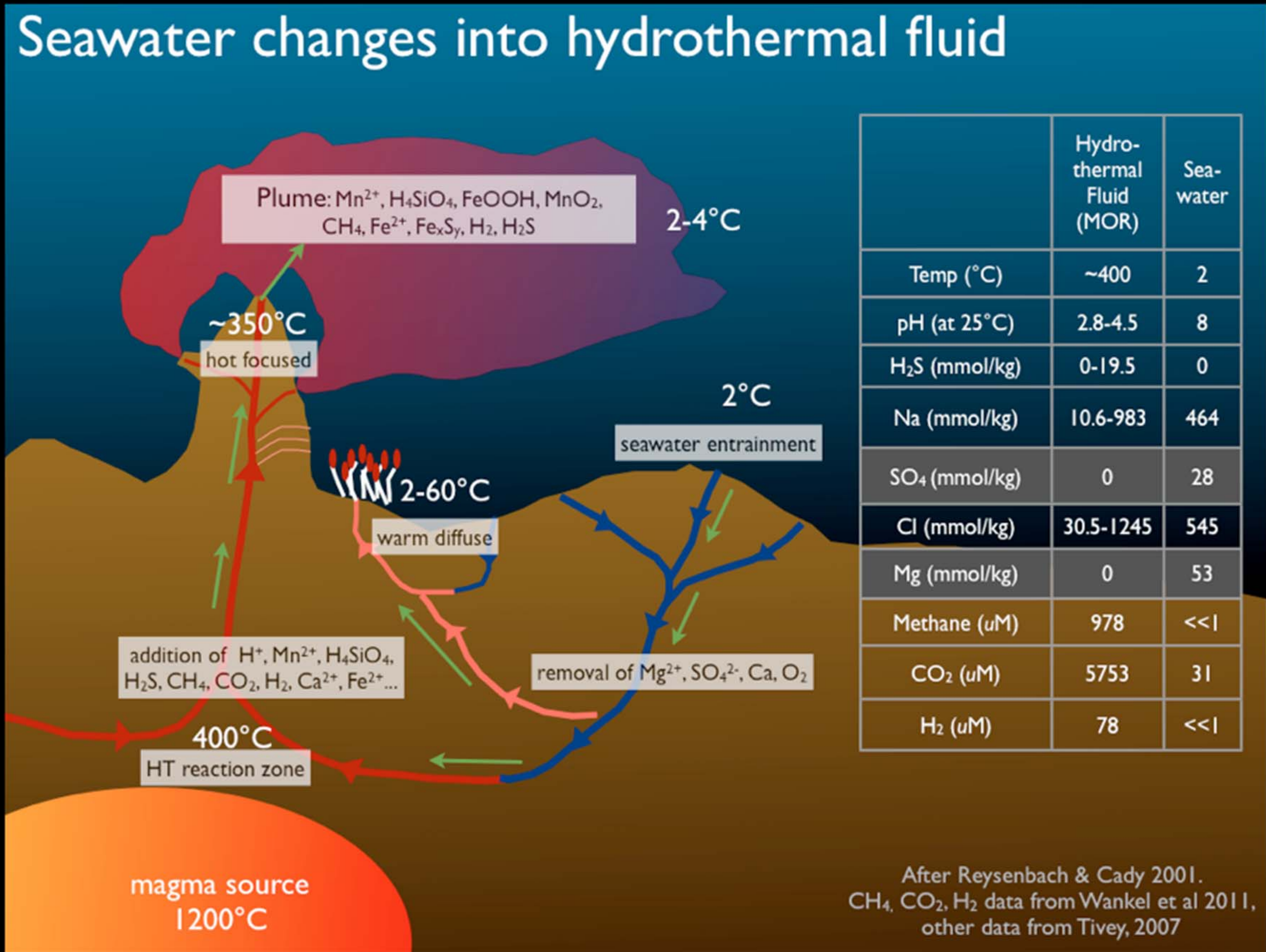
Oceans at shallow depths

no Phosporus in planetary ices



Oceans at shallow depths

Hydrothermal vents – that helps a lot…

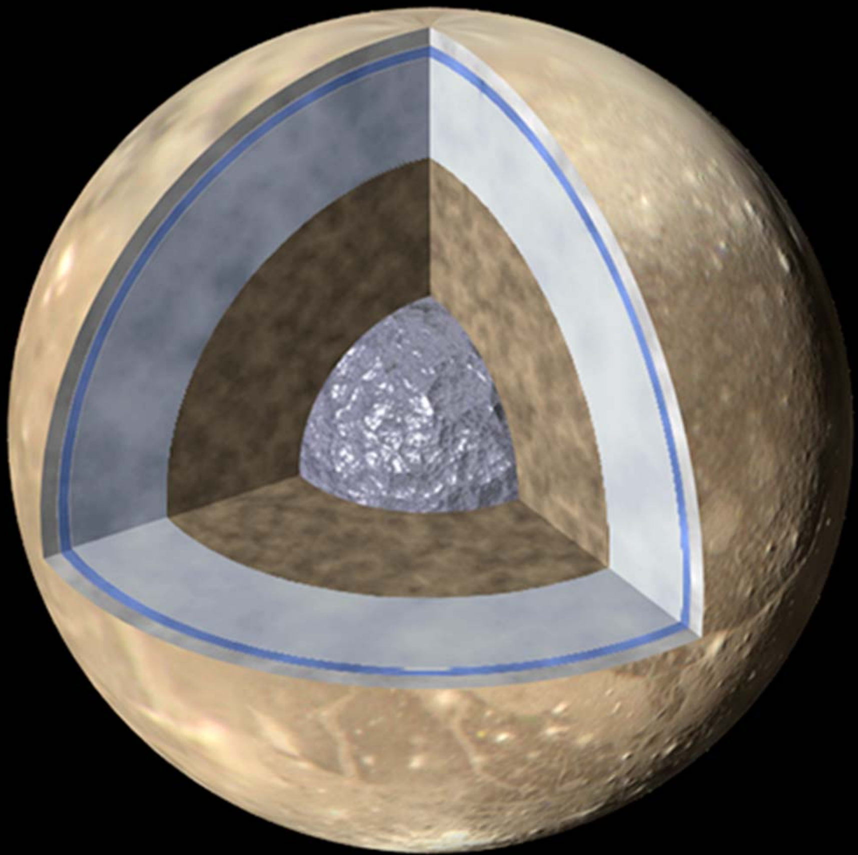


	Hydro-thermal Fluid (MOR)	Sea-water
Temp (°C)	~400	2
pH (at 25°C)	2.8-4.5	8
H_2S (mmol/kg)	0-19.5	0
Na (mmol/kg)	10.6-983	464
SO_4 (mmol/kg)	0	28
Cl (mmol/kg)	30.5-1245	545
Mg (mmol/kg)	0	53
Methane (uM)	978	<<1
CO_2 (uM)	5753	31
H_2 (uM)	78	<<1

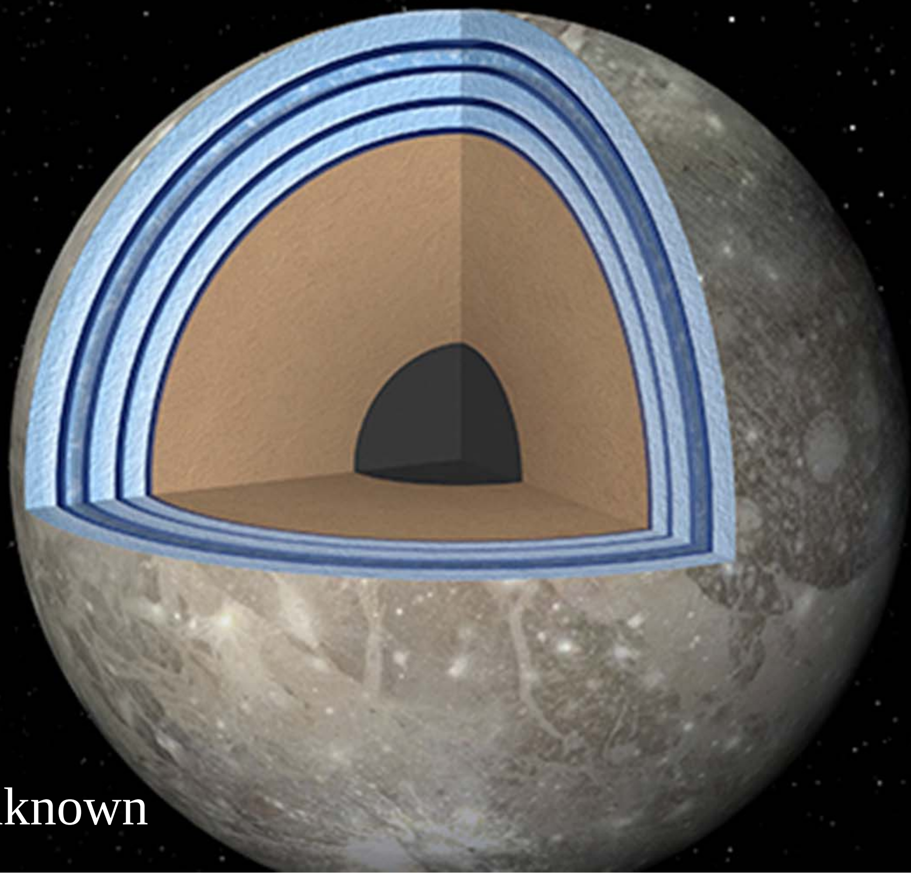
Very deep oceans

Icy worlds – the complex chemistry is a key player (NH_3, H_2SO_4, CO_2, H_2S, …)

Density contrasts of water mixtures…



Vance et al., 2014

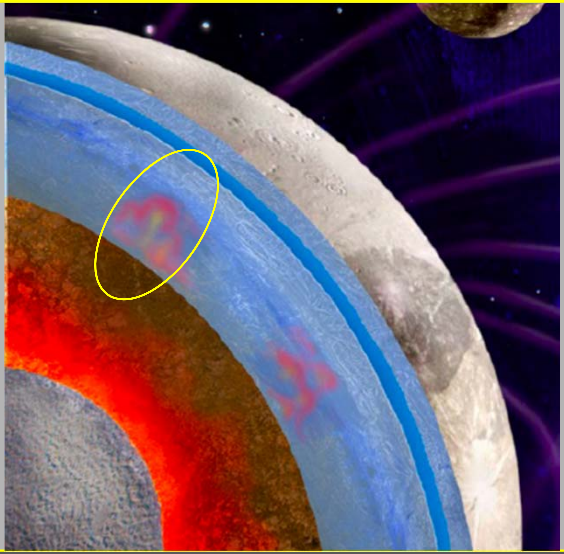


The internal structure of the moons is still unknown

Very deep oceans

A comparison

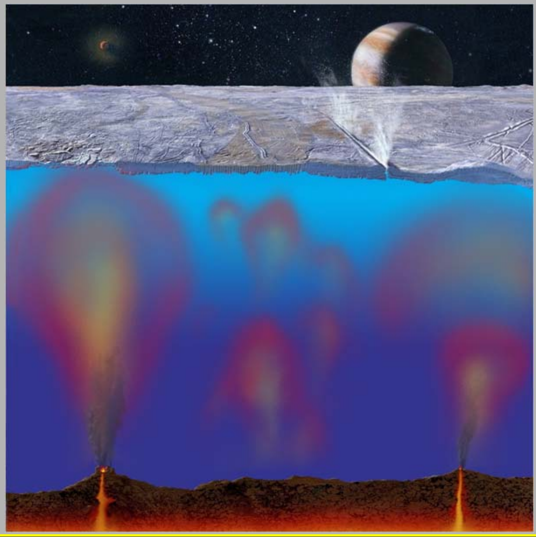
Ganymede type: liquid layers trapped between two icy mantles



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

Key question:
Are these waterworlds habitable ?

Europa type: Liquid layer in direct conact with silicates (Earth's analog)

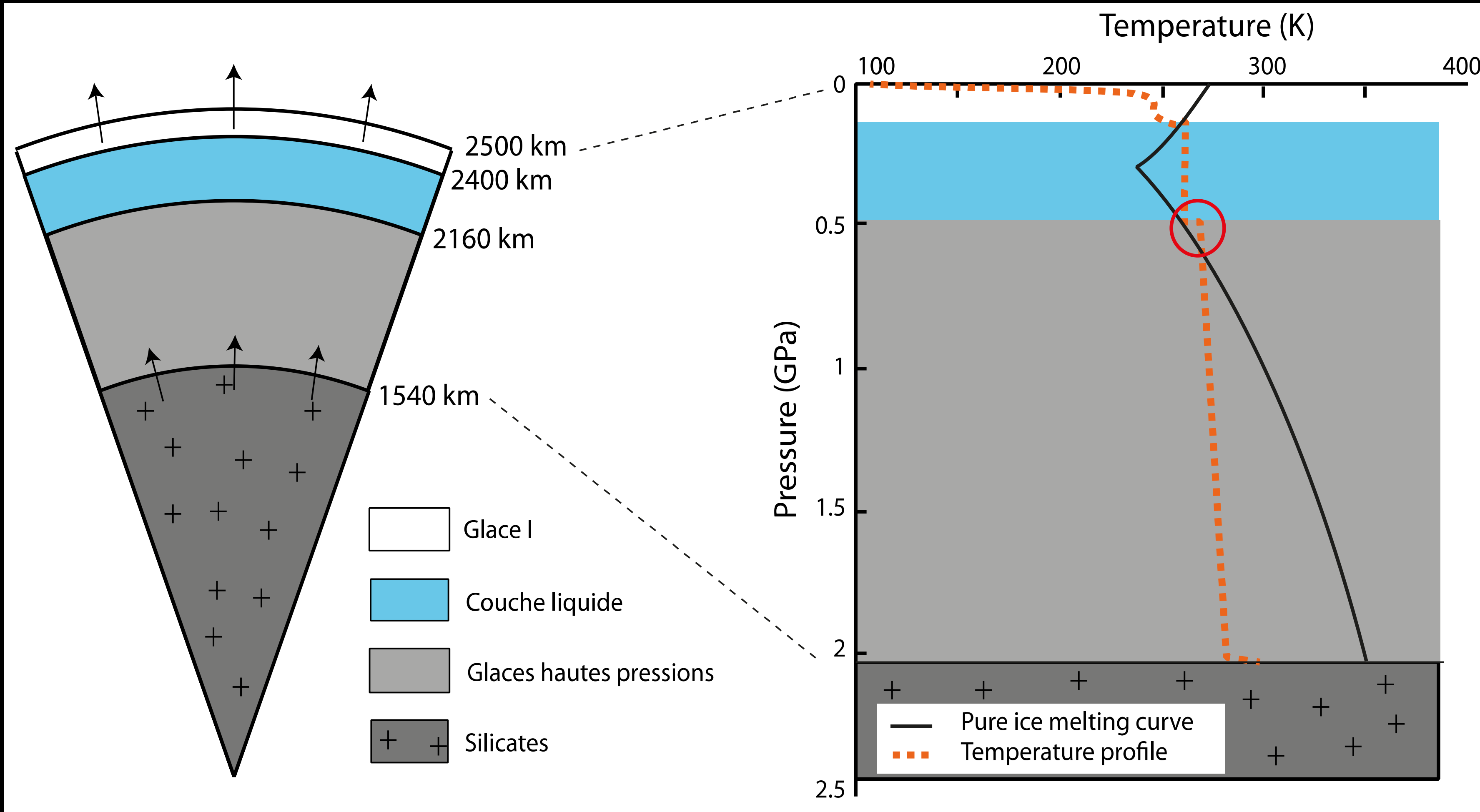


Occurrence:
Europa, Enceladus
Only possible for very small bodies

Key questions:
How are the surface active areas related to potential deep habitats?
Is the water in contact with silicates?

Very deep oceans

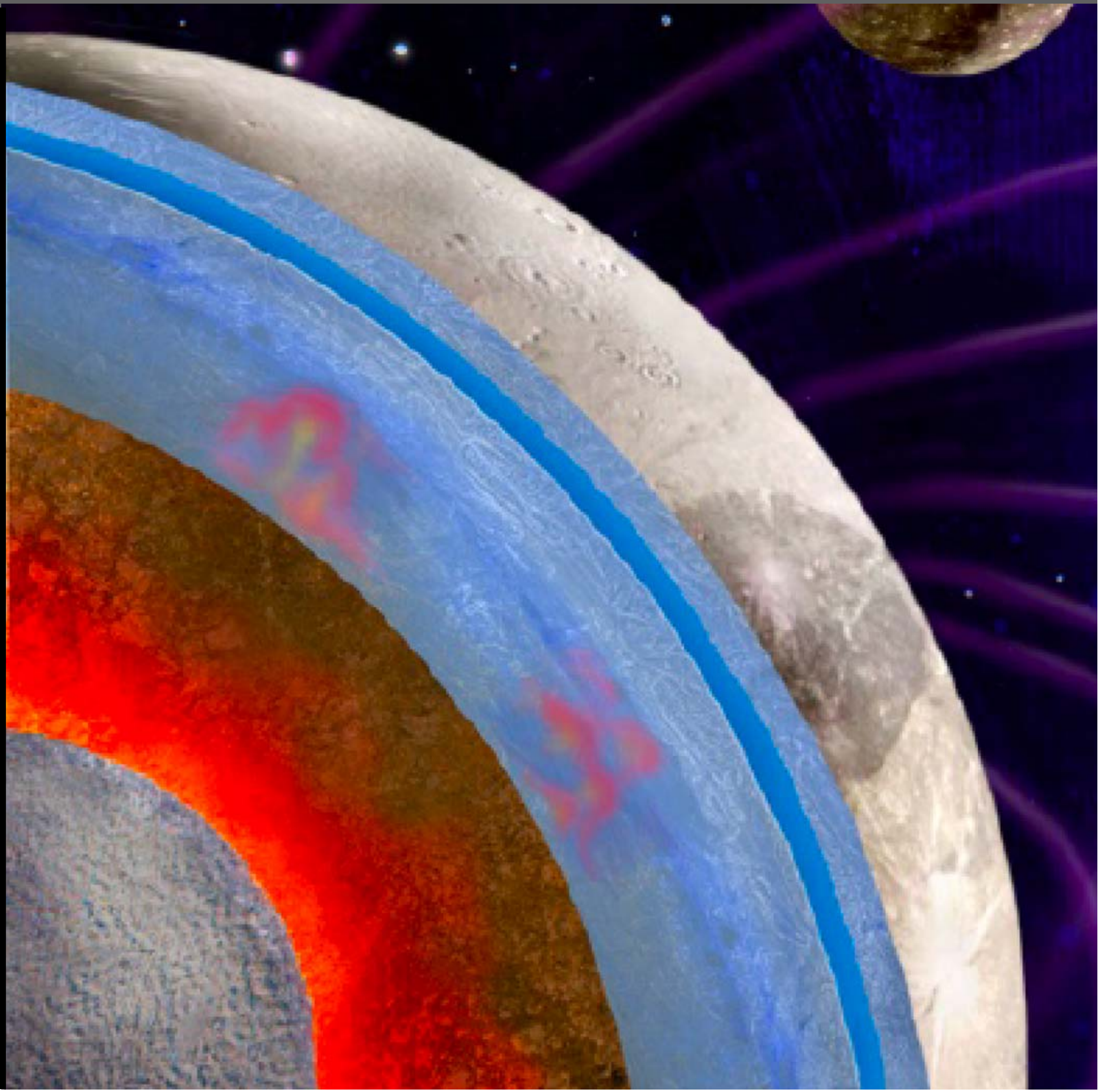
The dynamics of the system



Convective regime

How does that work?
Still unsolved

Very deep oceans



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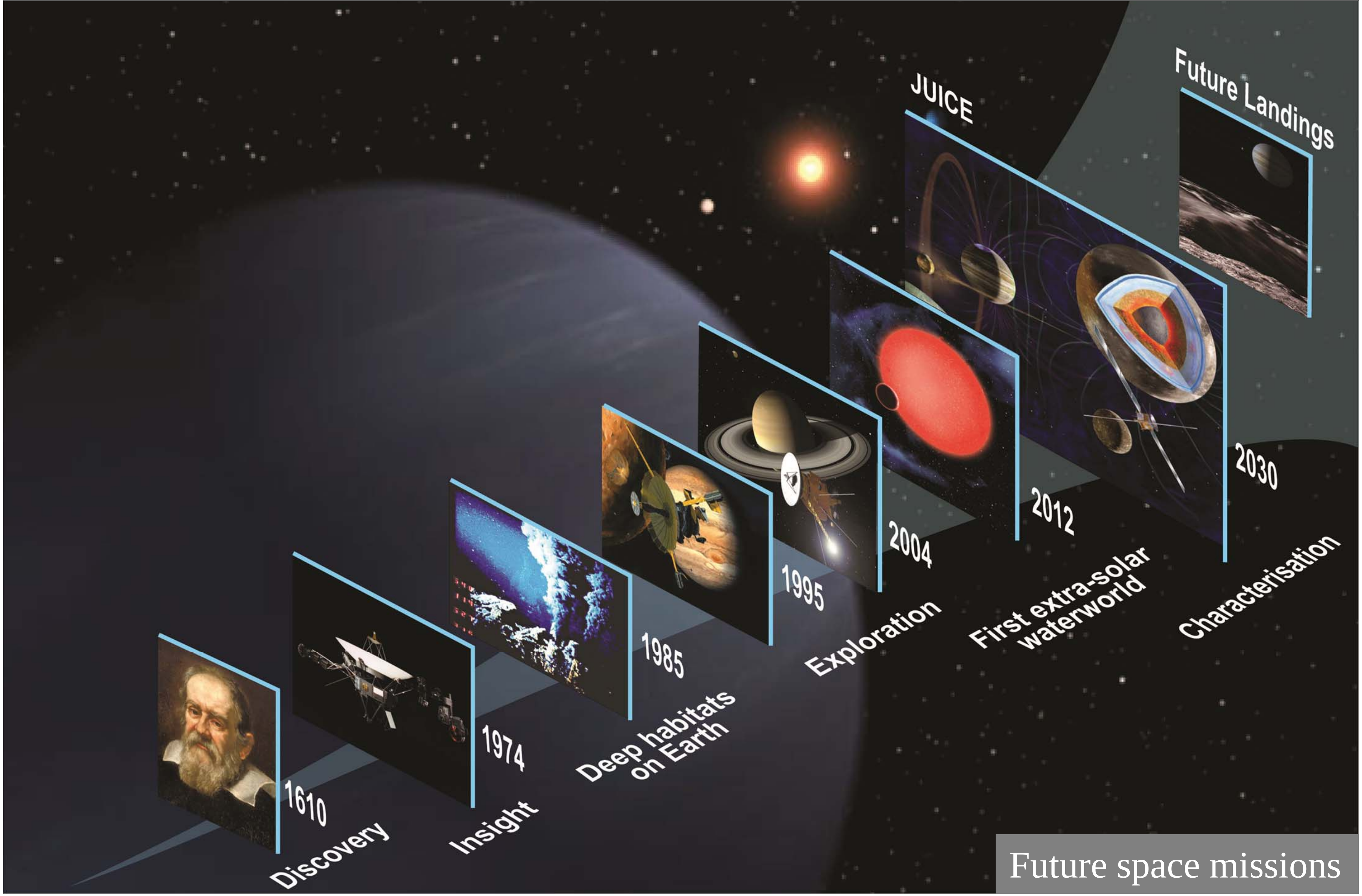


Future space missions

JUICE: JUpiter Icy moons Explorer

Emergence of habitable worlds around gas giants

Jupiter system as an archetype for gas giants

Callisto:

remnant of the early solar system

- *Icy shell, ocean*
- *Geology, surface composition*
- *Past activity*

Europa: *recently active zones*

- *Surface non-water-ice material*
- *Search for liquid water*
- *Recent activity*

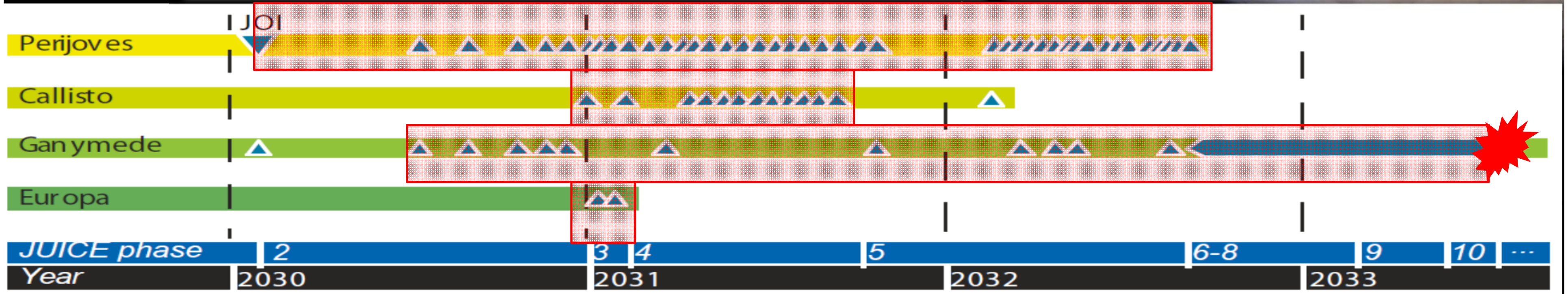
Ganymede:

planetary object and potential habitat

- *Sub-surface, ice shell, ocean, interiors*
- *Geology, surface composition*
- *Atmosphere, ionosphere*
- *Magnetosphere, plasma environment*

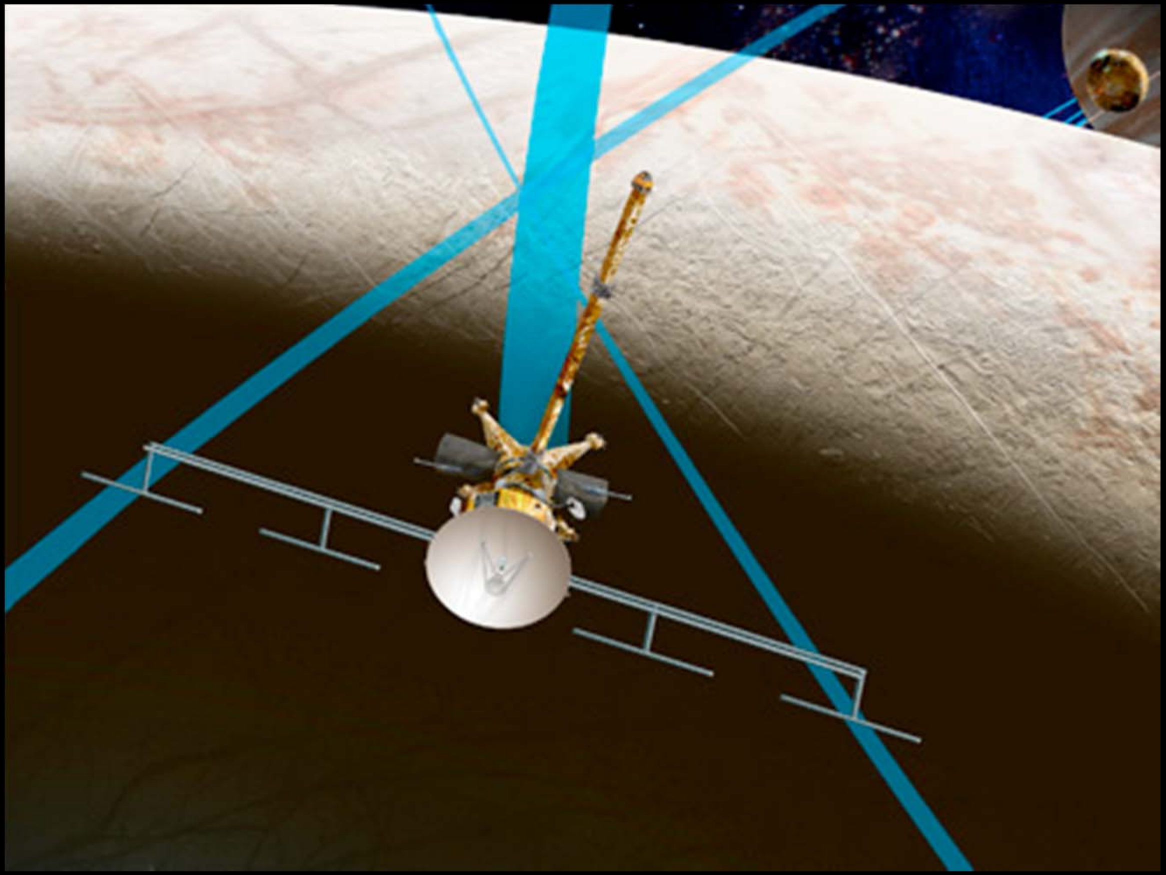
Jupiter System:

- *Atmospheric structure, chemistry and dynamics*
- *Magnetosphere as fast rotator and giant accelerator*
- *Moons as plasma sources and sinks*
- *Couplings and interactions*



Space missions

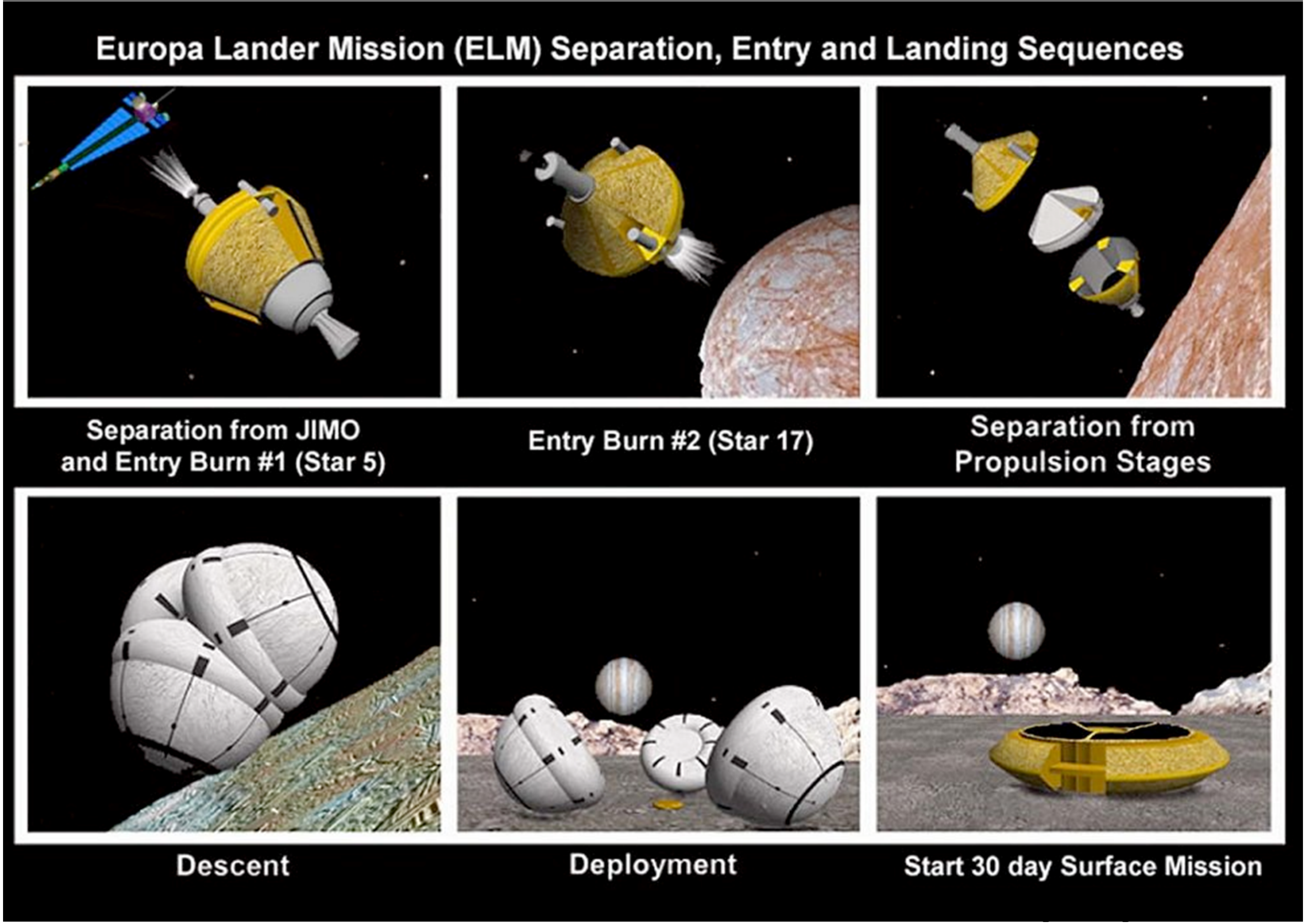
Outer system: the future projects cannot be dedicated to astrobiology



Europa Clipper

Europa lander: still a dream

Futures missions – quelques exemples vers le système externe



Space missions

Outer system: future projects to Titan and Enceladus