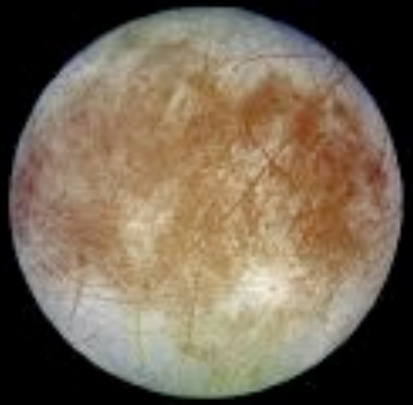
L’habitabilité des lunes glacées de Jupiter (JUICE Mission)

O.Grasset

Europa et Ganymede: les deux meilleurs exemples des “habitats profonds”

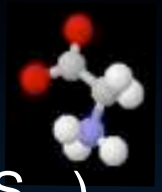


I. Généralités sur les mondes habitables – focus sur les habitats profonds

II. L’apport de JUICE – première mission Large de l’ESA dans Cosmic Vision

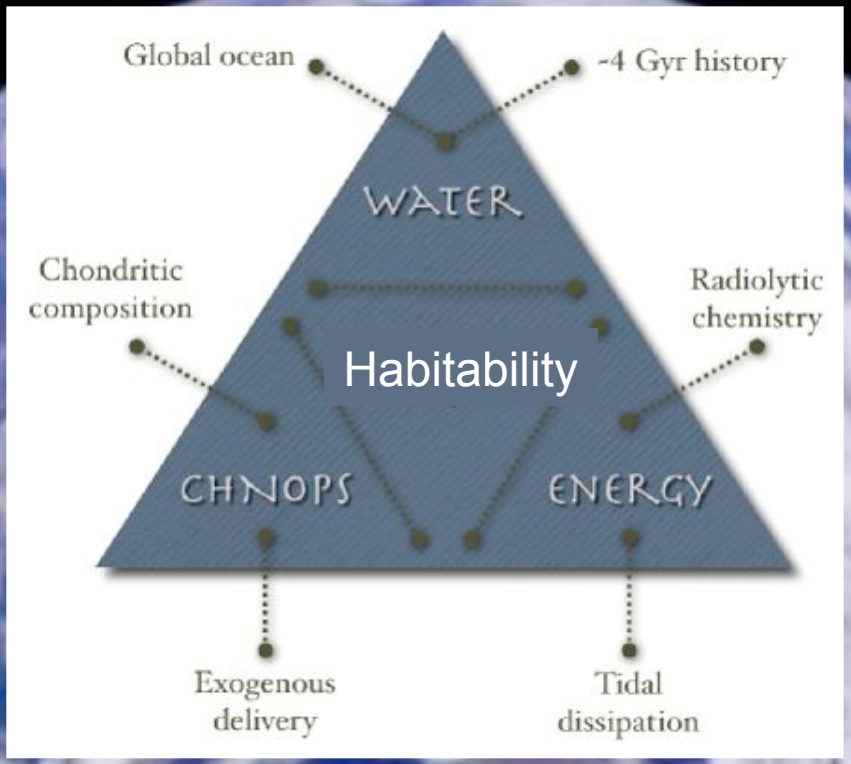
Définir un environnement "Habitable" : Les ingrédients

water

essential elements (CHNOPS...) 

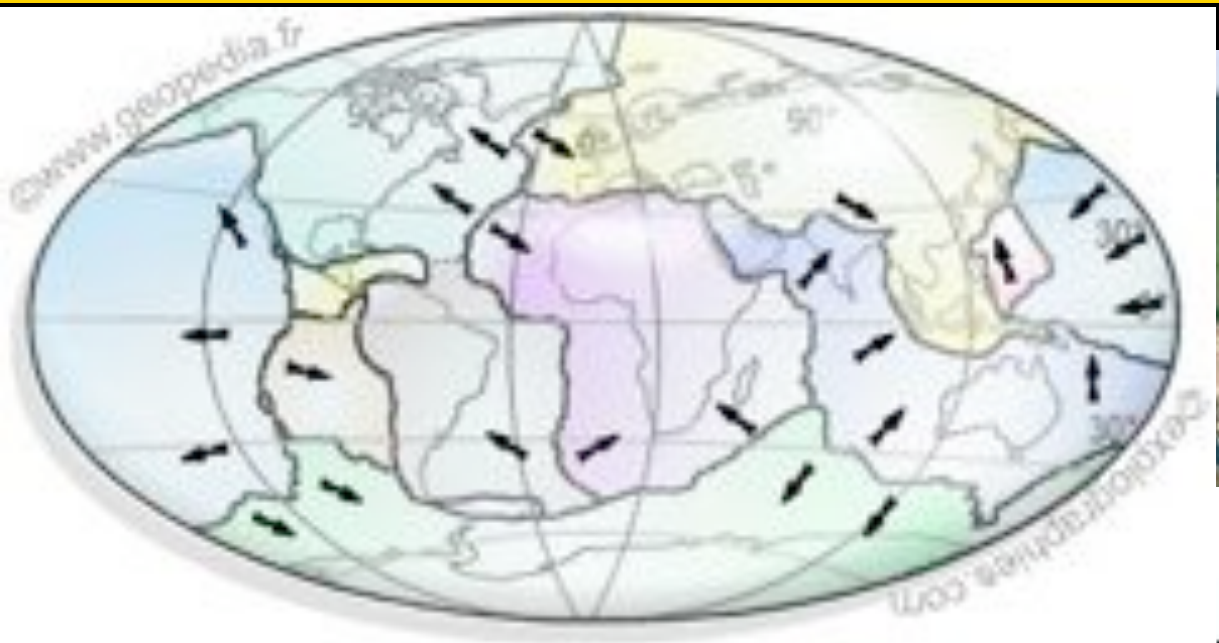
chemical energy

stable environment

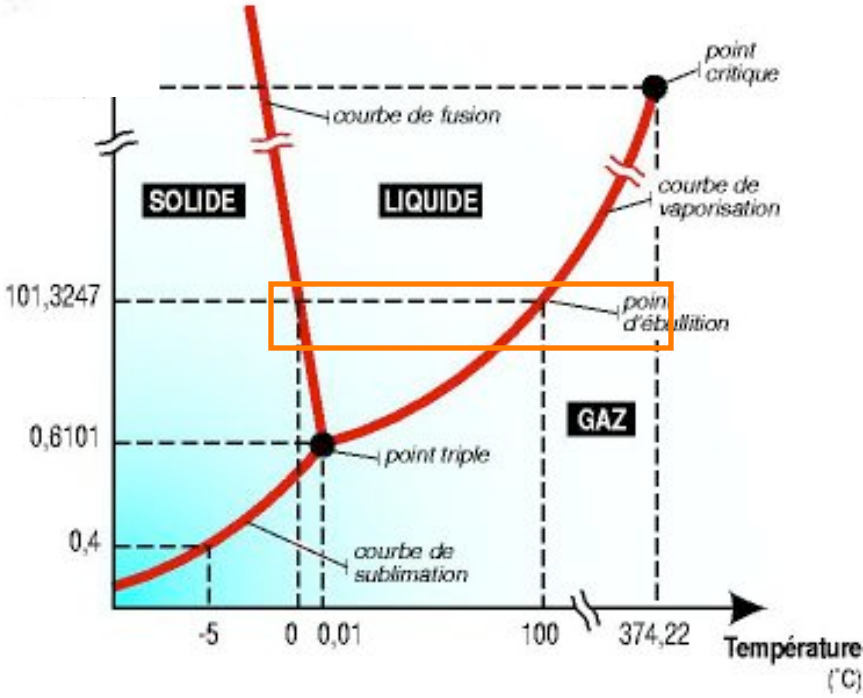


Quels sont les mondes habitables

Classe I – Type Terre

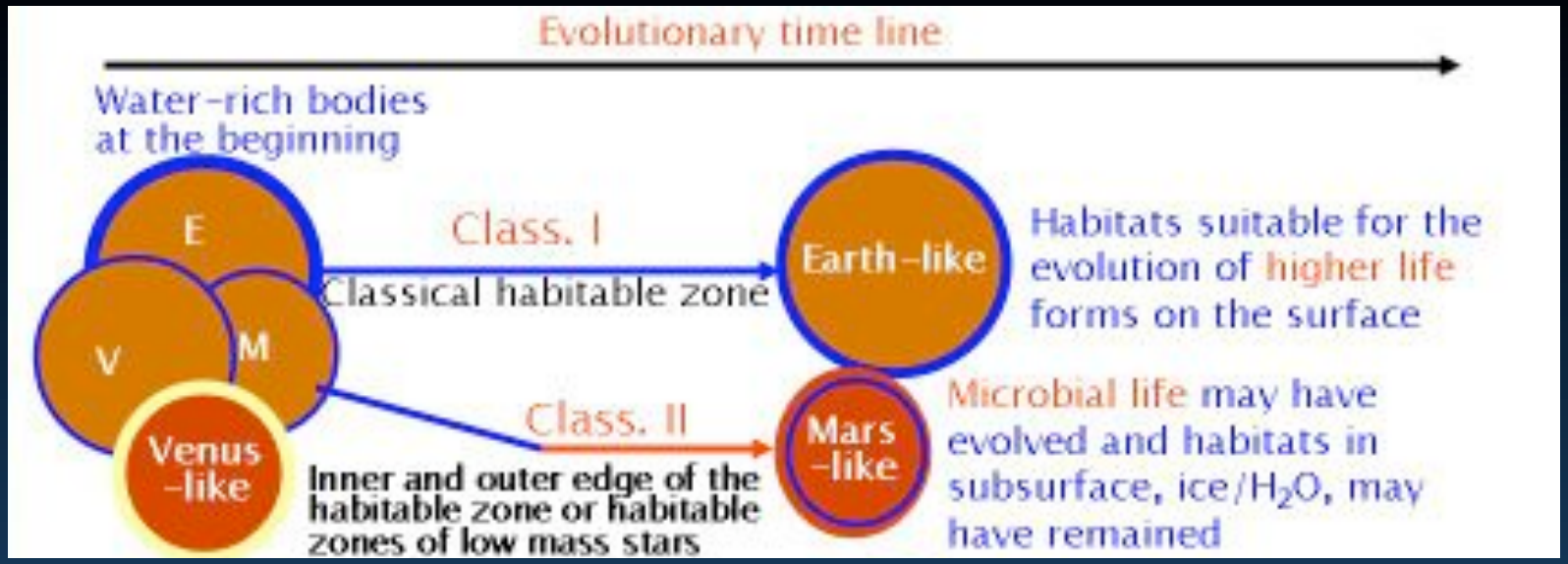


- Tectonique des plaques
- L'eau existe dans les trois états L-G-S
- Peu d'eau…(0.01 %wt)
- Atmosphere dense
- Protection magnétique
- Stabilité relative



Quels sont les mondes habitables

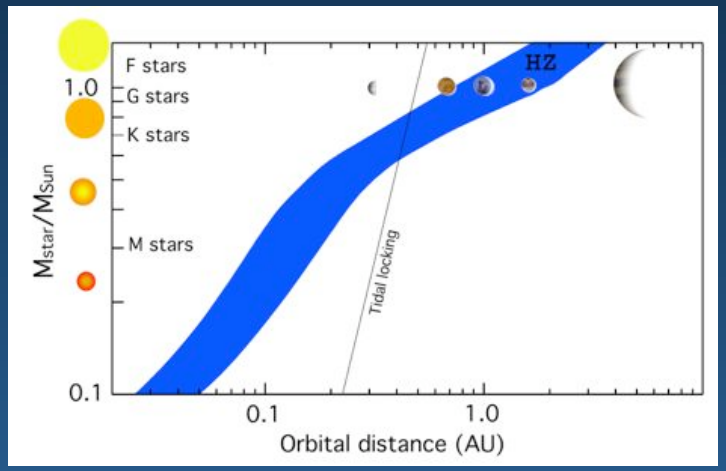
Classe II : environnement habitable dans le passé mais évolution du cas Terre



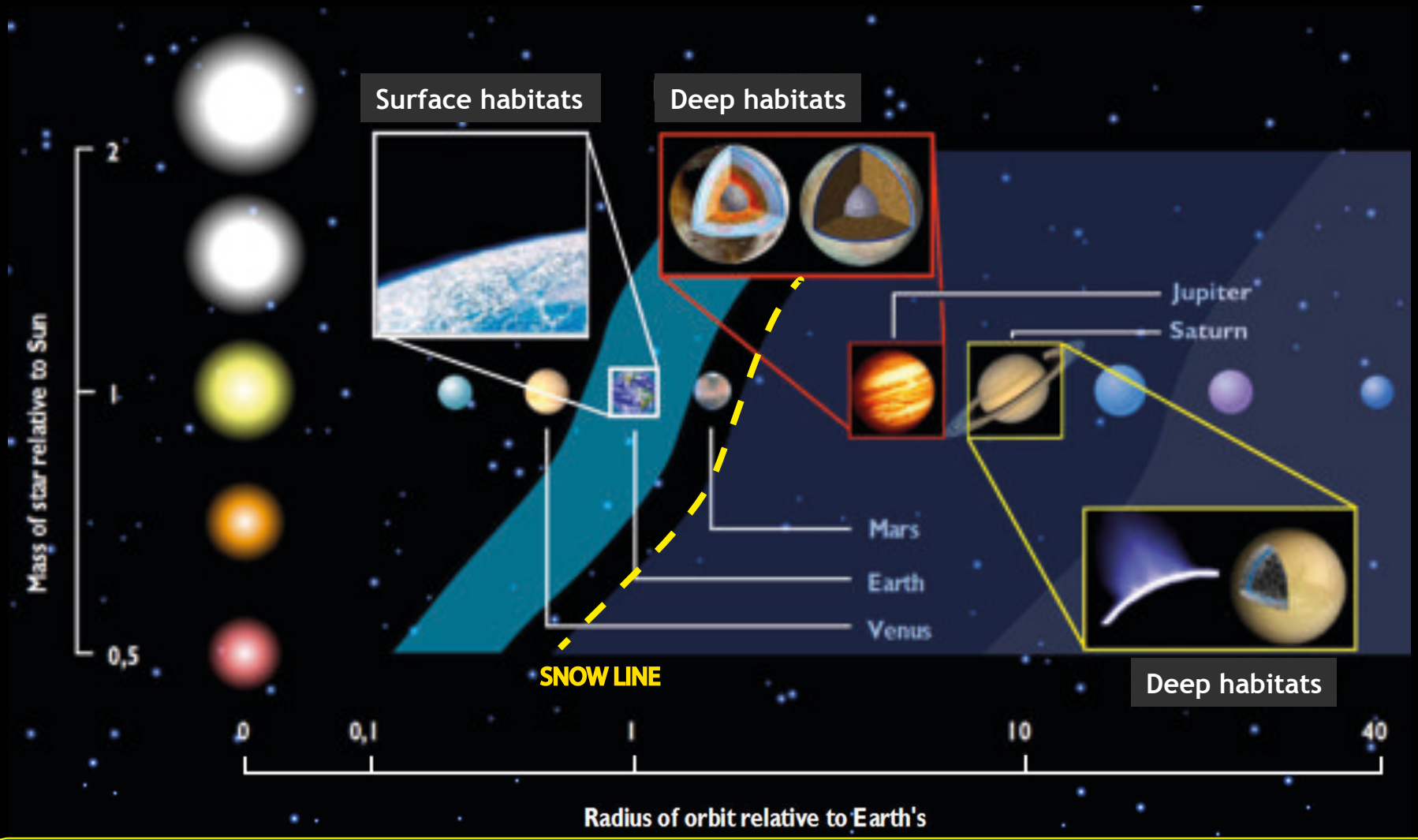
Lammer et al., 2009

La dimension Temps est cruciale

- migration due to star evolution
- Location within the HZ
- Weak magnetic fields
- Dynamical evolution
- Atmospheric loss processes



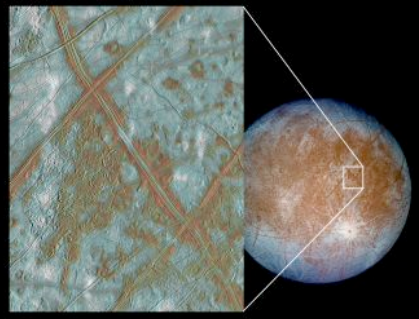
Mondes glacés dans un contexte global



Classes I-II: zone habitable en surface, peu d'eau, domaine restreint
Au delà de la snow-line: habitats profonds au sein des hydrosphères

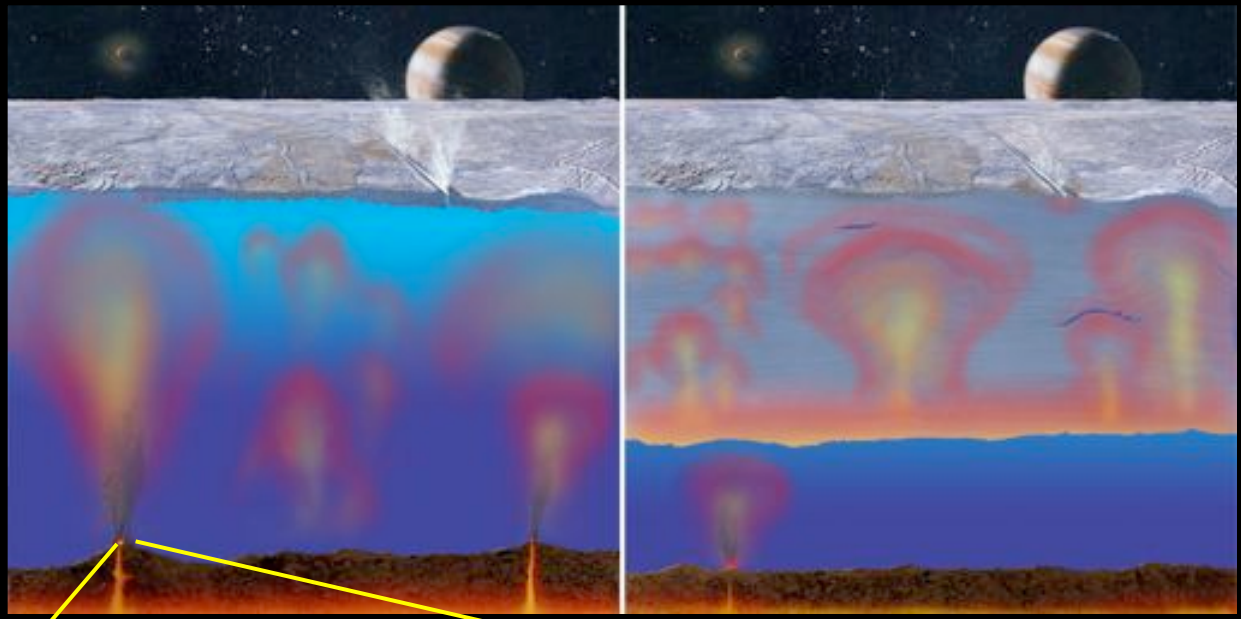
Quels sont les mondes habitables

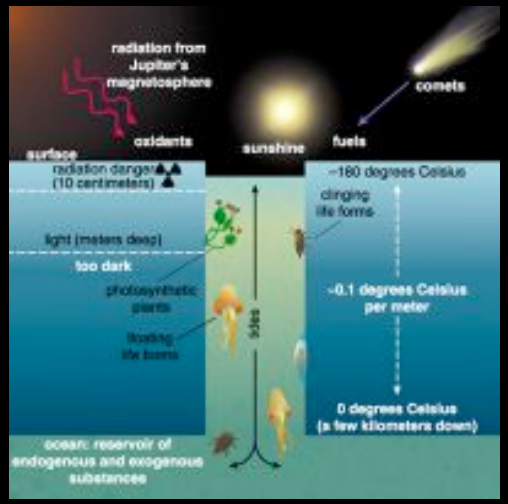
Classe III : océans de subsurface en contact avec les silicates



Type Europa

- Eau
- Elements essentiels
- Energie chimique
- Environment stable



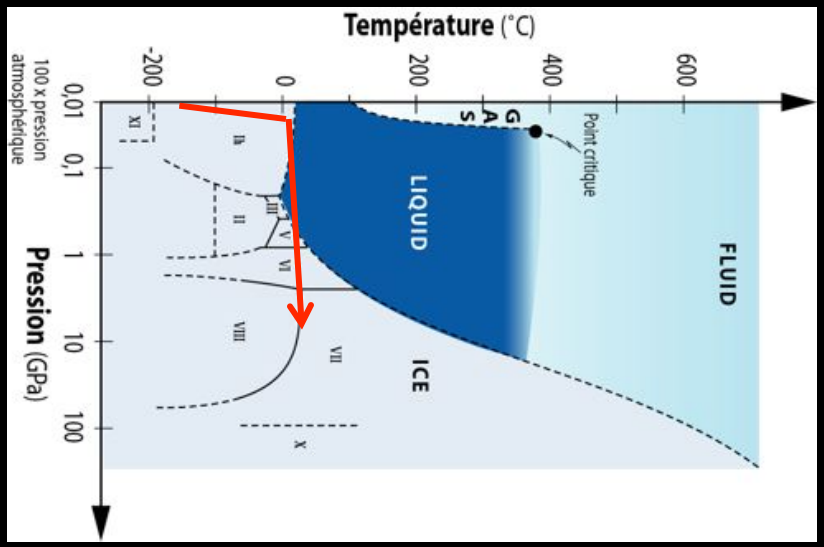


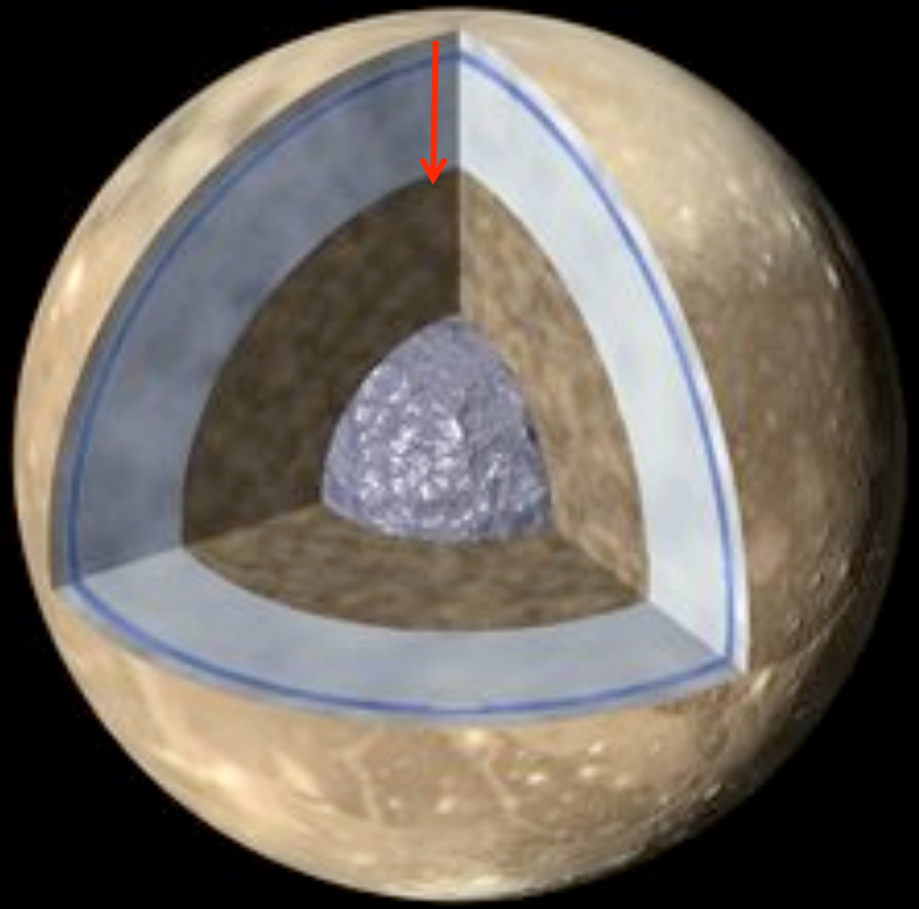
Quels sont les mondes habitables

Classe IV : océans de subsurface sans contact avec les silicates

Type Ganymede

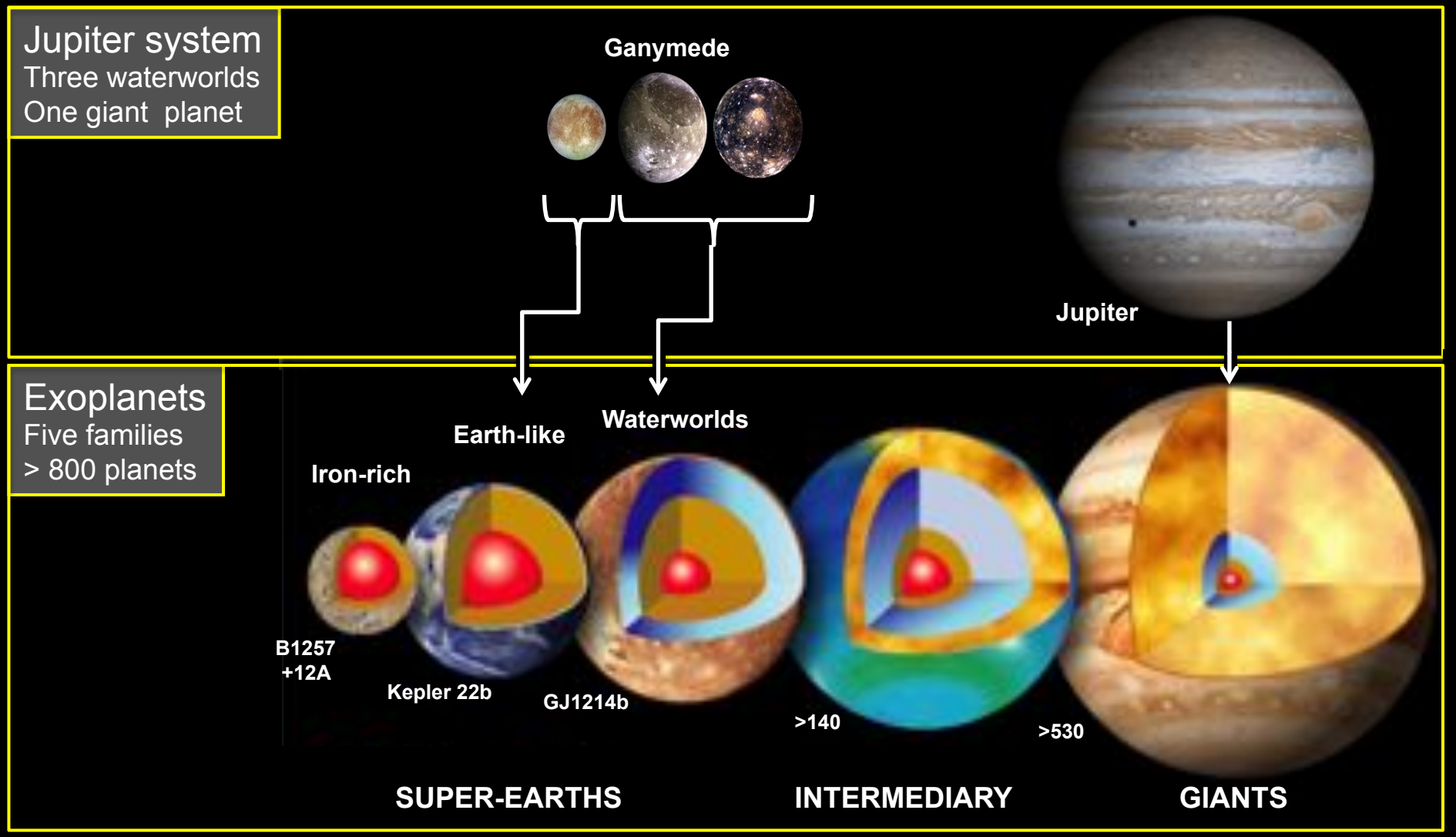
- Eau liquide
- Elements essentiels: des silicates?
- Energie chimique : des silicates?
- Environment stable





H2O Well-known since 1912 (Bridgman)
Modern experiments (for planetology) devoted to complex mixtures.

Ganymède est le “modèle réduit” des exoplanètes riches en eau



Europe et Ganymede sont des archétypes des classes III et IV

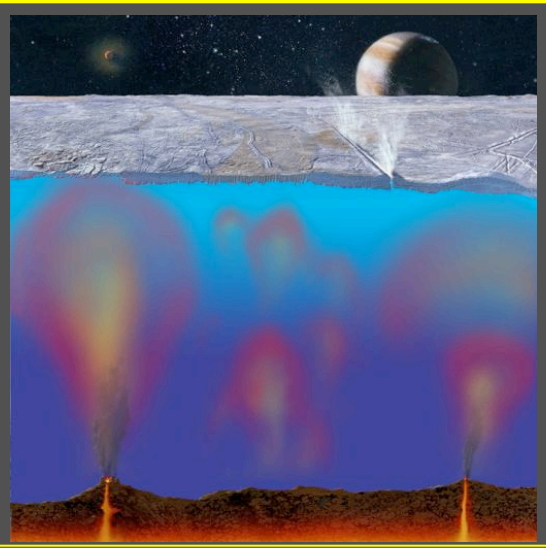
Waterworlds: If habitable, the liquid layers are trapped between two icy layers

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

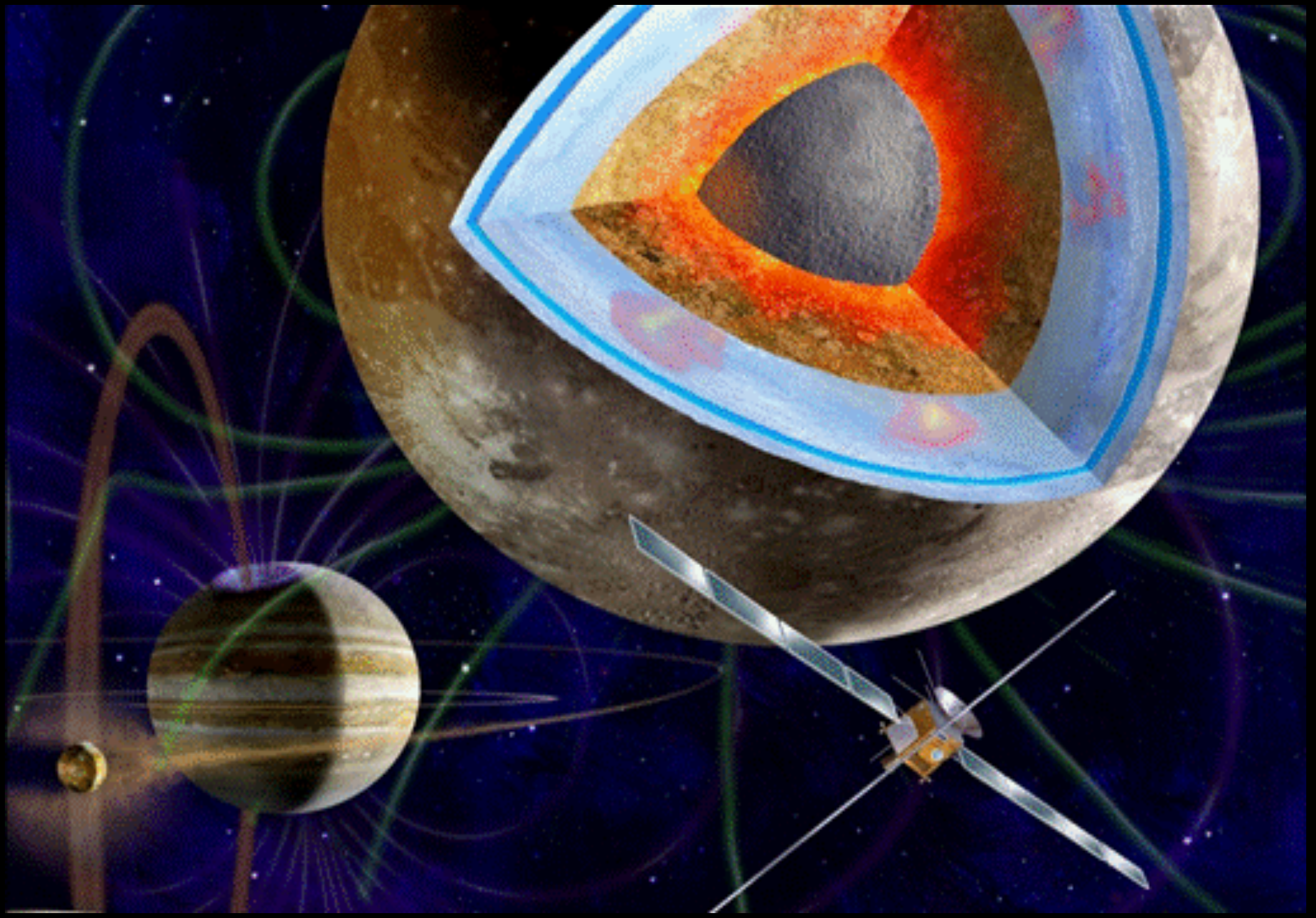


Occurrence:
Europa, Enceladus
Only possible for very small bodies

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

La mission JUICE

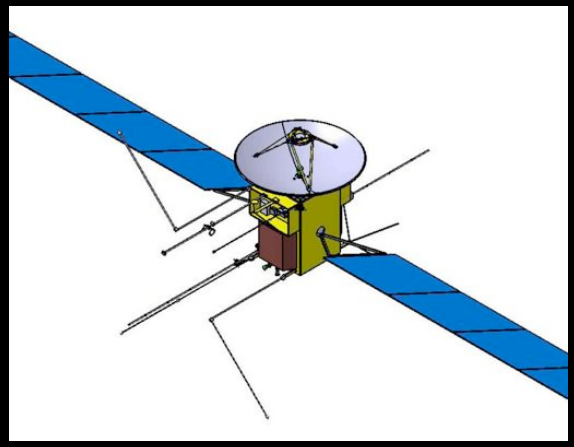


Mission design

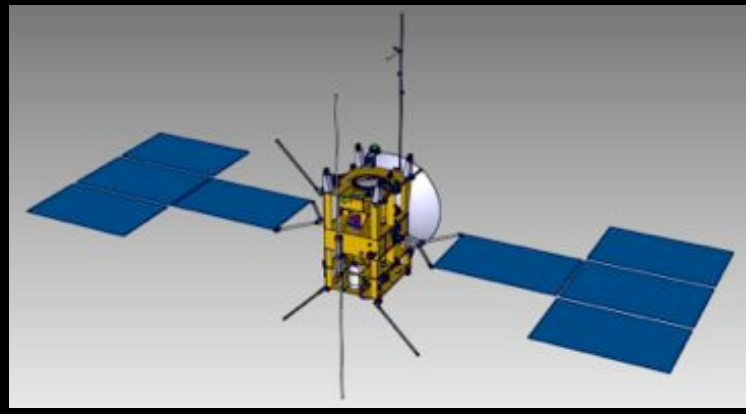
Spacecraft Design

- Dry mass ~1900 kg, propellant mass ~2900 kg
- High Δv required: 2600 m/s
- Model payload 104 kg, ~120 – 150 W
  Imaging, Spectroscopy, In situ Fields and Particles, Radio science and sounders
- 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)

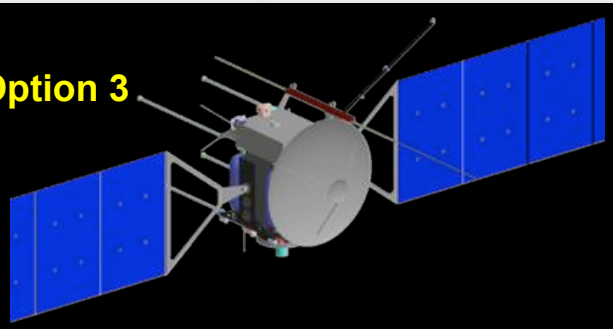
Option 1



Option 2



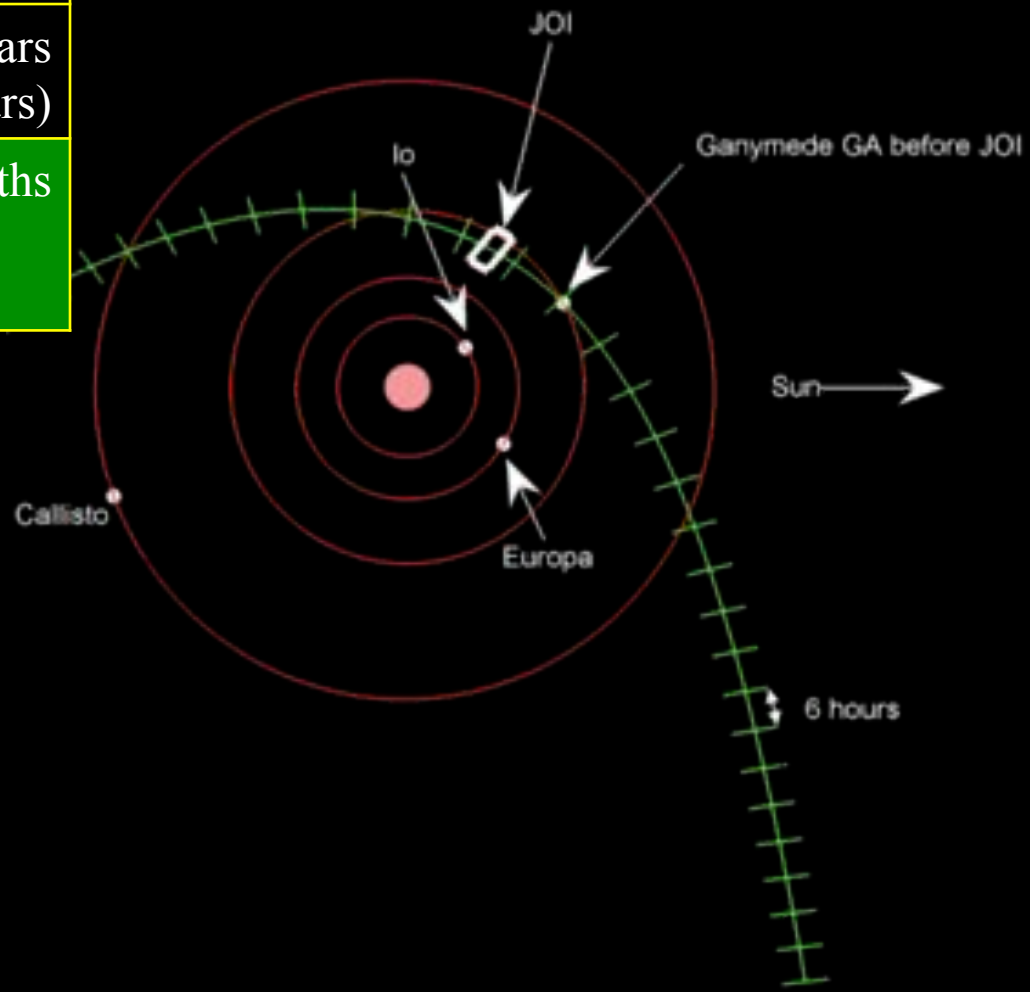
Option 3



Mission design

Mission phases

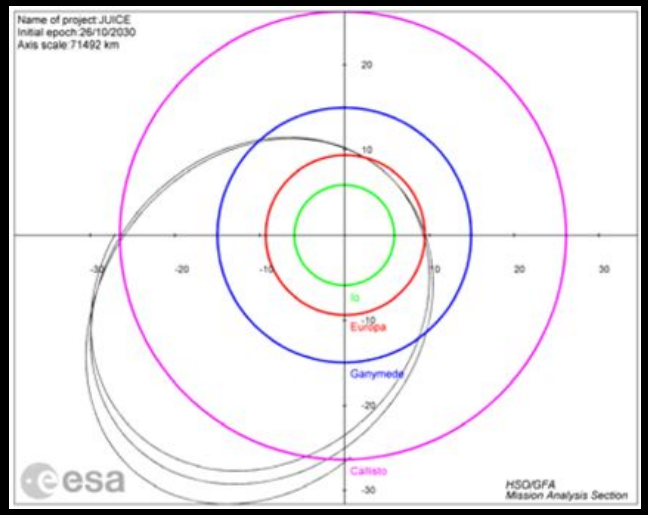
Launch	June 2022 (August 2023)
Interplanetary transfer (Earth-Venus-Earth_Earth)	7.6 years (8 years)
Jupiter orbit insertion and apocentre reduction with Ganymede gravity assists	11 months

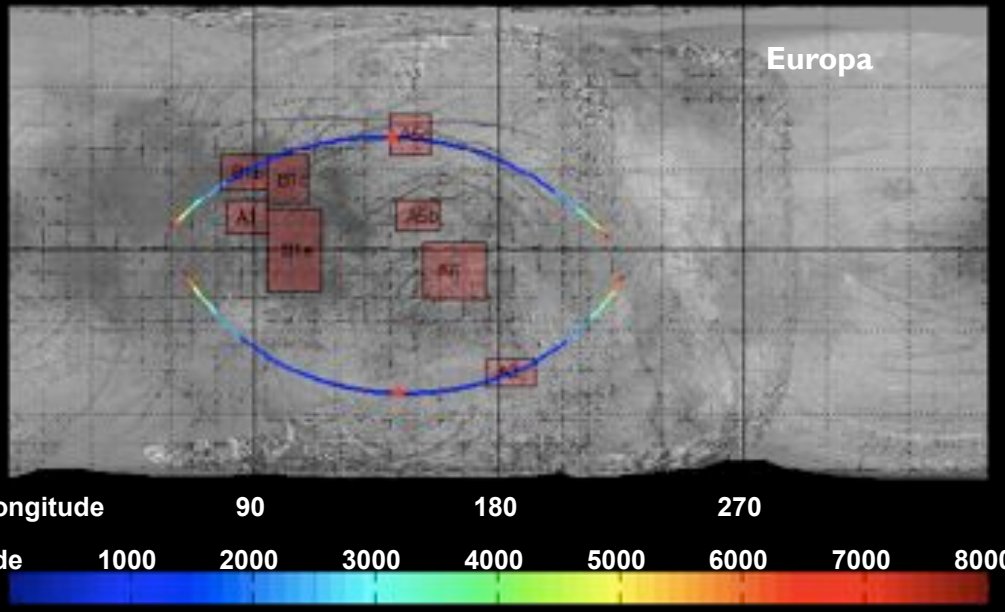


Mission design

Mission phases

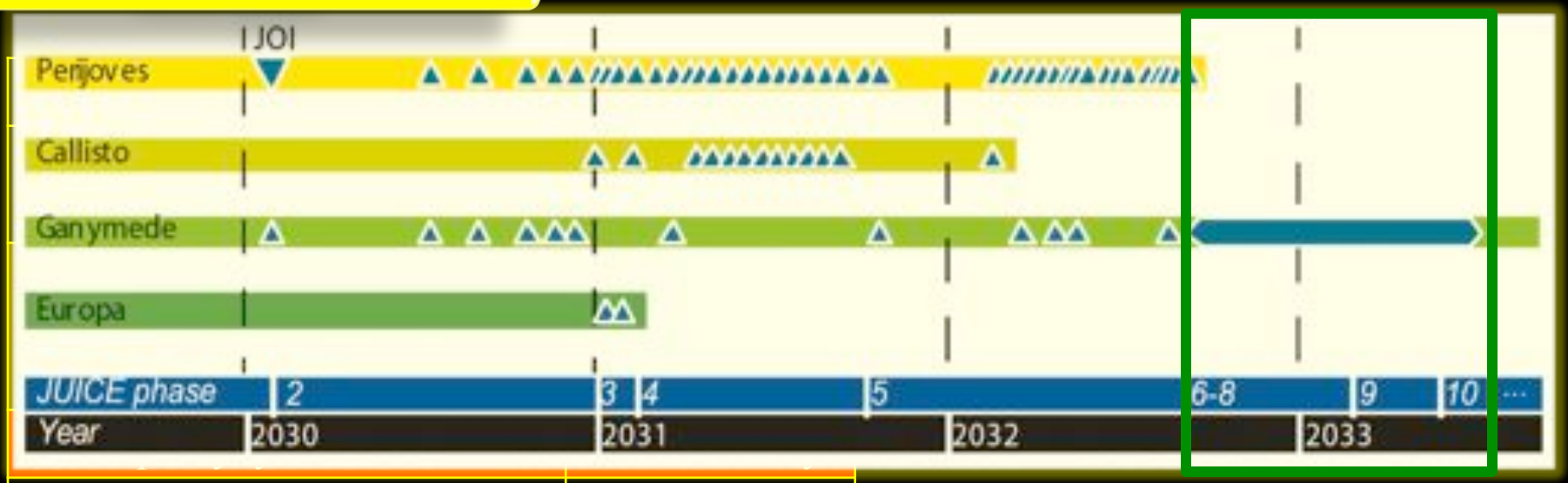
Launch	June 2022
Interplanetary transfer (Earth-Venus-Earth_Earth)	7.6 years
Jupiter orbit insertion and apocentre reduction with Ganymede gravity assists	11 months
2 Europa flybys	36 days



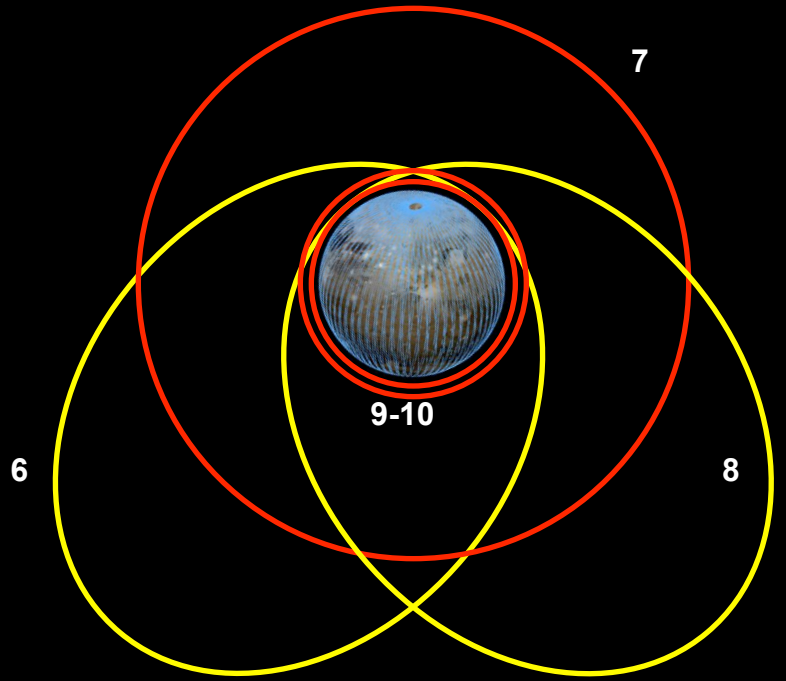


Mission design

Mission phases

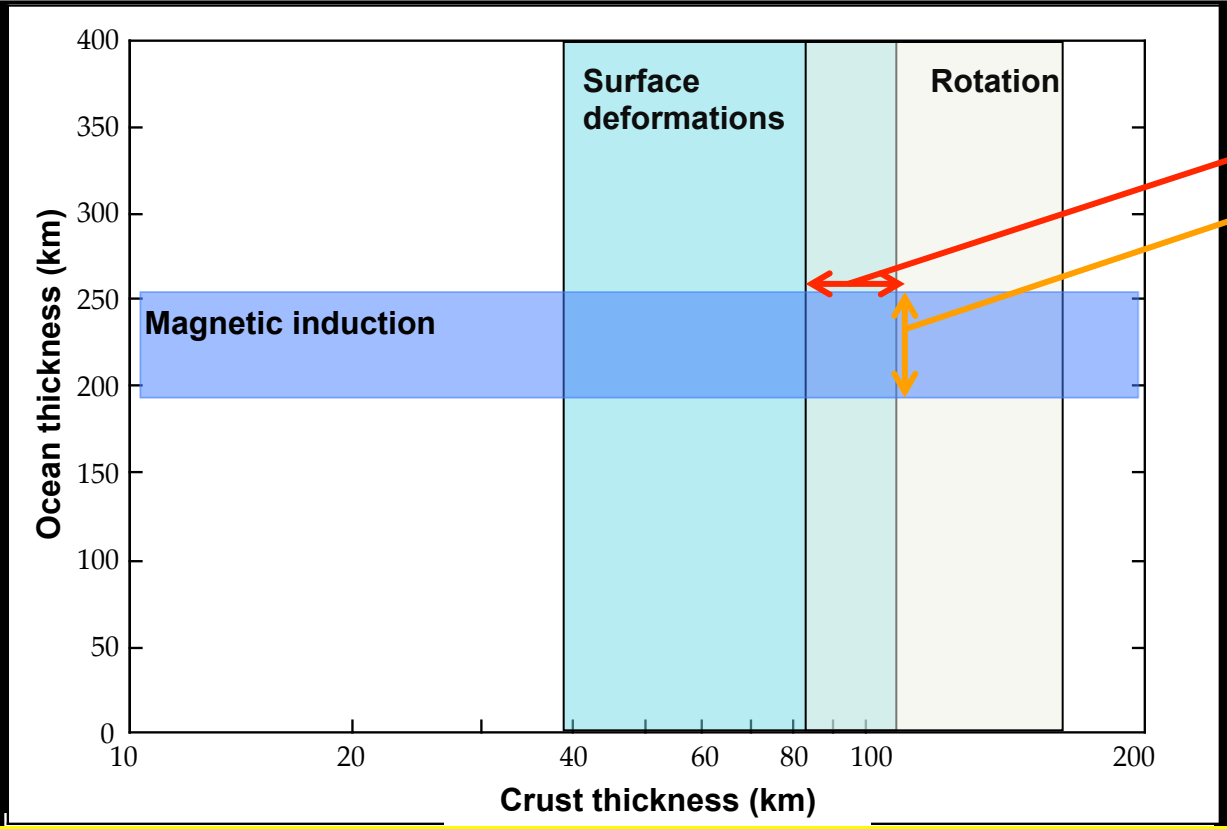


Reduction of v_{inf} (Ganymede, Callisto)	60 days
Increase inclination with 10 Callisto gravity assists	200 days
Callisto to Ganymede	11 months
Ganymede (polar) 10,000x200 km & 5000 km 500 km circular 200 km circular	 150 days 102 days 30 days
Total mission at Jupiter	3 years

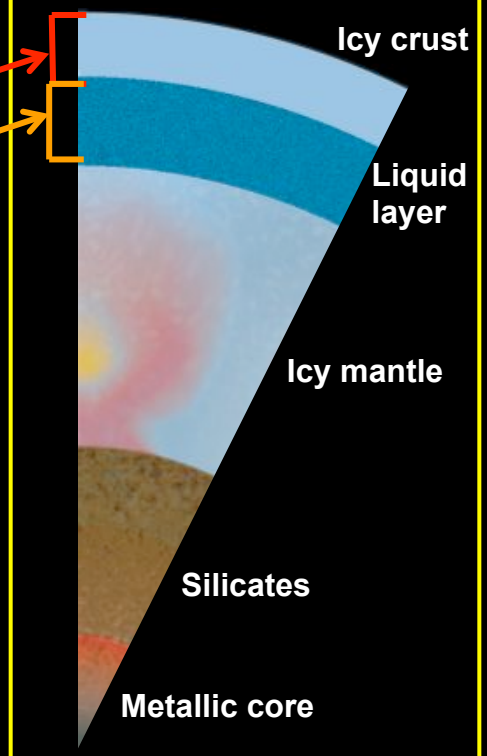


Characterise Ganymede as a planetary object and possible habitat

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



Internal structure



JUICE measurements

- Surface deformations
- Rotation
- Magnetic induction

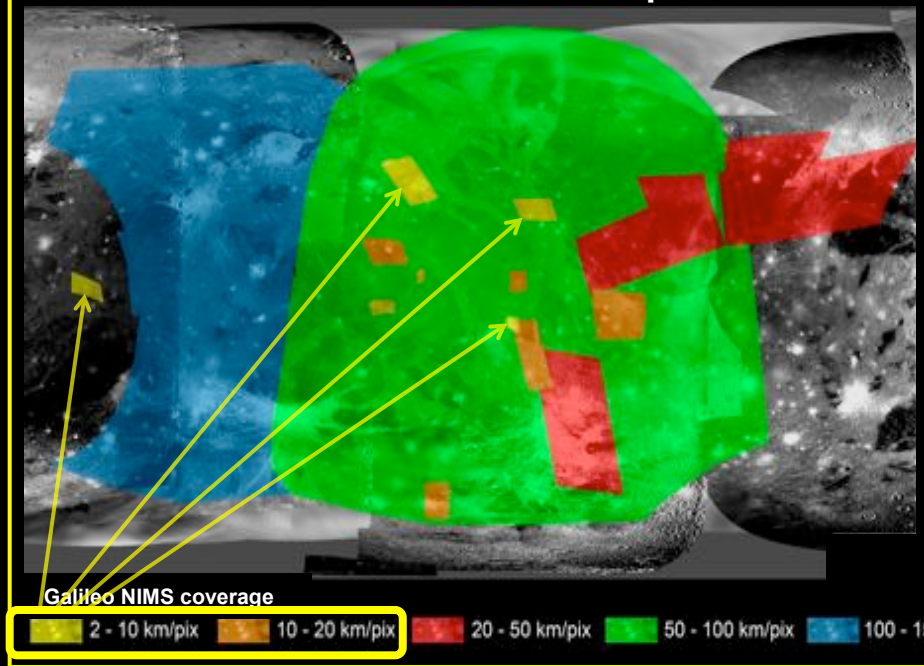
Instrument Packages

- 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 coverage

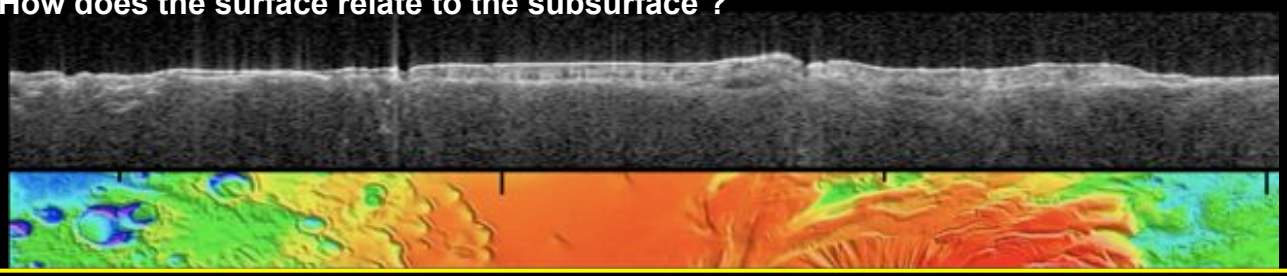
- 4 times better than Galileo NIMS
- Close to lab data quality when needed

Exogeneous / endogeneous ?

Volatiles

Ions and Neutrals

How does the surface relate to the subsurface ?

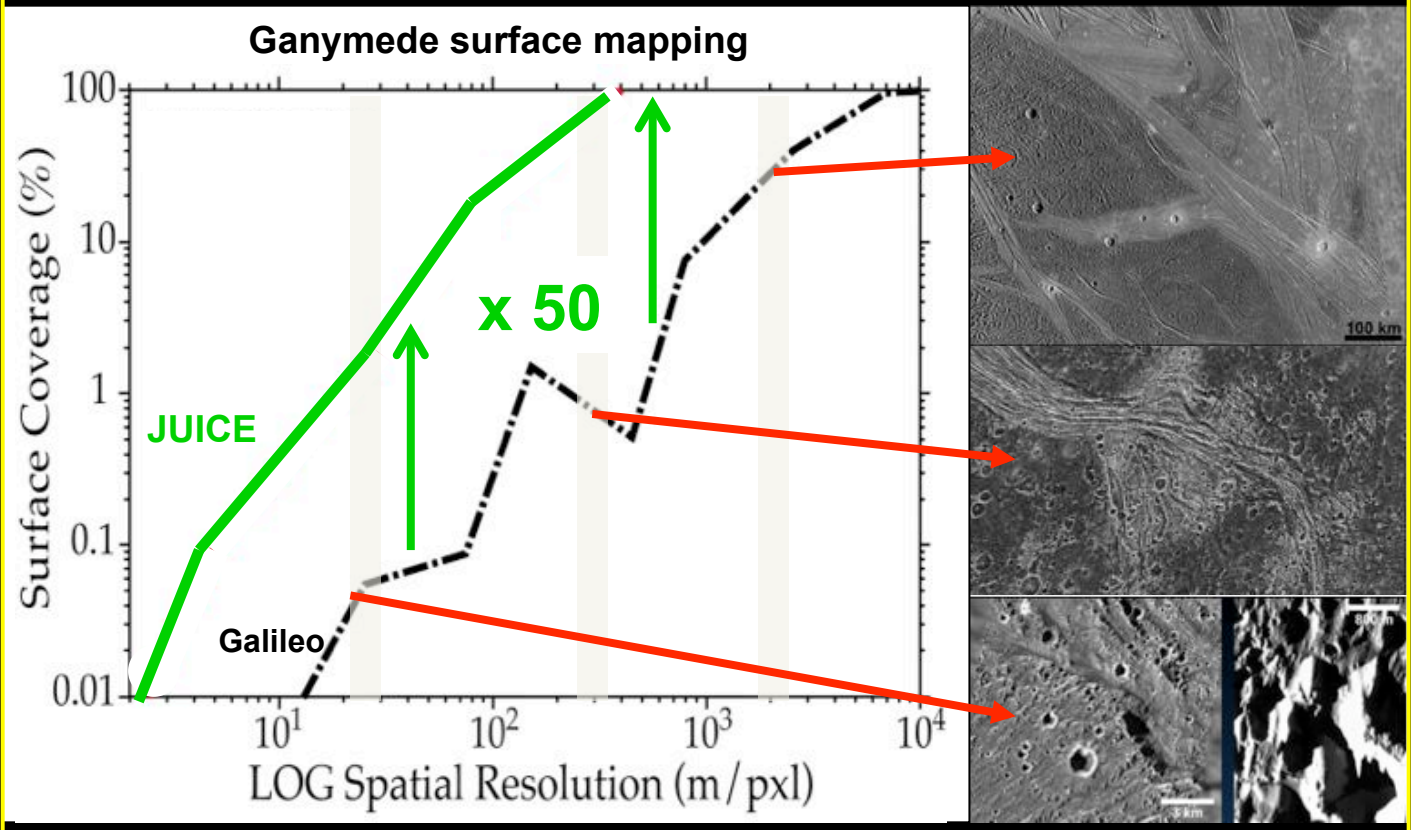


Instrument Packages

- Spectroscopy
- Imaging
- In situ
- Radar sounder

Characterise Ganymede as a planetary object and possible habitat

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



Measurements

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

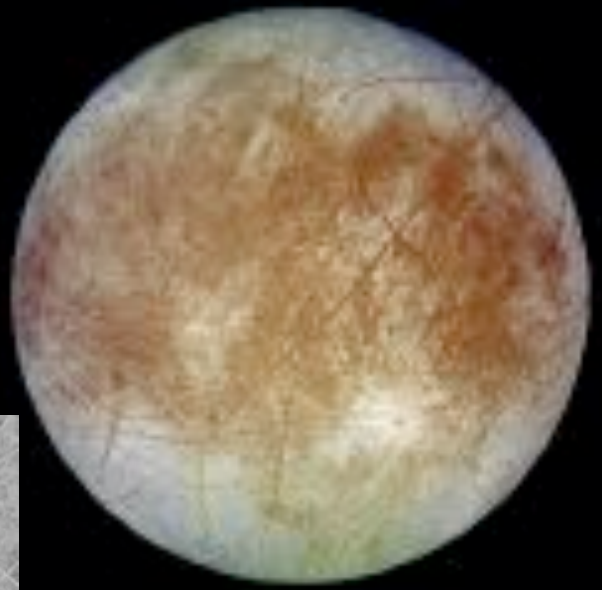
Instrument Packages

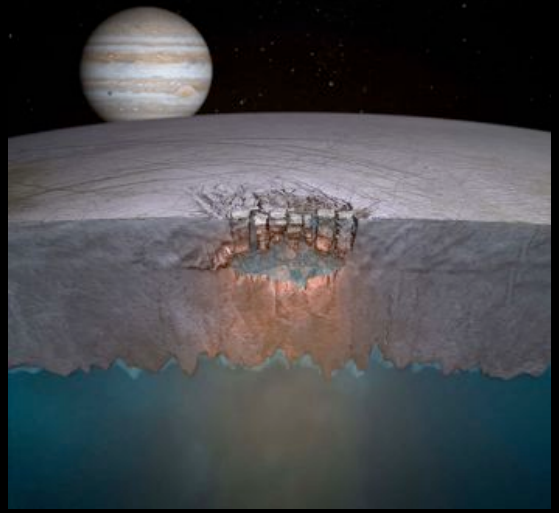
- **Imaging**
- **Spectrometers**
- **Sounders**

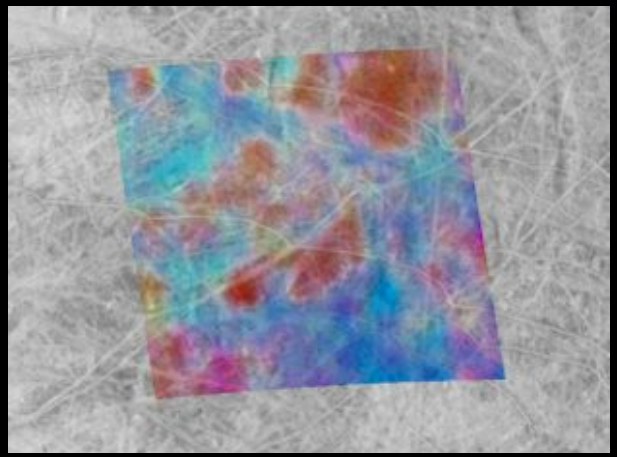
Explore Europa recently active zones

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







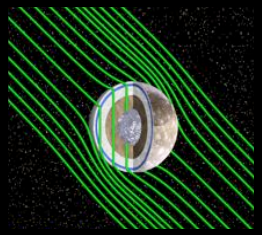
Europa				
Year	2030	2031	2032	2033

Explore Europa recently active zones

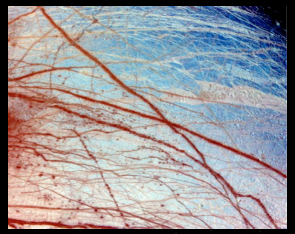
Flyby strategy:

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

Will result in :

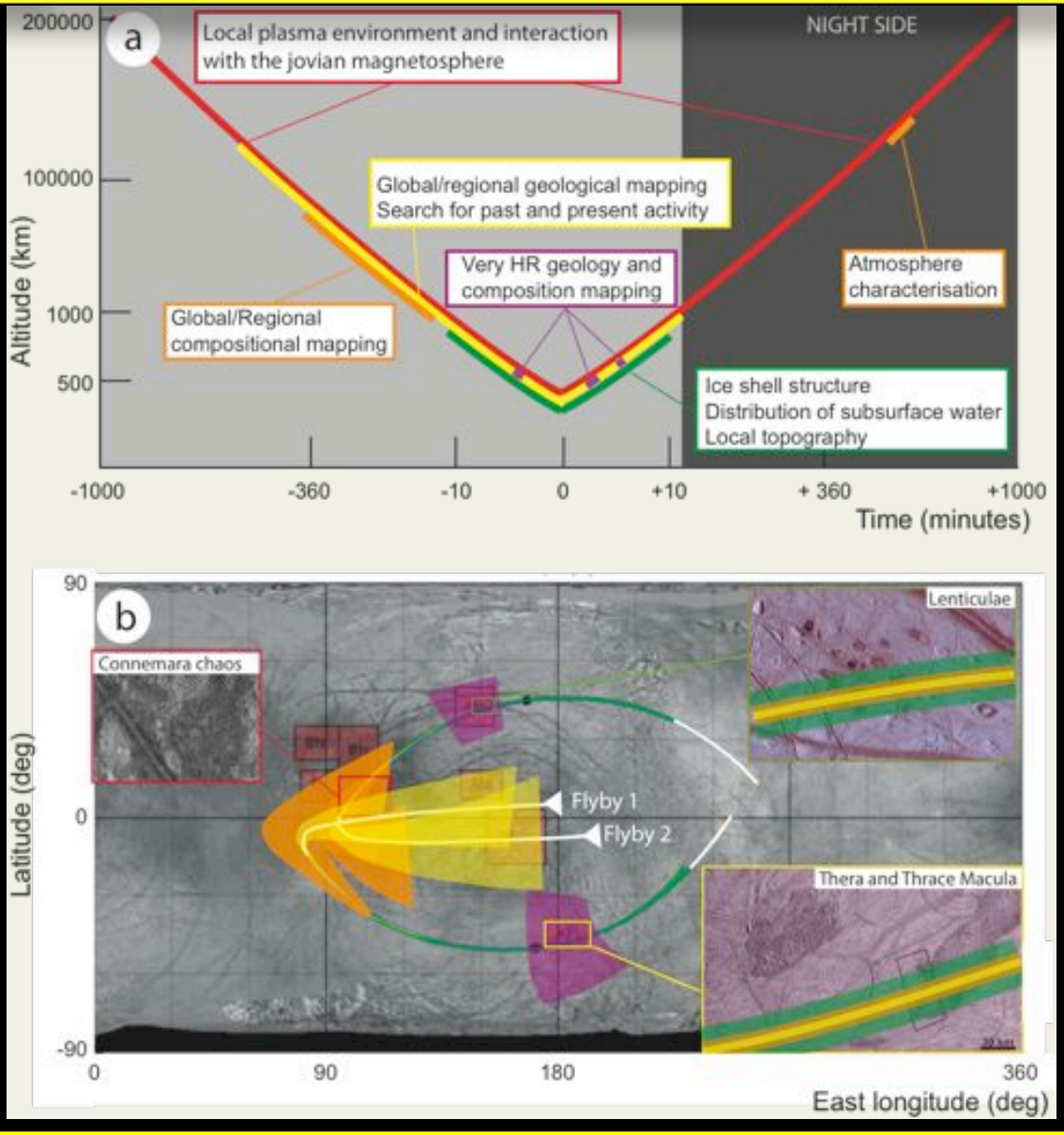


Characterisation of induced field



Composition and geology of areas of high interest

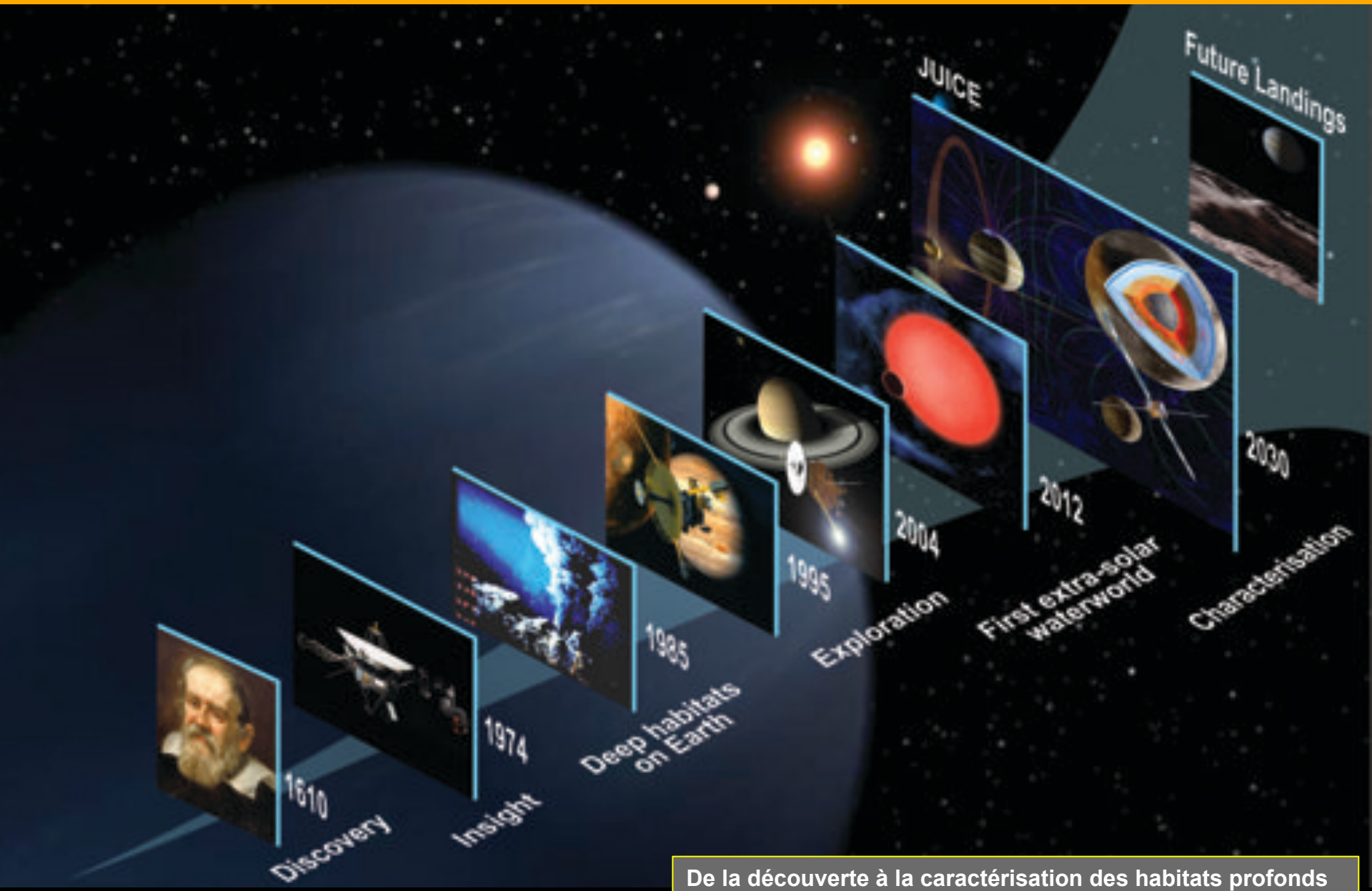
First subsurface exploration of recently active regions



Europa				
Year	2030	2031	2032	2033

Conclusions

JUICE : Etudes de Jupiter, sa magnétosphère, et des lunes gelées



De la découverte à la caractérisation des habitats profonds

L'eau dans le système solaire

Le système interne– peu d'eau disponible

Mercure et la Lune

Quelques traces

Mars et Venus

Non négligeable mais pas suffisant pour l'habitabilité (present time)

Quantité d'eau passée inconnue, mais nettement plus élevée

La Terre

0.01%wt de la planète– Peu d'eau, mais assez pour l'habitabilité…

Le système externe– beaucoup d'eau conservée au delà de la snow line

Système jovien

Environ 50 %wt: Noyau Jupiter, Ganymede, Callisto, petites lunes???

Environ 10 %wt: Europa

Pas d'eau: Io

Système de Saturne

Environ 50 %wt: Noyau Saturne, Titan, Enceladus

Environ 20-30 %wt: Mimas, Thetys, small moons

Pas d'eau: aucun

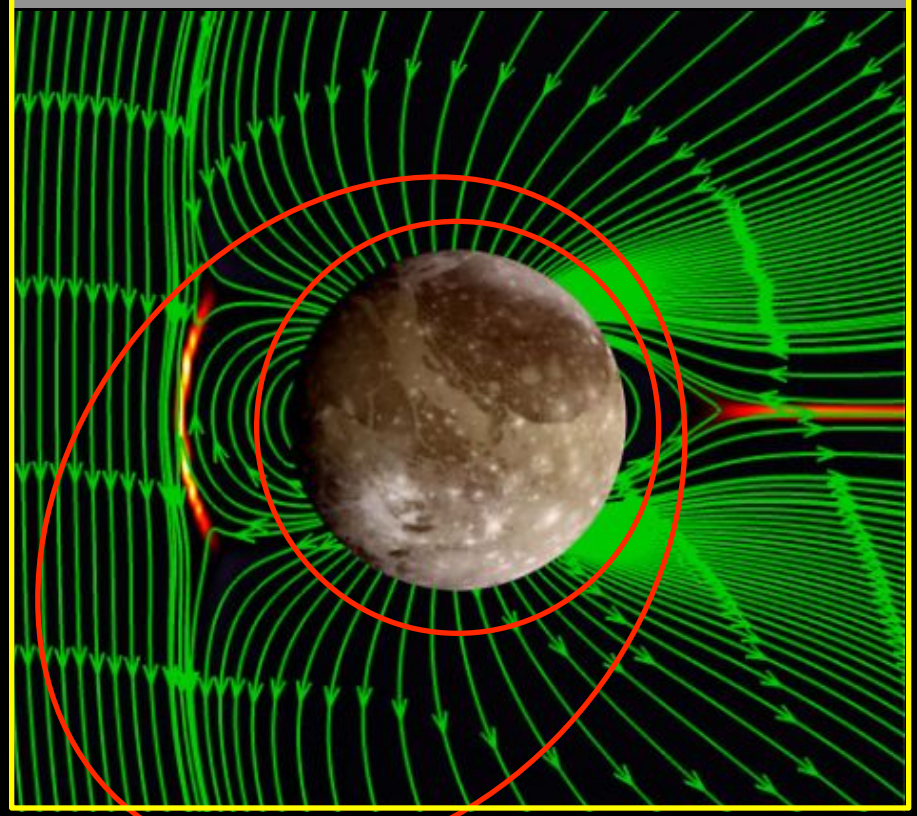
Uranus, Neptune, et au-delà

Probablement > 60 %wt dans les noyaux planétaires

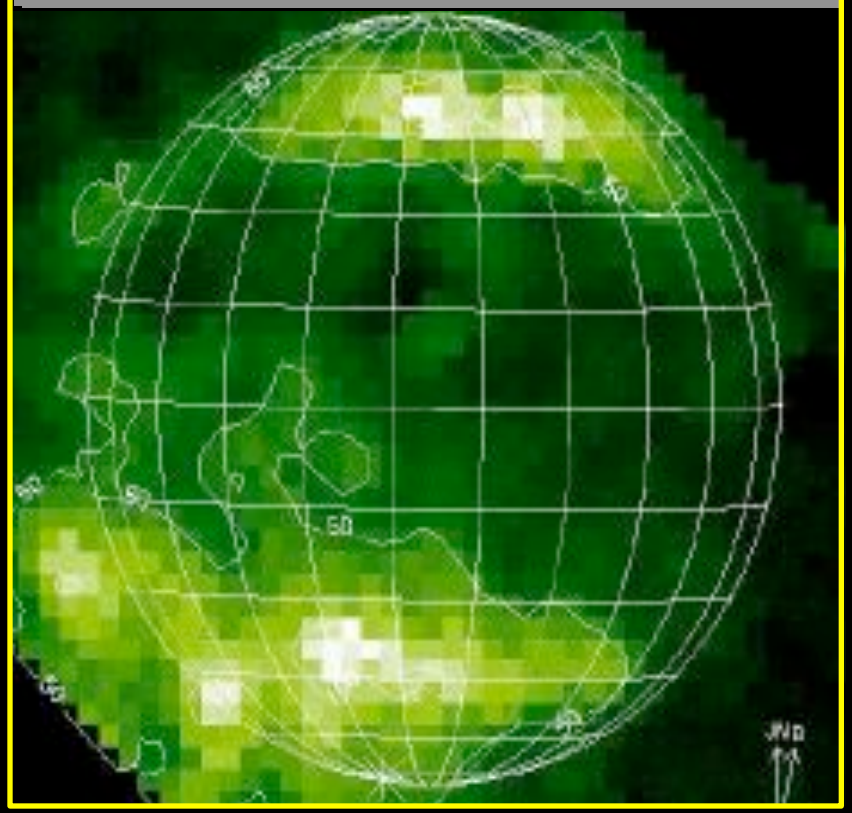
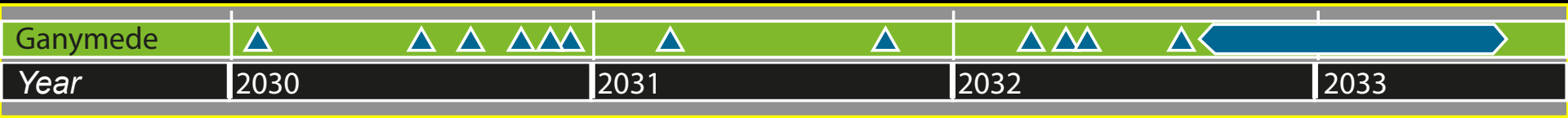
Characterise Ganymede as a planetary object and possible habitat

4. Characterise the local environment

Dipole magnetic field and mini-magnetosphere



Coupling to Jupiter's magnetosphere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