



Imperial College  
London

# Space Missions to the Outer Planets

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## Imperial involvement and leadership

Our world class science output drives the instruments we build and our space mission involvement

Focus on two outer planetary missions:

- NASA/ESA Cassini/Huygens mission to Saturn system
- ESA JUICE mission to Jupiter system

Cassini – PI on magnetometer instrument

- orbiting Saturn since July 2004, mission end in September 2017
- discovery of water vapour atmosphere at Enceladus

JUICE – ESA Science Definition Team Lead and PI of magnetometer instrument

- ESA's first L-class mission, due for launch in 2022, arrival at Jupiter in 2030, mission end 2033
- focus on 3 of Galilean moons with liquid water oceans, orbit Ganymede
- emergence of habitable worlds around gas giants

High profile success of Cassini science drove JUICE science and selection

## Technology links

World leading, low noise, stable fluxgate magnetic sensor (Ultra Electronics)

Recent developments:

- miniaturised sensor based on anisotropic magneto-resistive materials
- radiation hardened ASICs (Astrium)

Areas of new focus linked to the JUICE mission include:

- radiation environment and modeling
- miniaturisation
- optimisation of instrument resources
- integrated payload approach
- integrated payload data handling project (Astrium)
- internal charging
- long, stiff magnetometer booms



DENMARK



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IRELAND



HUNGARY



SWEDEN



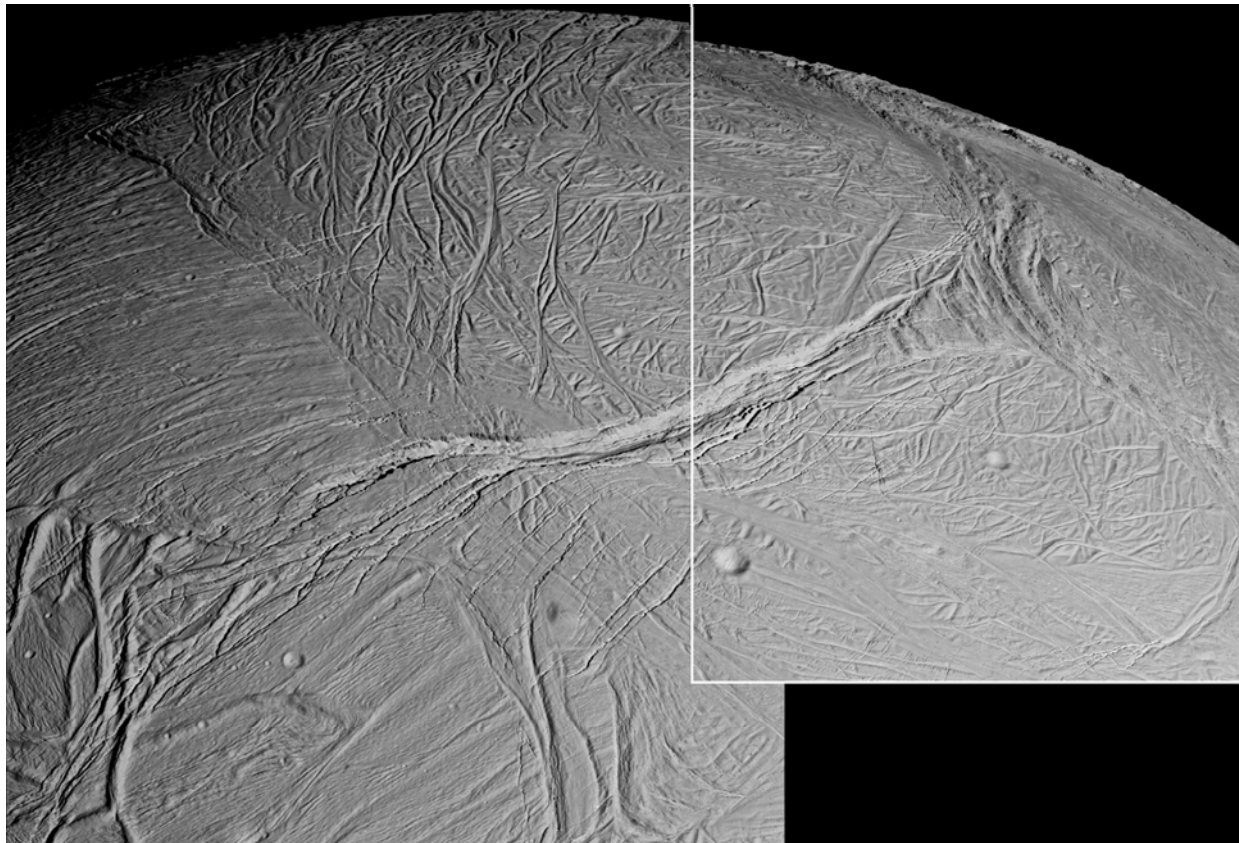
NORWAY



INTERNATIONAL PARTICIPATION IN

CASSINI  
SATURN ORBITER AND  
HUYGENS TITAN  
PROBE

## Enceladus



Three Cassini flybys  
(1265km, 500km, 173km)

In inner  
magnetosphere

Source of  
Saturn's E ring?

Relatively young  
surface

Cracks on surface

## Saturn's ring system

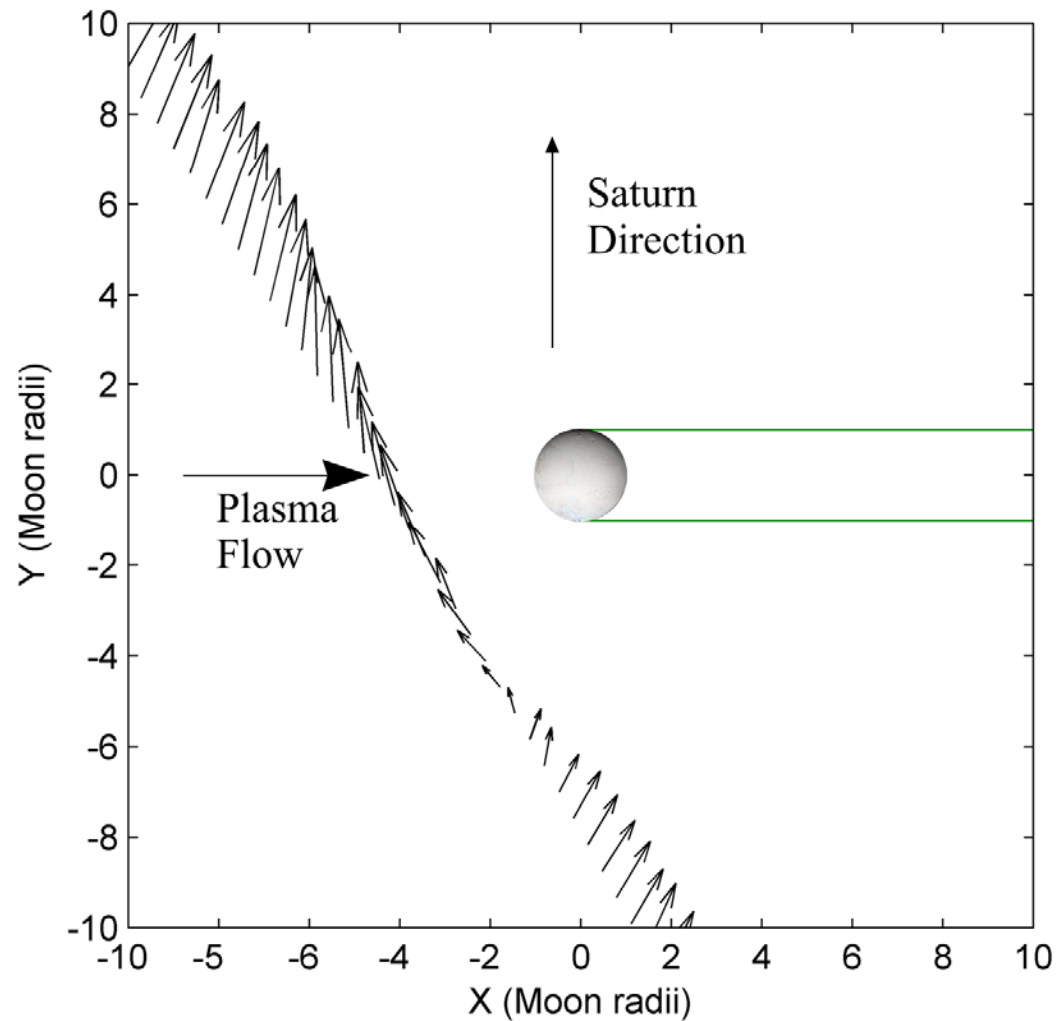


- Rings are an enormous, complex structure
- E ring largest planetary ring in solar system
- Particle's in rings mainly water ice

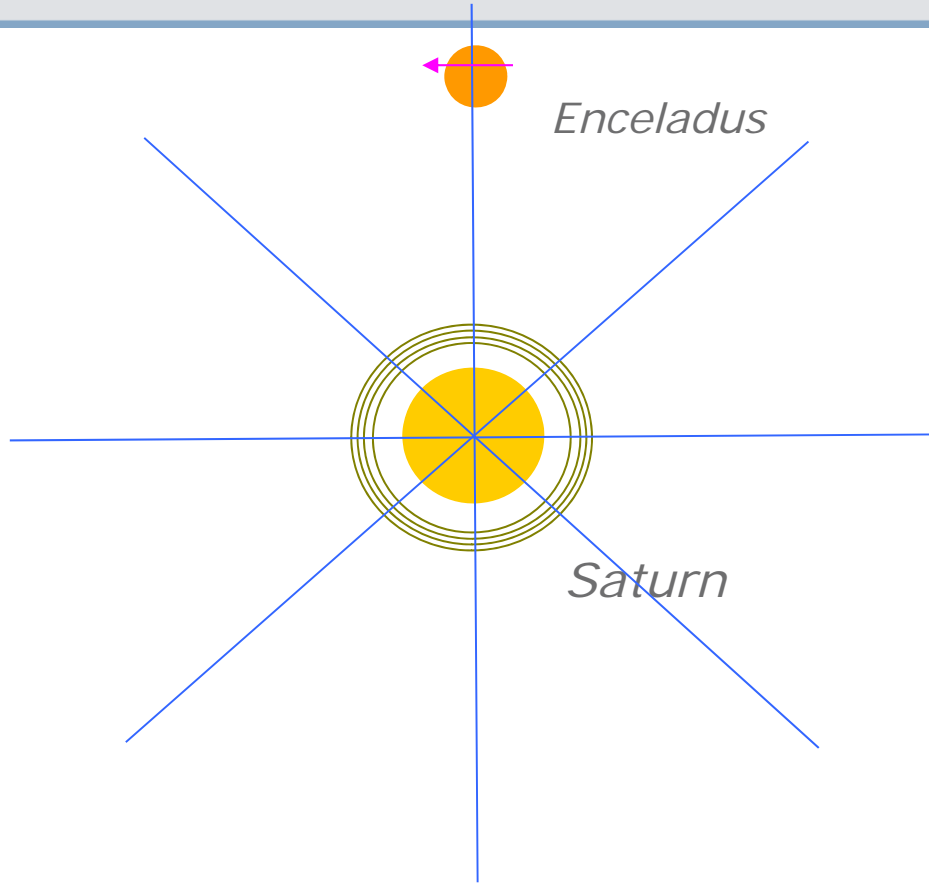
## Surprising magnetic field observations

Large  
increase in  
ion  
cyclotron  
wave  
activity

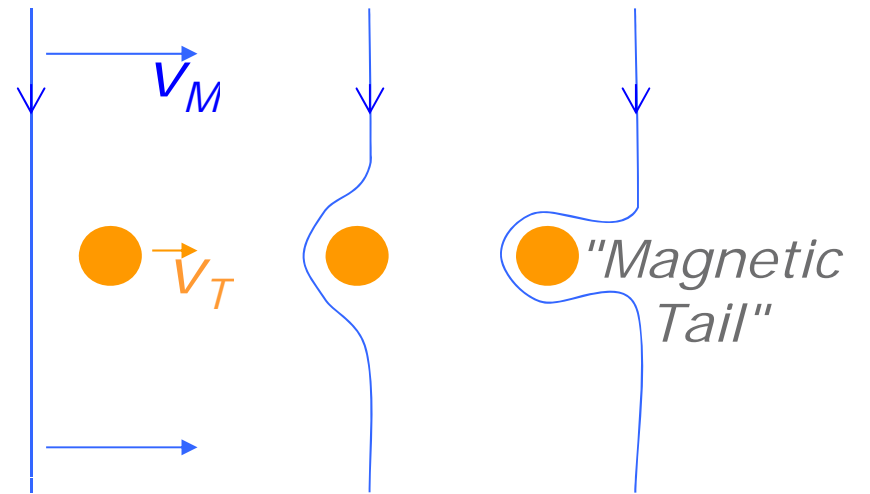
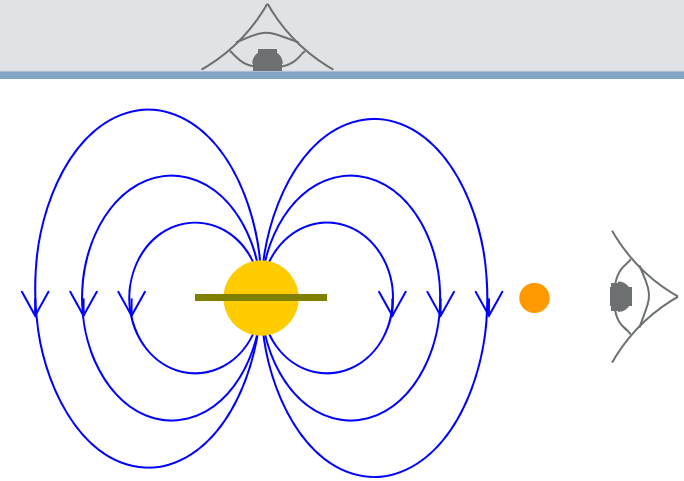
Water group  
ions



# Field Line Draping

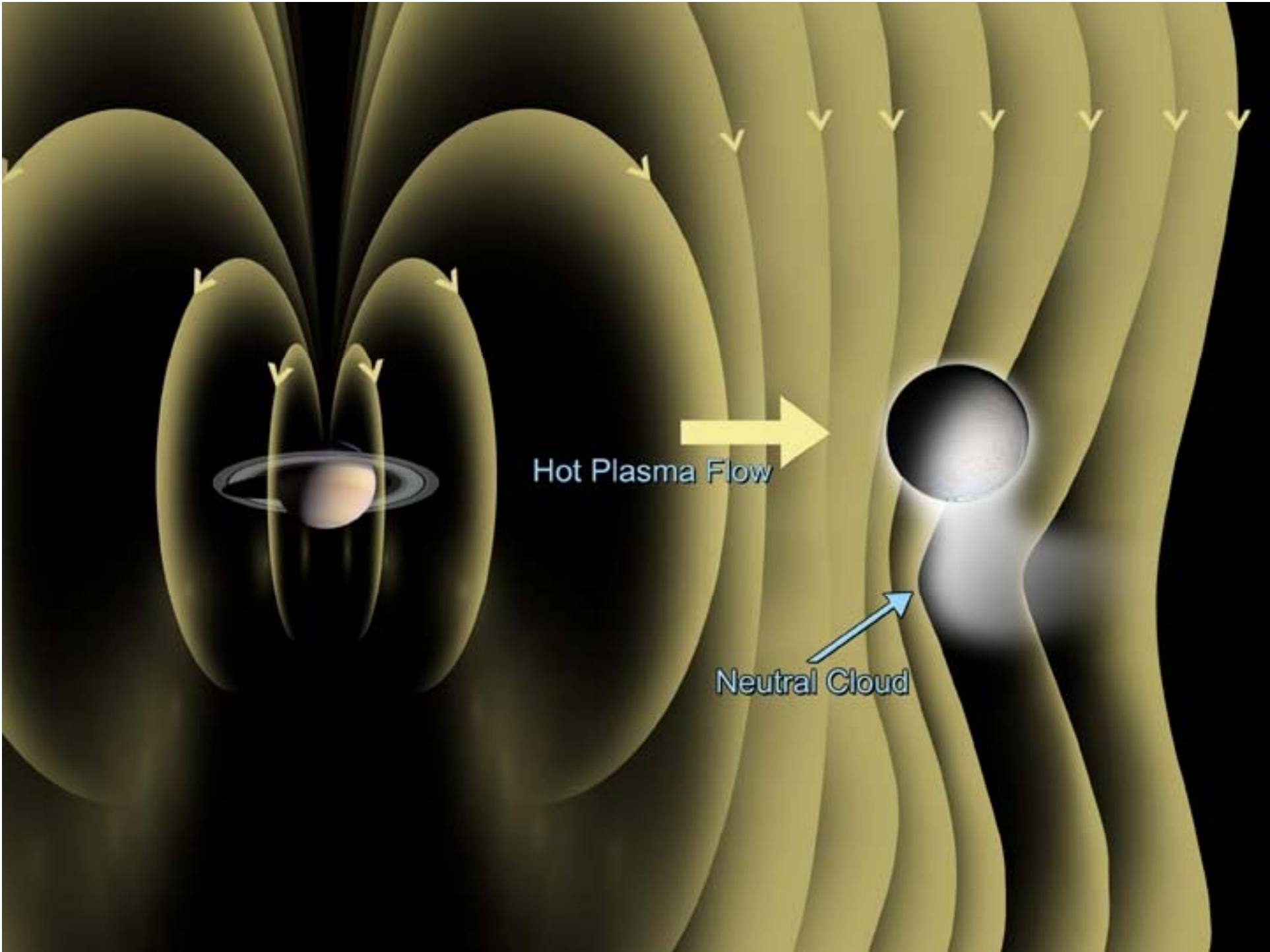


"Co-rotating" plasma

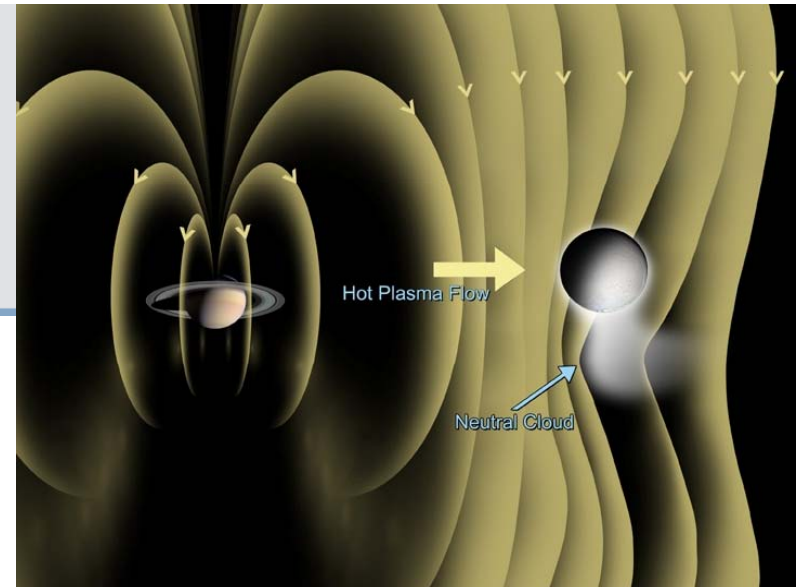


$$V_M > V_T$$

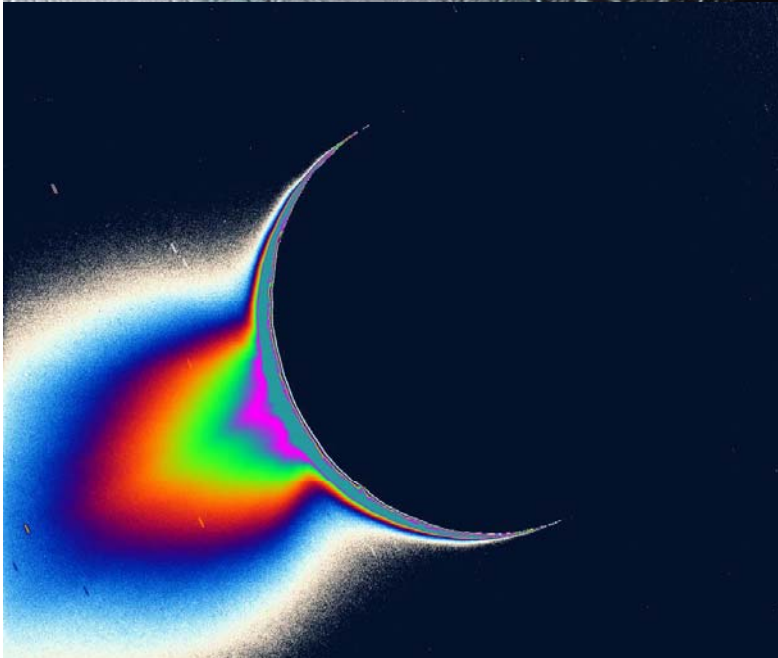
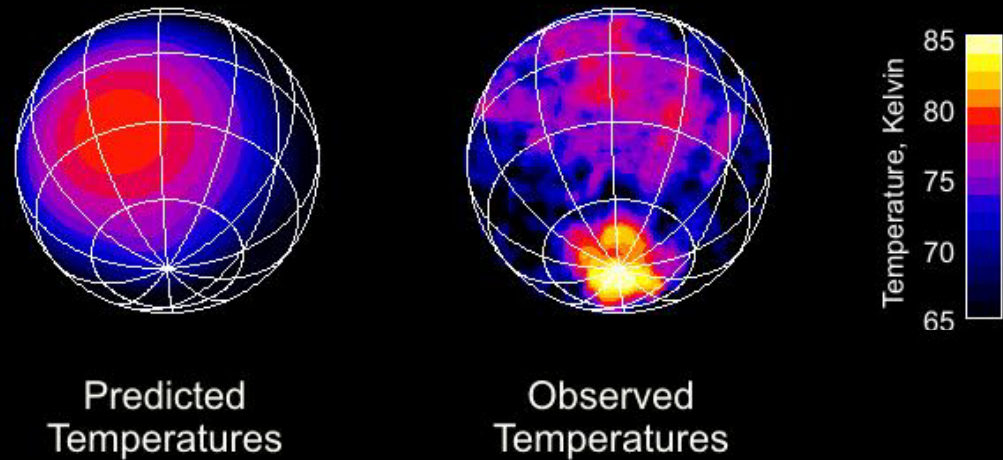




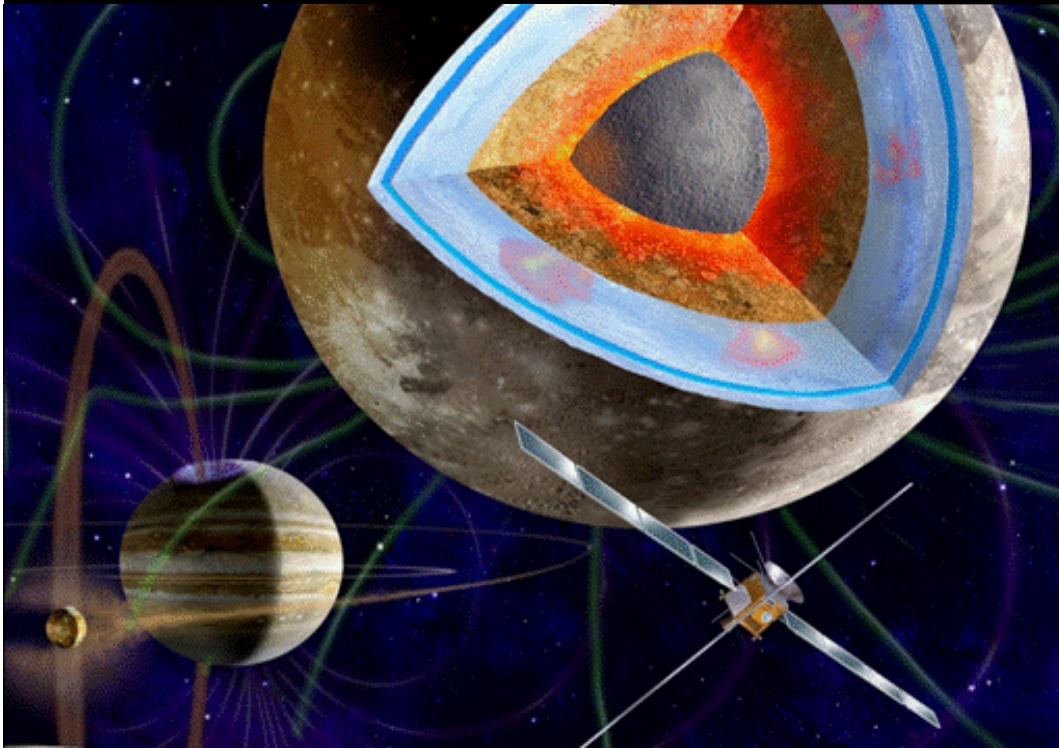
## Example of interdisciplinary success



### Enceladus Temperature Map



Internal heat source, water vapour plume with organic material and dust, variable outgassing rate



## JUICE Science Themes

- *Emergence of habitable worlds around gas giants*
- *Jupiter system as an archetype for gas giants*
- *Focus on three moons: Ganymede, Europa and Callisto*
- *And the Jupiter magnetosphere and atmosphere*

## JUICE concept

- *European-led mission to the Jovian system*
- *First orbiter of an icy moon*
- *Launch planned in 2022*
- *Jupiter Orbit Insertion 2030*

# Exploration of the habitable zone

JUICE

Three large icy moons to explore

## Ganymede

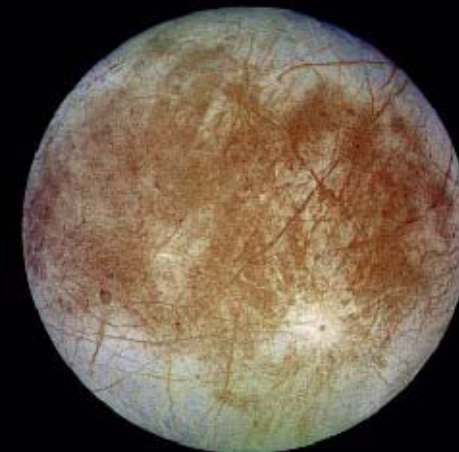
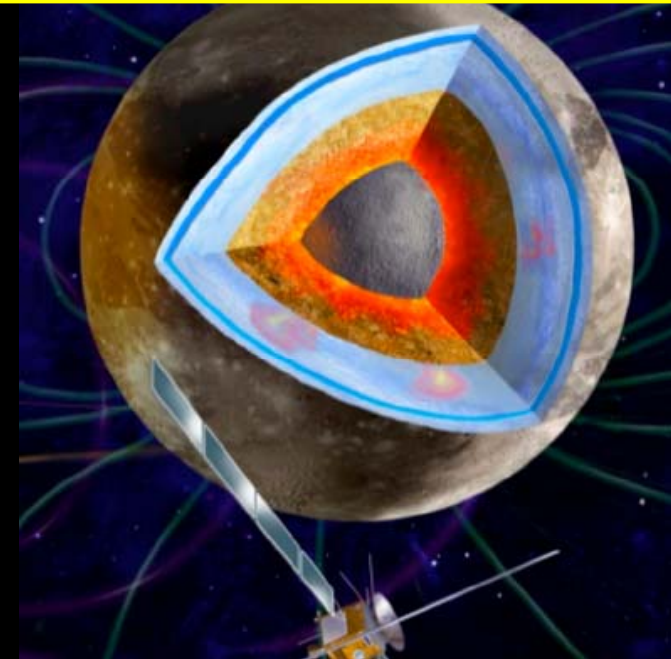
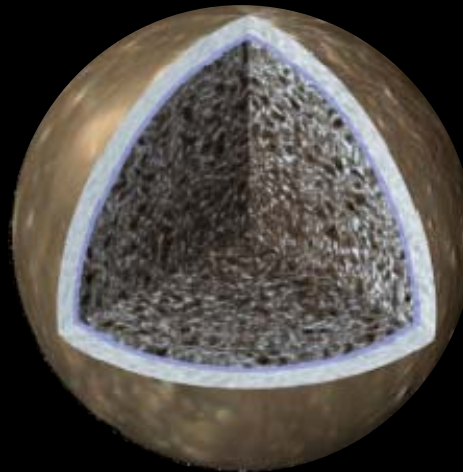
- Largest satellite in the solar system
- A deep ocean
- Internal dynamo and an induced magnetic field – unique
- Richest crater morphologies
- Archetype of waterworlds
- Best example of liquid environment trapped between icy layers

## 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



## Science Case I: Resolve interior structure of icy moons

Resolve strength of induced magnetic fields

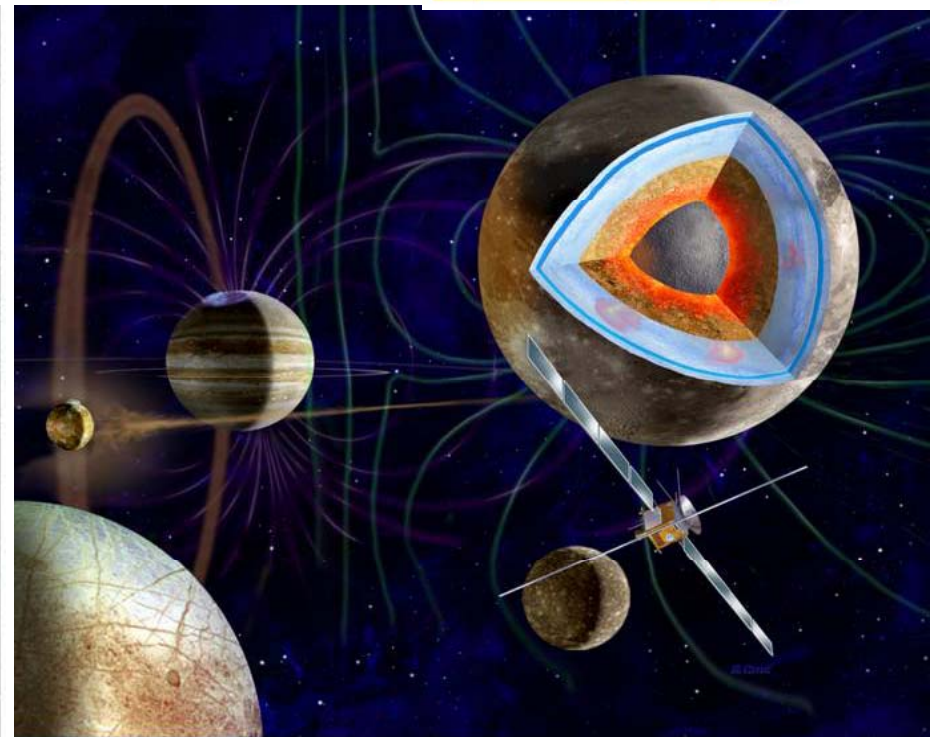
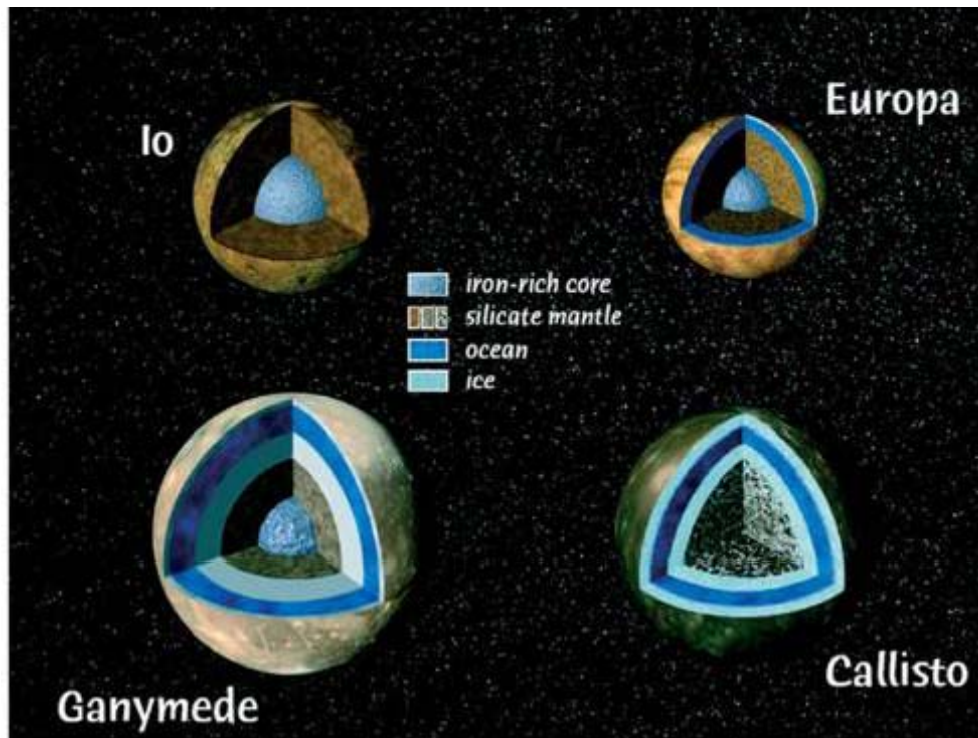
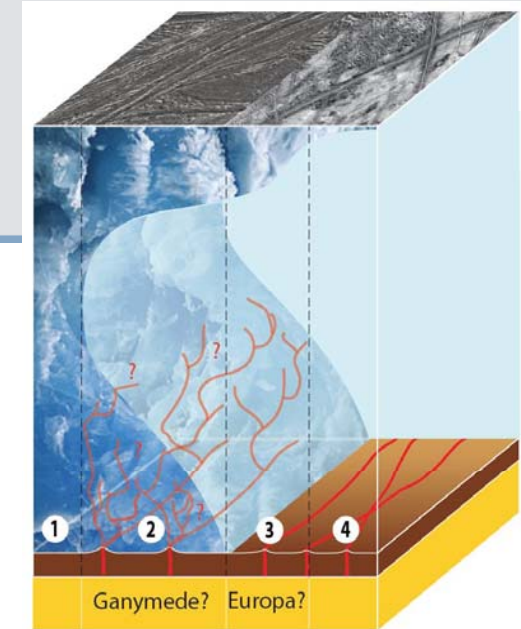
What are depth of the liquid oceans beneath icy surfaces

What is the conductivity of the water?

Resolve strength of Ganymede internal magnetic field

Implications for the deep interior structure of Ganymede

Compare differentiated with undifferentiated body



## Science Case II: Dynamical plasma processes

Magnetic field measurements are vital to allow better understanding of dynamical plasma processes

Interactions of the magnetosphere of Ganymede within the Jovian magnetosphere

Dynamics of Jovian magnetodisk

Generation of aurora and of the various current systems which arise

