

# Towards a Radiation Monitor for the Jovian System

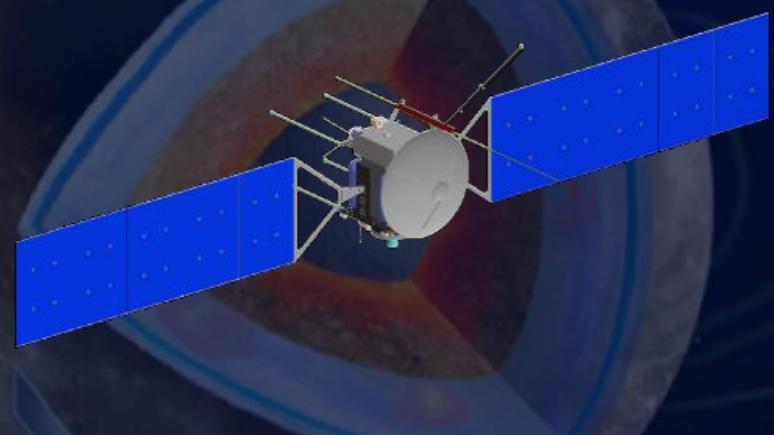
**Patrícia Gonçalves**  
**XXIII ENAA**

# JUICE

## The Jupiter Icy Moons Explorer



Next Class-L (Large) ESA Mission



### Current JUICE mission plan

Jun 2022	Jan 2030	11 months	1 month	9 months	11 months	Sep 2032	9 months	Jun 2033
Launch Ariane-5	Jupiter orbit insertion	Transfer to Callisto	Europa phase: 2 Europa + 2 Callisto flybys	Jupiter High Latitude Phase	Transfer to Callisto	Ganymede Orbit insertion	Ganymede tour: Orbits at several altitudes: High altitude 500 km 200km	End of nominal mission

# Juice Mission Objectives

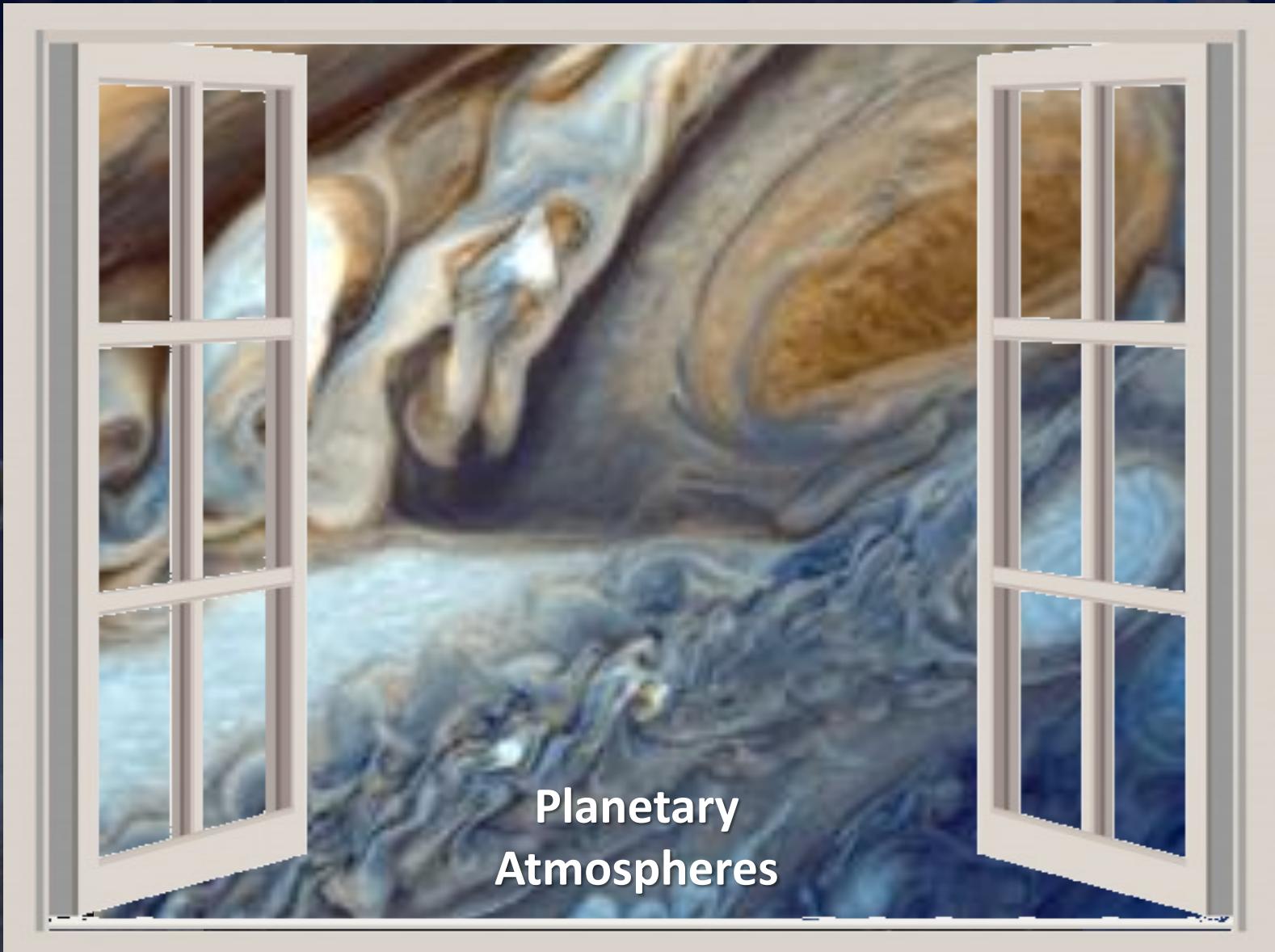
**Study the emergence of habitable worlds around gas giants**



- Characterise the Jupiter Icy Moons: Ganymede, Europa and Callisto as planetary objects and potential habitats
- Explore the Jovian system as an archetype for gas giants

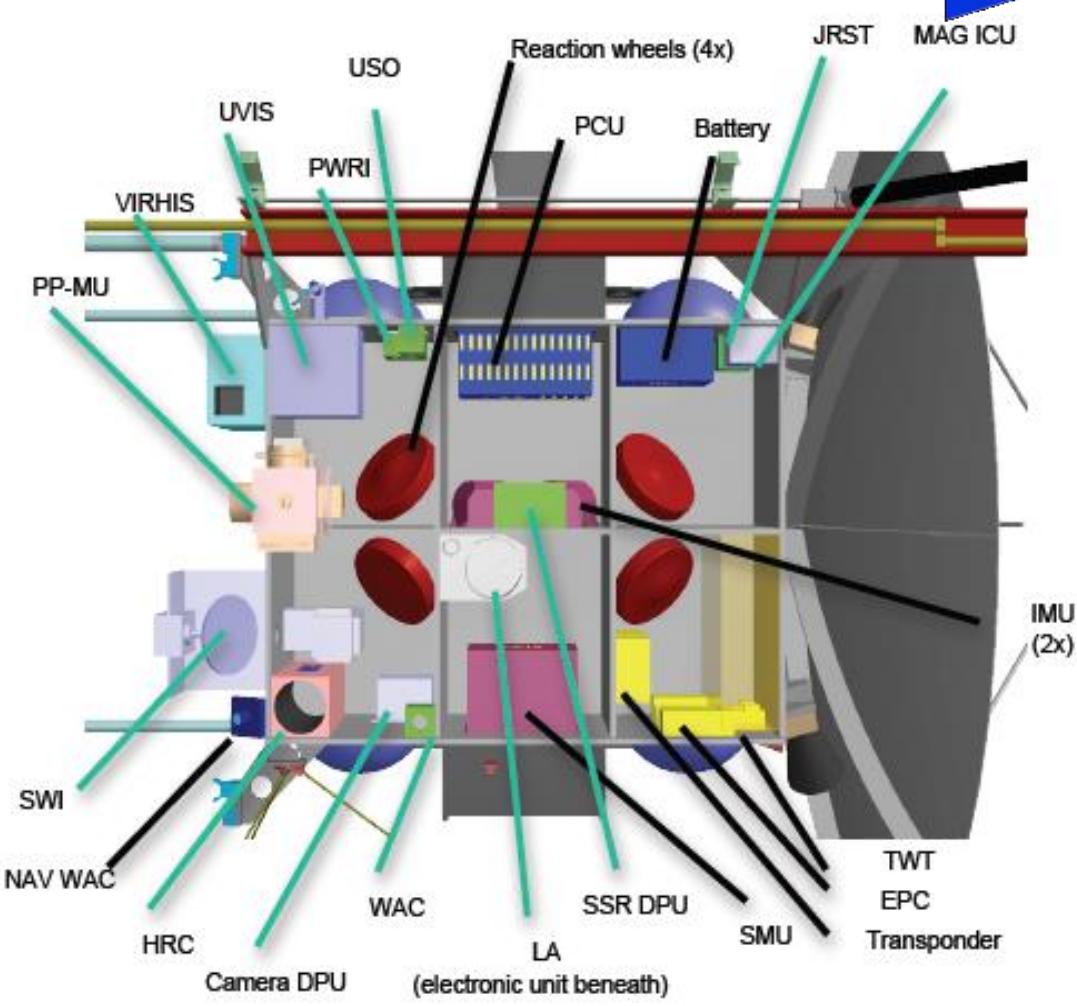
# Juice mission

## Implications for Astrophysics & Planetary Physics



# Juice Scientific Payload

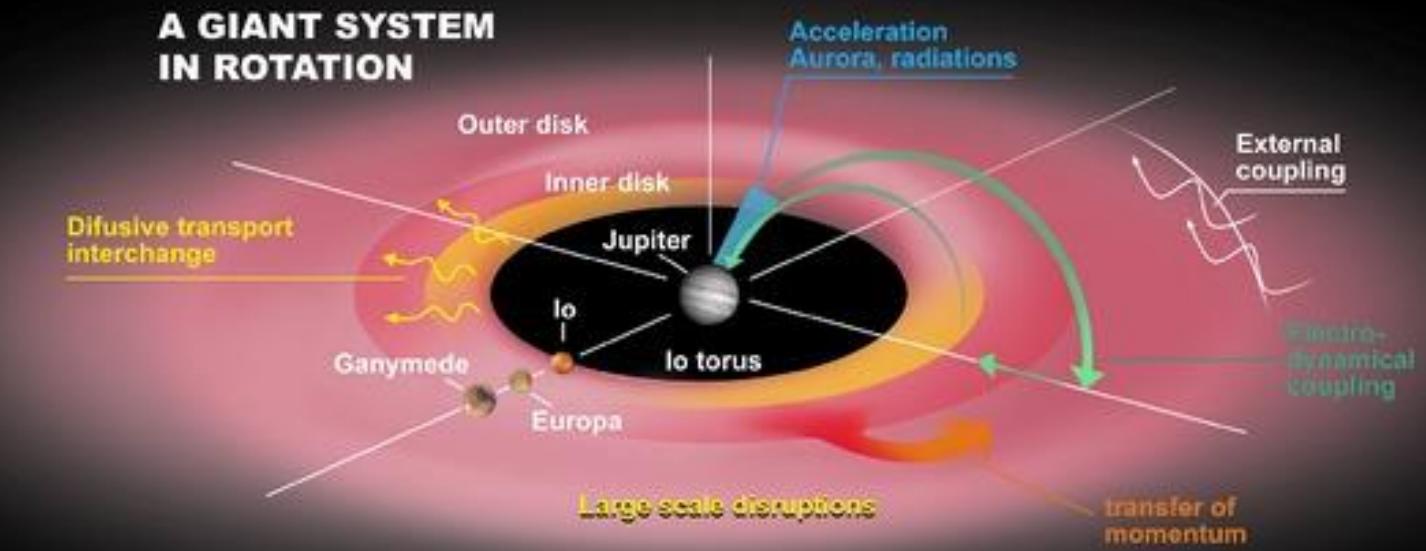
11 instruments with total mass of ~100 kg



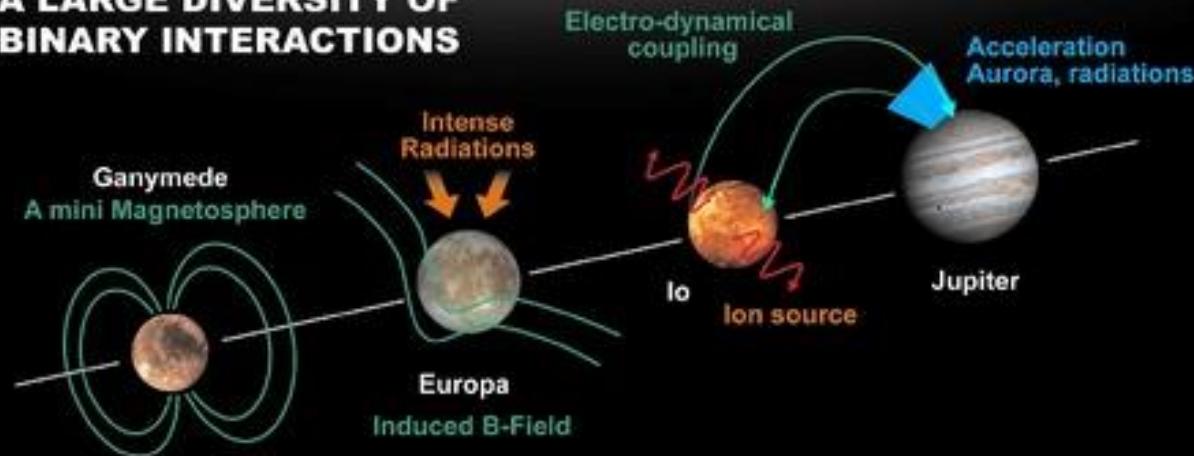
Possible configuration for Scientific Payload accomodation

# Jovian System Energetic Particle Environment

Severe environment in terms of ionizing particles

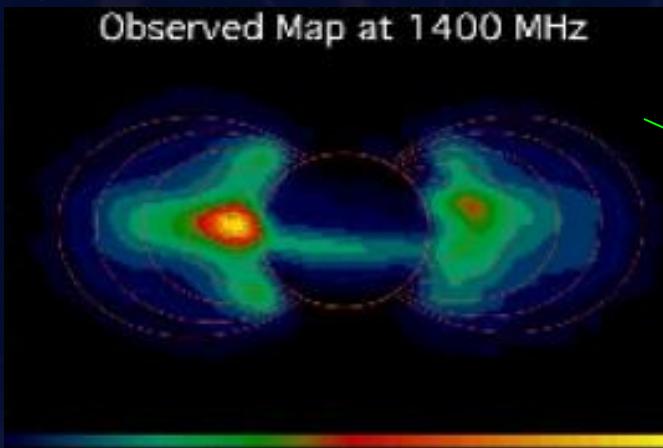


## A LARGE DIVERSITY OF BINARY INTERACTIONS

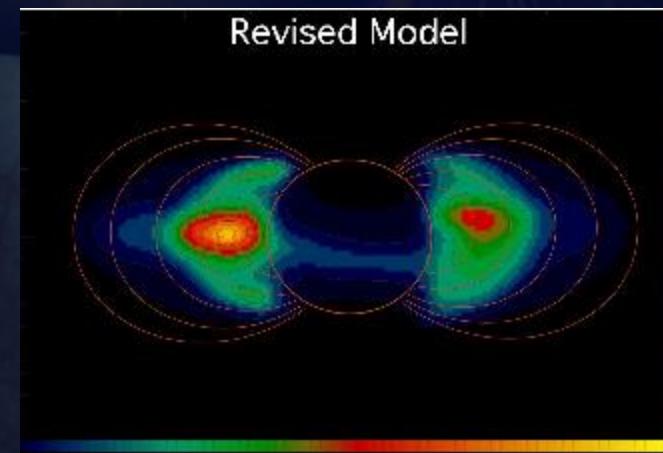


# Data and models

## Synchrotron emission observations

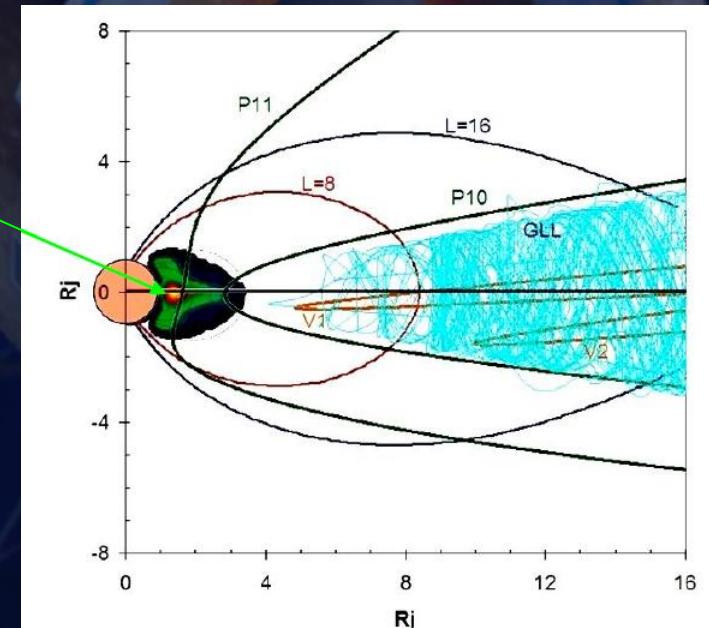


## Synchrotron emission predictions from Divine model



## Limited data from Missions

- Pioneer 10-11 (1973, 1974)
- Voyager 1-2 (1979)
- Galileo (1989)
- Ulysses and Cassini (2000)



Courtesy of H.B.Garret, Jet Prop.Lab

## Models

- Divine e- and proton models
- GIRE (Galileo Interim Radiation Environment Model)
- Salammbô(e-belt model from Jupiter surface to Europa)
- JOSE (based on Divine+GIRE+Salammbô+data)

# What is a radiation monitor?

**1**  
Radiation  
Housekeeping

**2**  
Alert and  
safeguarding

**3**  
Support to  
platform and  
payload

**4**  
Future mission  
preparation &  
provision of  
science data



**Mass ~ 1 kg**  
**Power ~ 1 Watt**  
**Volume - 1 lt**

# RADEM - Radiation Hard Electron Monitor

a radiation monitor is a key piece in keeping the mission safe but it can also provide valuable scientific data!

## Instrument requirements:

### Electron detector

*Spectral range 300 keV – 40 MeV  
Peak flux  $10^9$  e/cm<sup>2</sup>/s*

### Proton and heavy ion detector

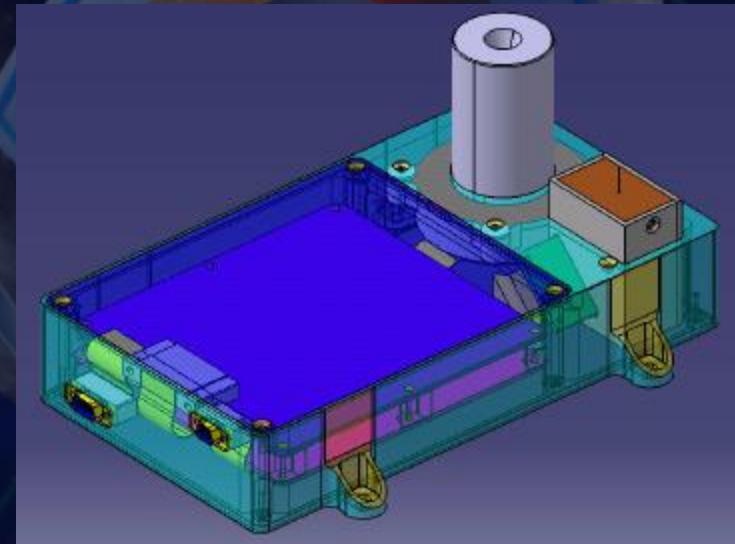
*Spectral range 5 MeV – 250 MeV  
peak flux  $10^8$  p/cm<sup>2</sup>/s*

### Radiation hard

*dose determination and alarm function*

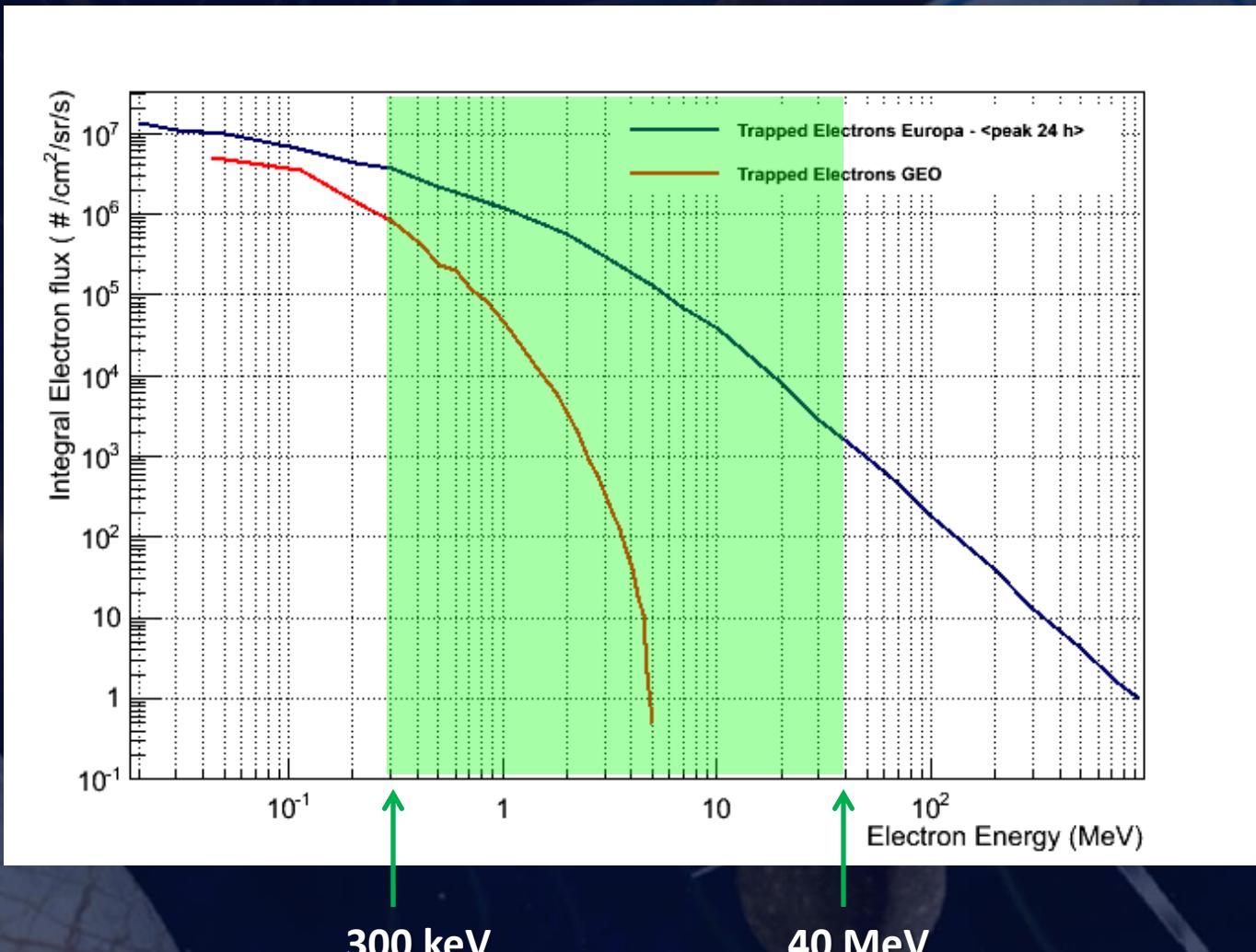
### Particle separation

*from Helium to Oxygen; LET spectra*



LIP is collaborating with european institutes and industry in a proposal for the design and development of RADEM ( phases B2, C & D).

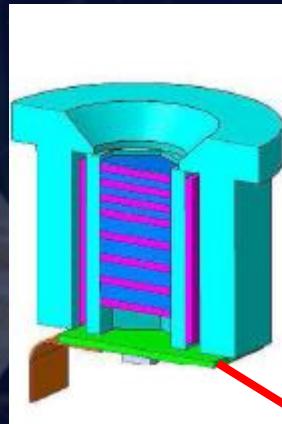
# Very Hard Electron Spectrum



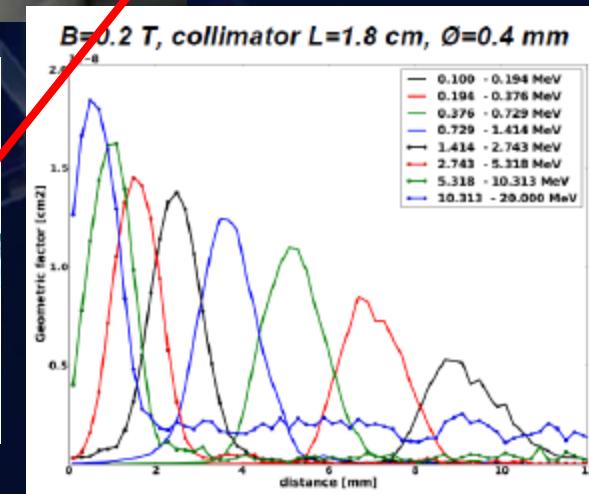
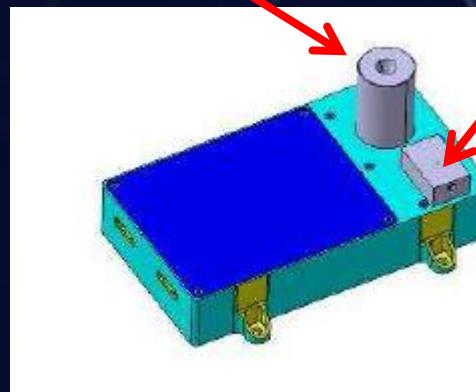
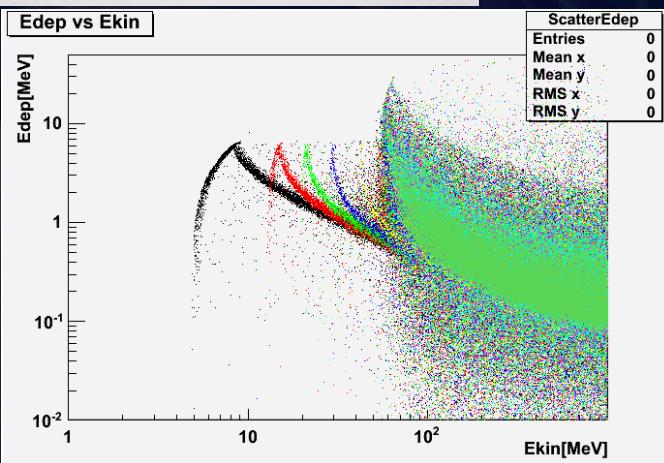
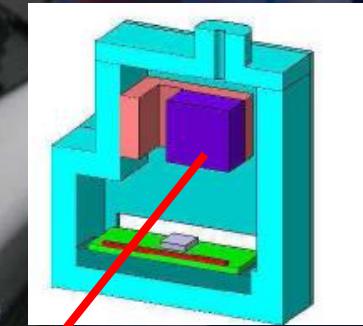
# RADEM

## Preliminary Analysis and Definition Phase A and B1 ( PSI & RUAG) - Complete

Proton Telescope  
8 Si layers, 8mm Copper shielding)



Electron Spectrometer  
permanent magnet

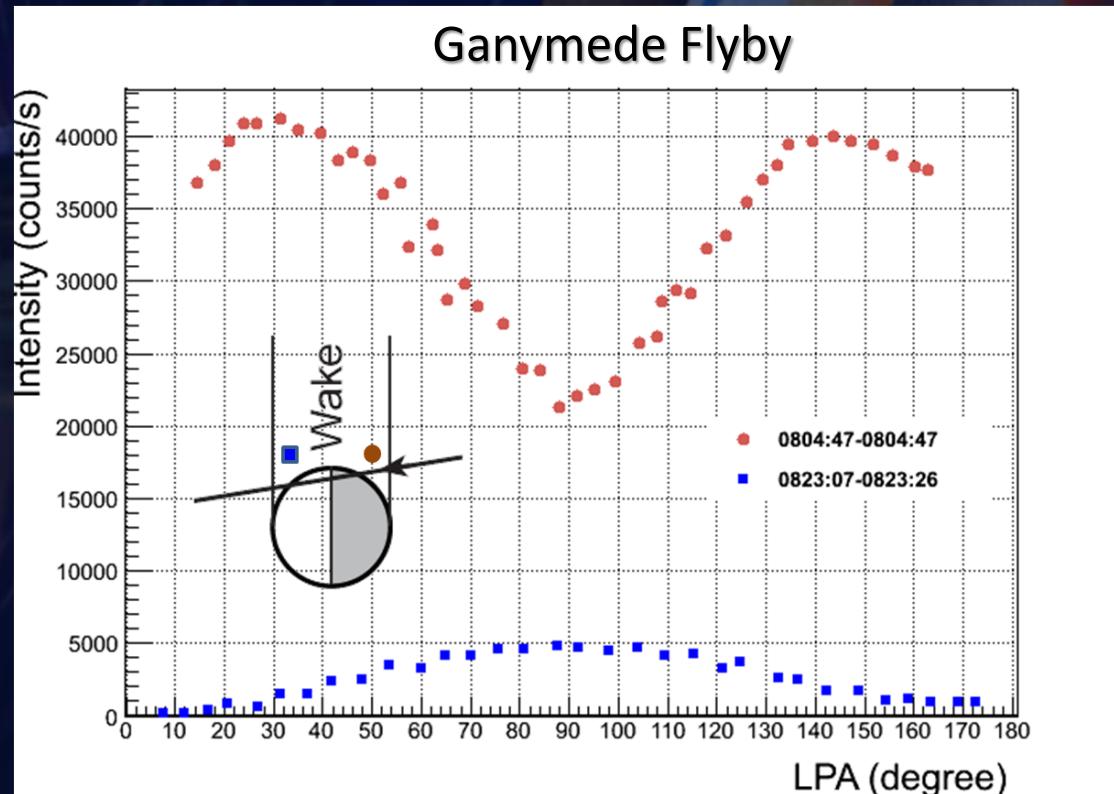


# Electron directionality

EPD measurements

Galileo G29 encounter with Ganymede

December 2000

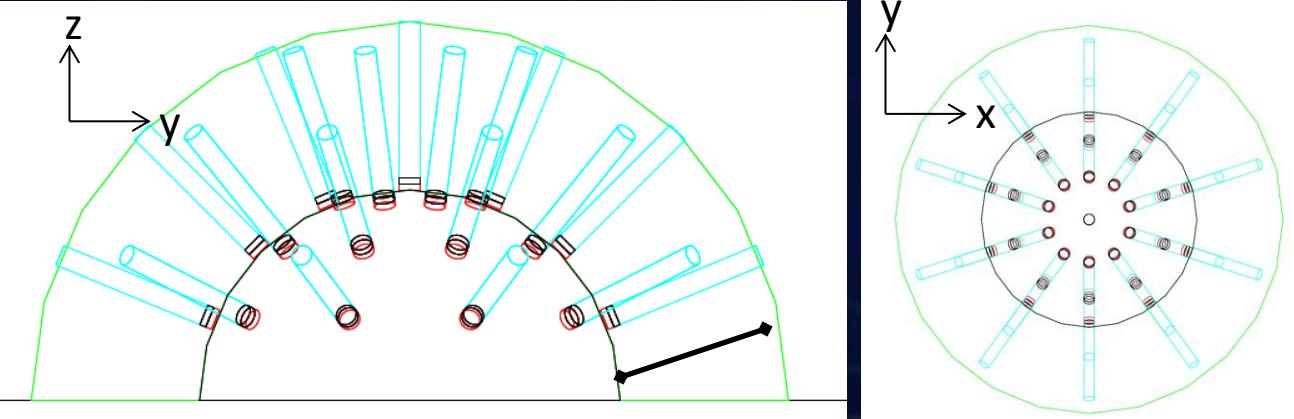


**304–527 keV electrons**

# Electron Directionality Detector

## An additional detector module for RADEM

31 Si sensors (300  $\mu\text{m}$ )  $\Delta\theta = 22.5^\circ$ ,  $\Delta\phi = 36^\circ$  & FOV= 7.2°



**Shielding:**  
8 mm Copper to stop electrons with  $E < 10 \text{ MeV}$

### Collimators

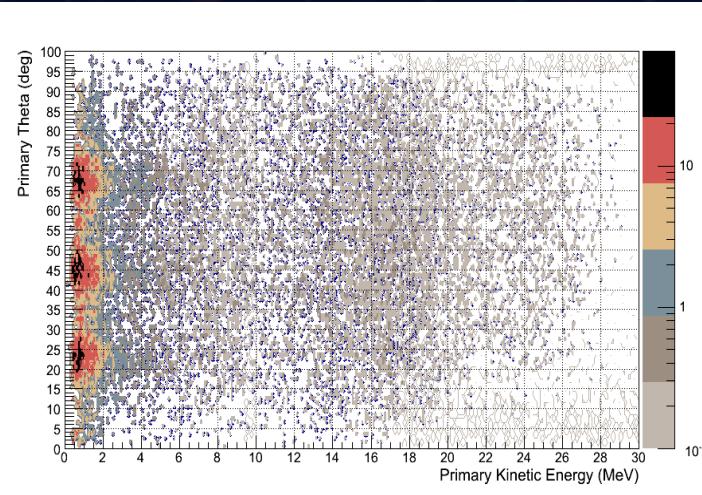
300  $\mu\text{m}$  Al absorber stops e- with  $E < 300 \text{ keV}$  & protons with  $E < 6 \text{ MeV}$



**Electrons**  
**300 keV < E < 10 MeV**

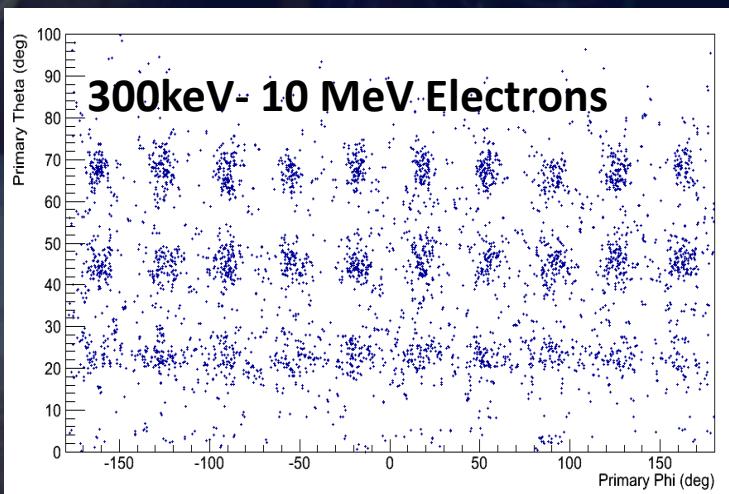
# Electron Directionality Detector

## Preliminary assessment



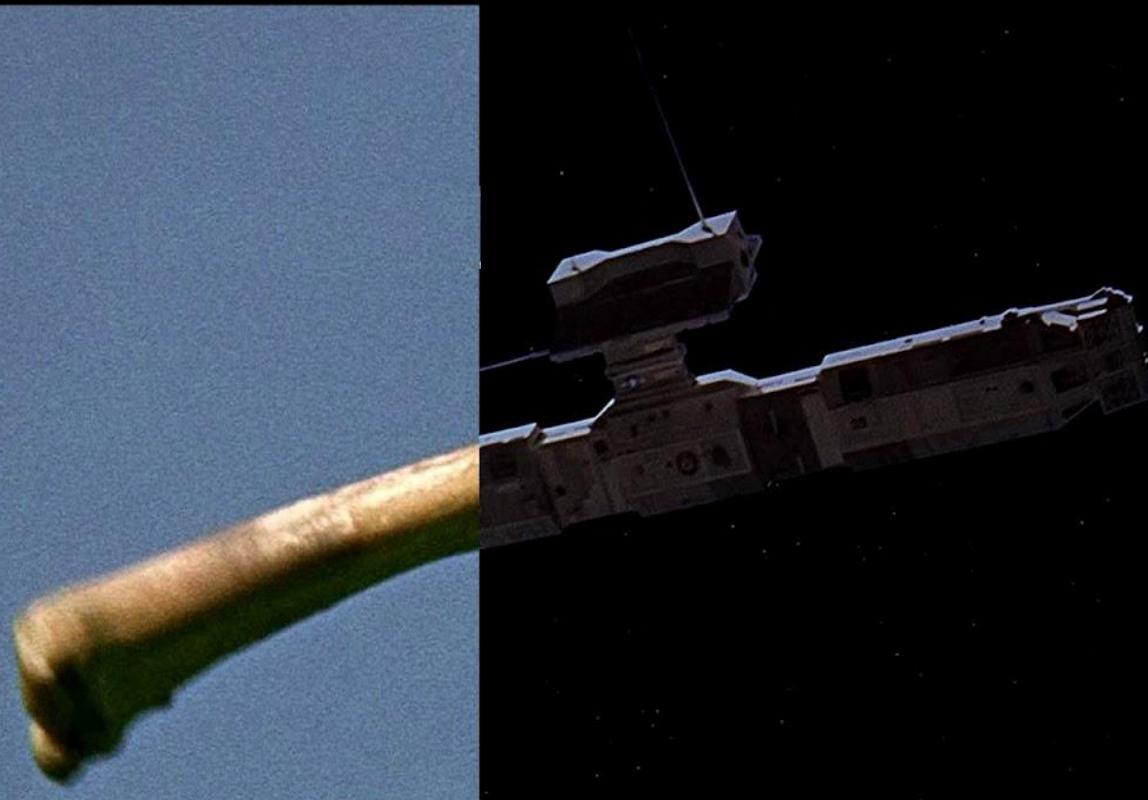
Geant4 models the detectors were developed and will be interfaced with electron, proton and ion source spectra predicted by the JOSE model at different locations in the Jovian System.

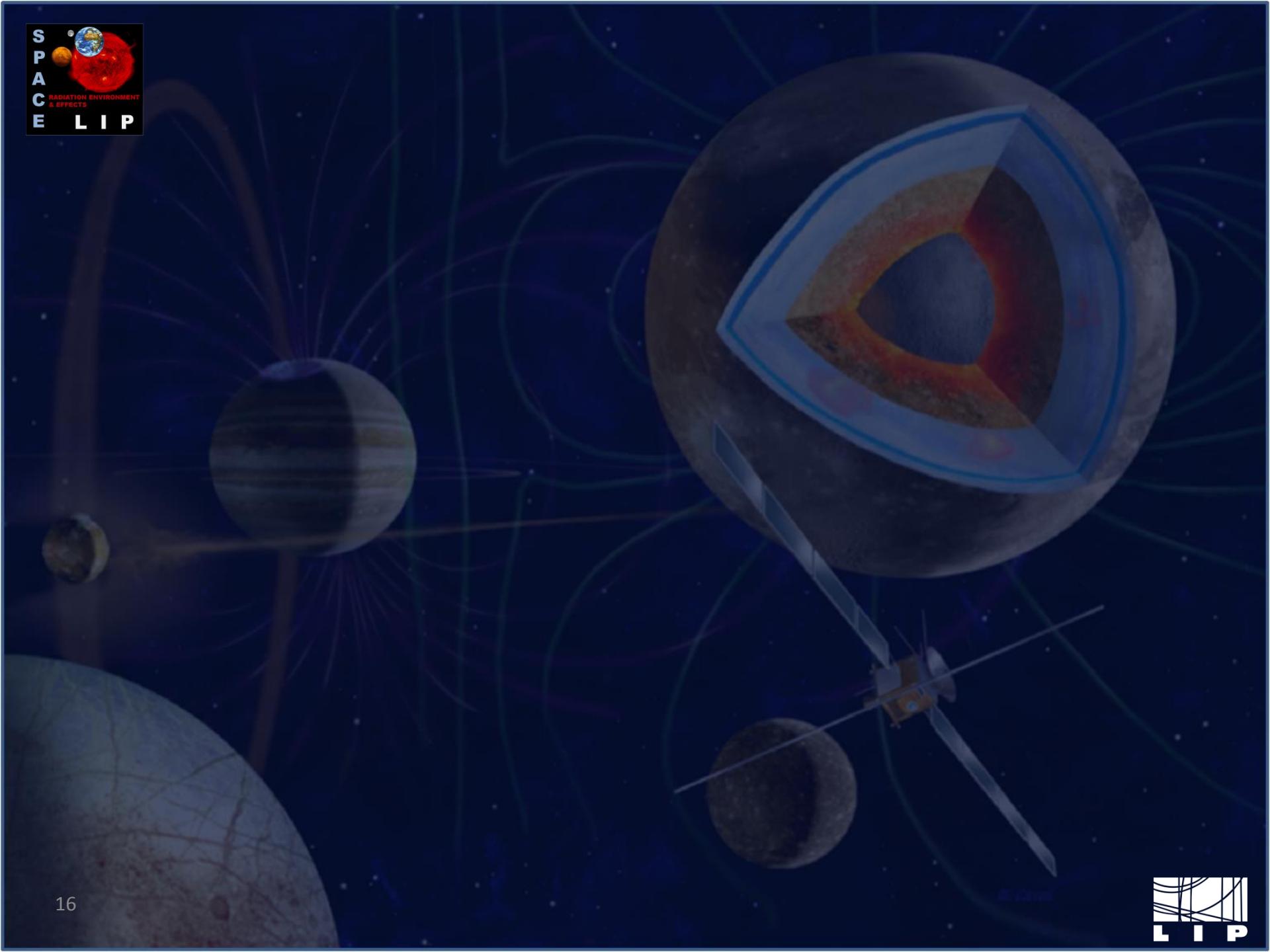
Detector configurations to be optimized during design and development of RADEM.



**WORK IN PROGRESS**

**It is not every year “we” travel to Jupiter!**





# Outlook

**The exploration of the Jovian System is an engineering & scientific challenge!**

**due to the complex and radiation hard environment, there are strong limitations for the JUICE mission**

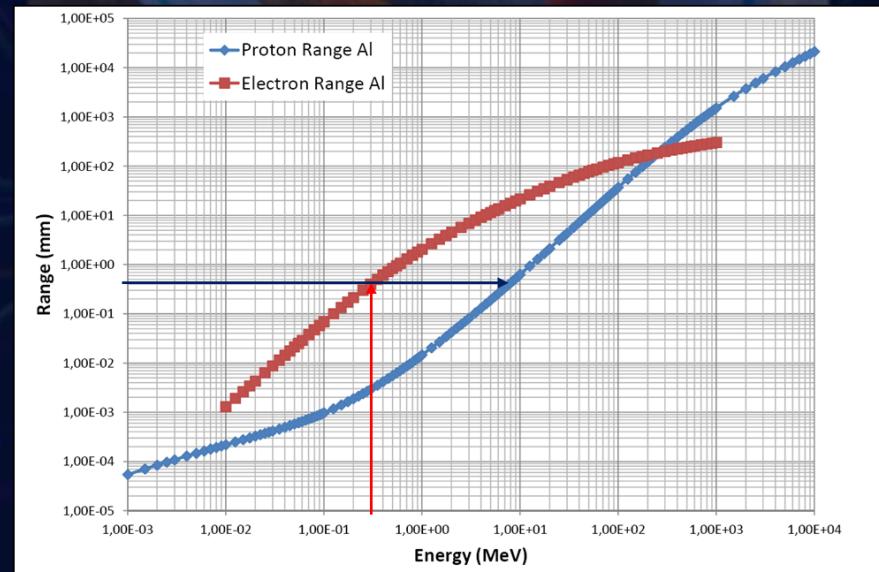
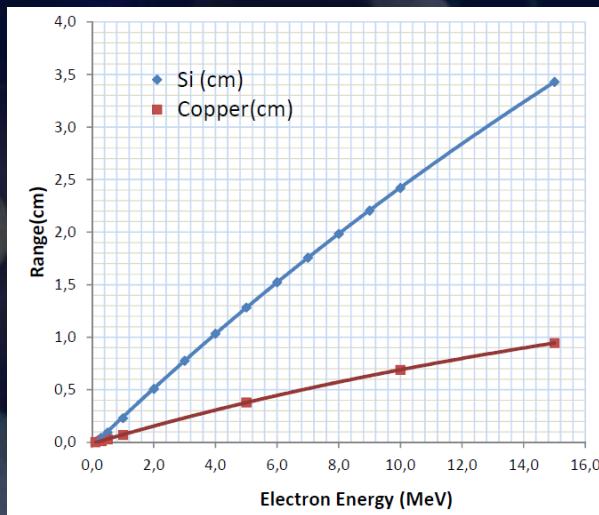
**a radiation monitor is a key piece in keeping the mission safe but it will also provide valuable scientific data.**

**LIP participates in a consortium with scientific institutes (PSI & LIP) and with the industry (RUAG, IDEAS, EFACEC) for the development of a proto-flight model of RADEM**

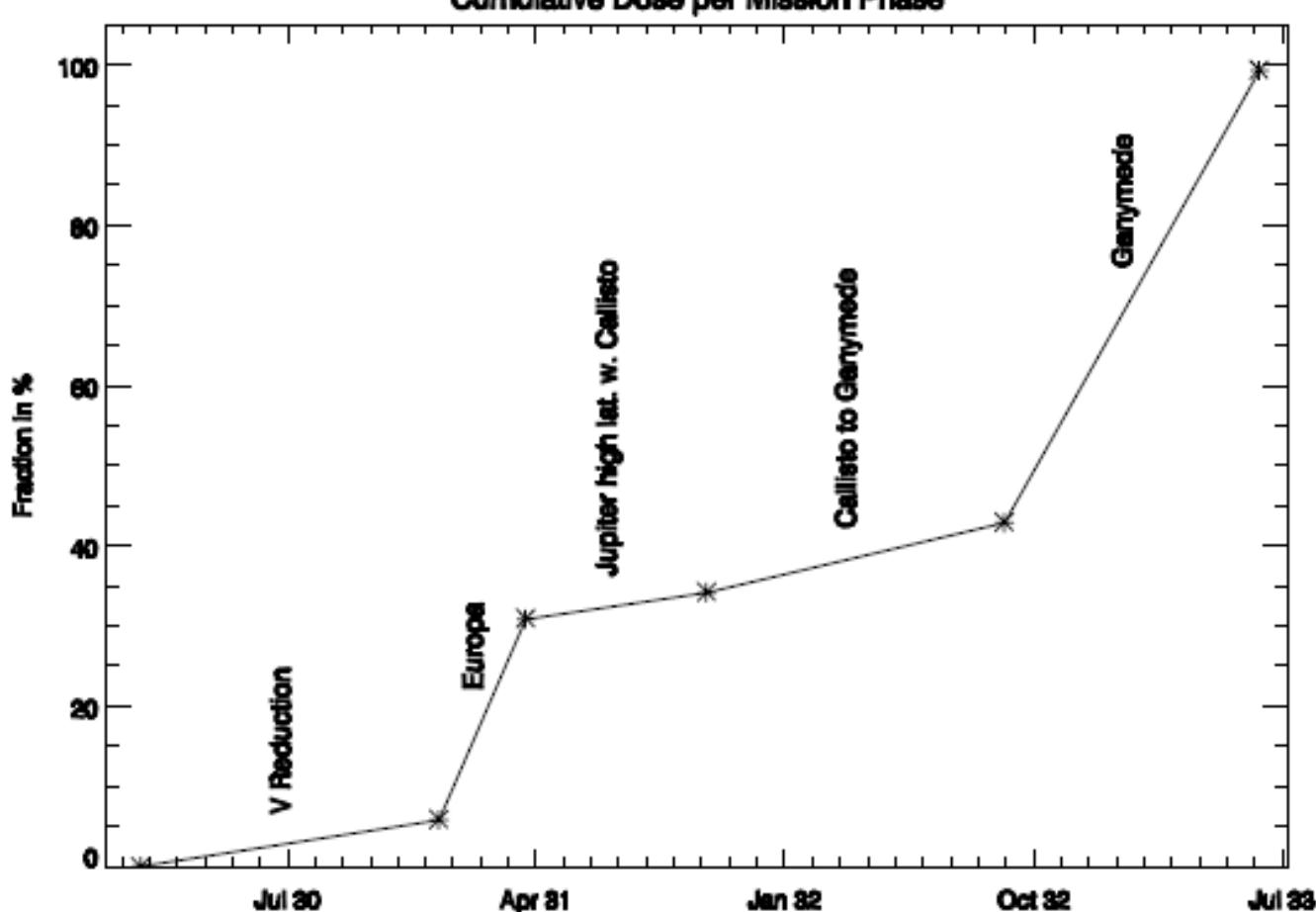
**WORK IN PROGRESS**

# Electron Directionality Detector

## An additional detector module



# Cumulative dose for the Juice mission



# Ganymede

# The Jovian Icy Moons

Jupiter

Ice layer.  
Thickness?  
Liquid water?

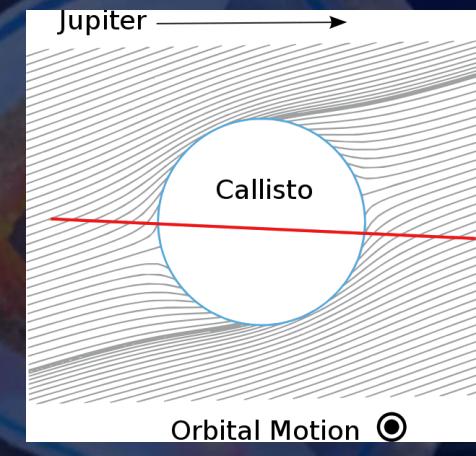
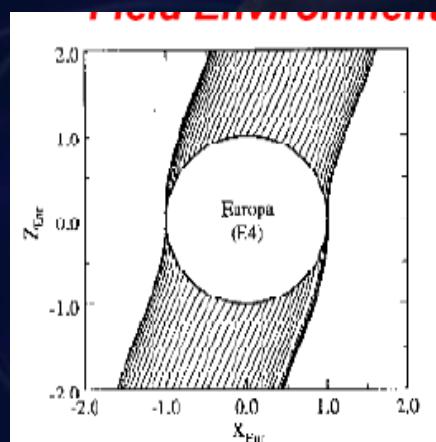
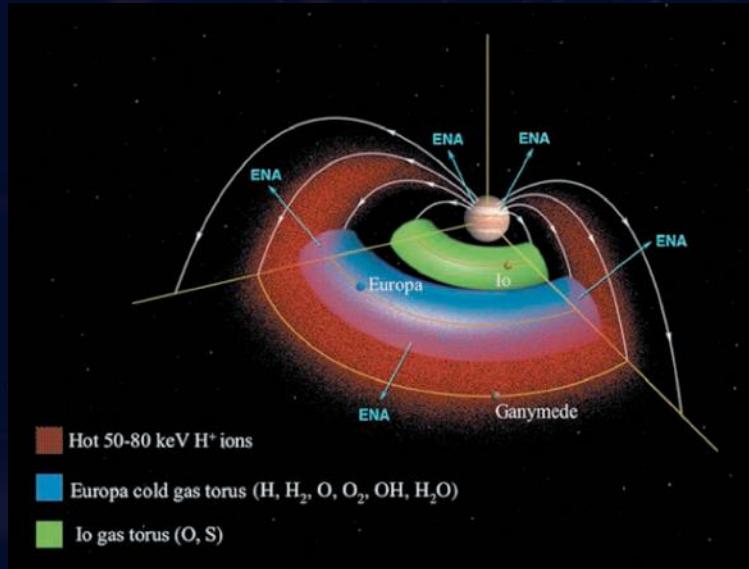
a cold rigid ice crust, an outer warm ice mantle, an inner silicate mantle, and a metallic core

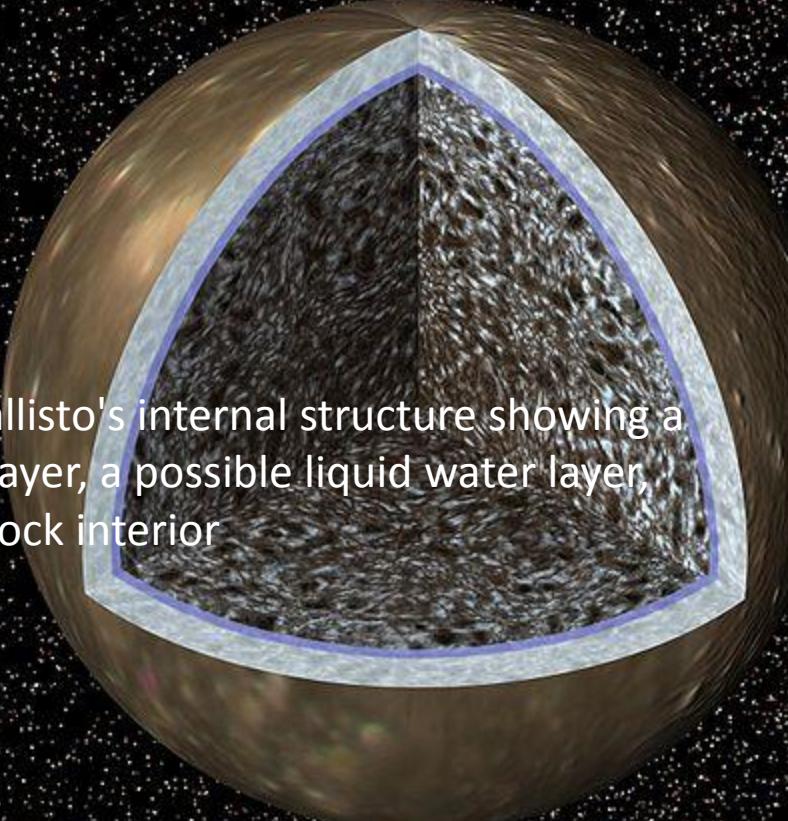
Europa

Surface and  
Subsurface  
composition  
Geology  
Loc environment  
Interaction with  
JM

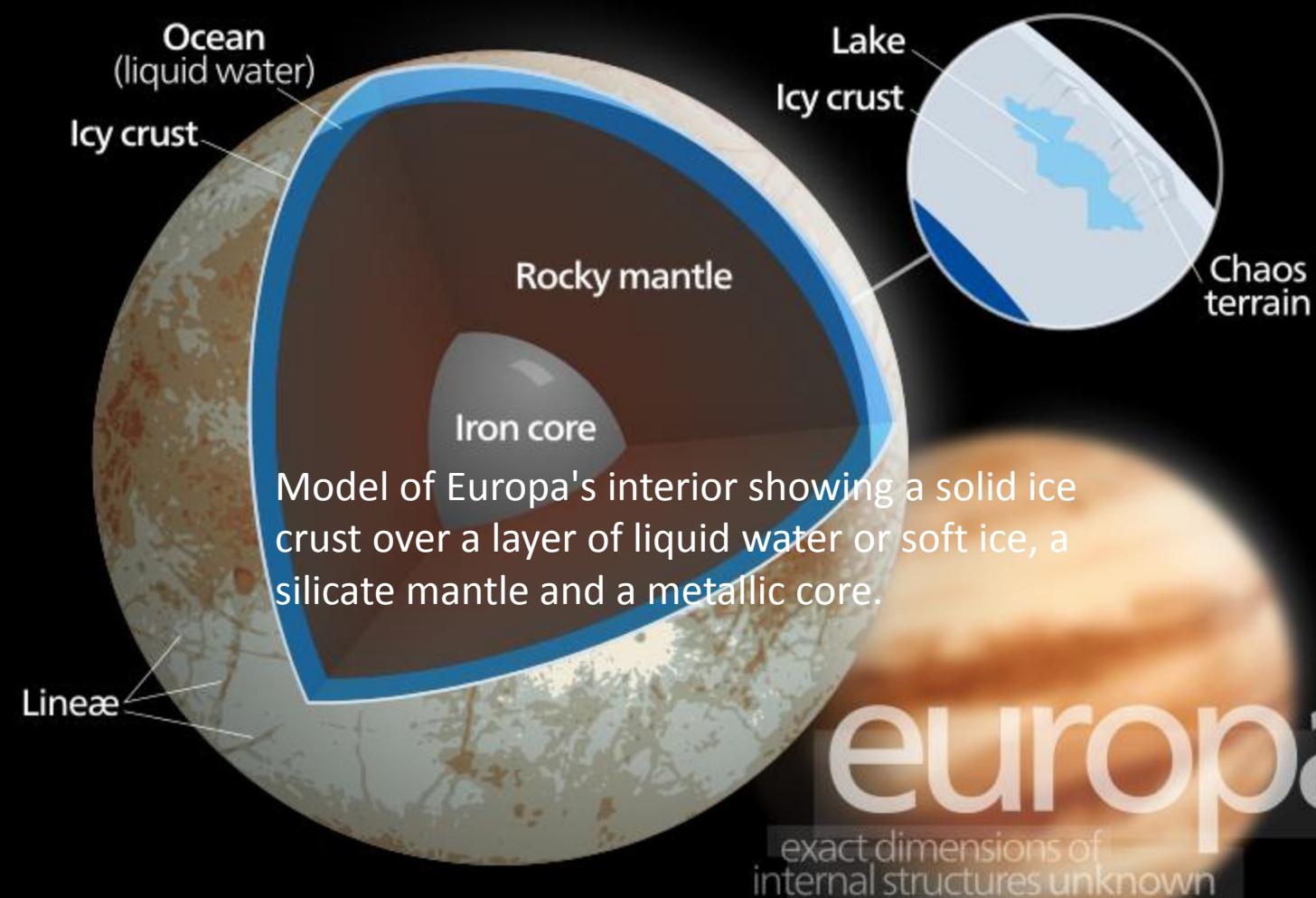
Callisto

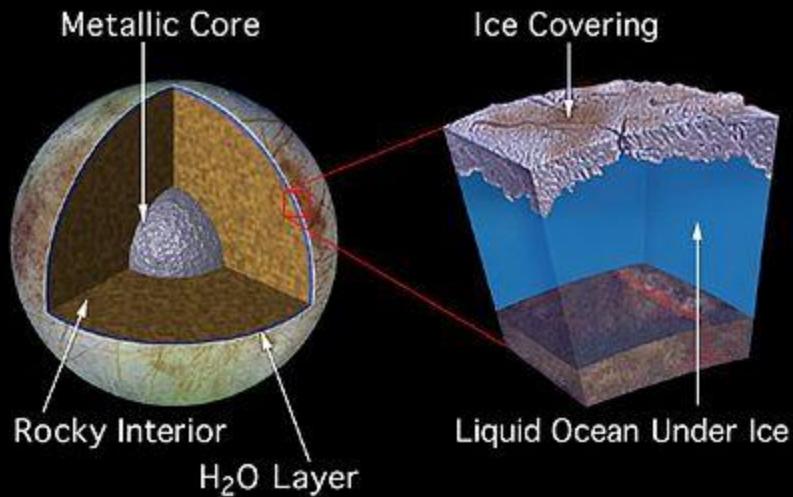
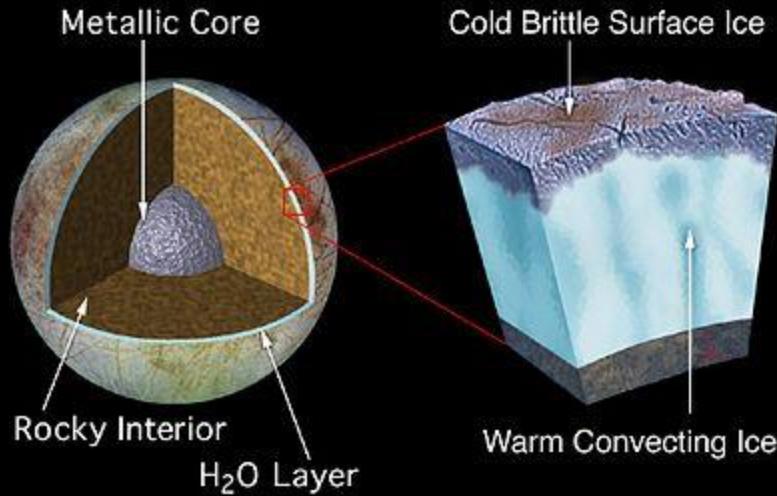
Ice layer.  
Thickness?  
Liquid  
water?





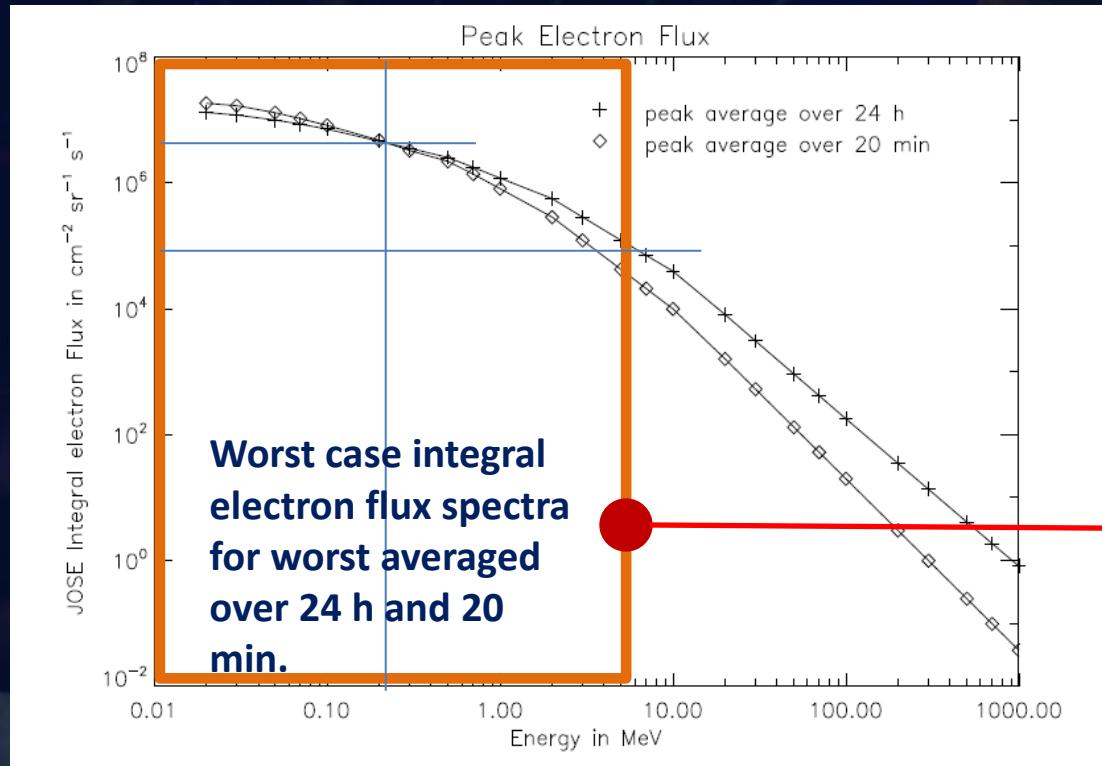
Model of Callisto's internal structure showing a surface ice layer, a possible liquid water layer, and an ice-rock interior



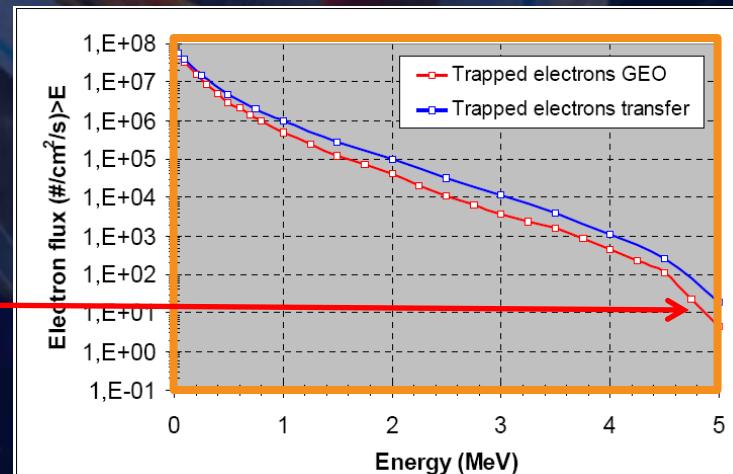


# Very Hard Electron Spectrum

Jupiter - JUICE



Earth - GEO



Electron Flux  
#/( $\text{cm}^2 \cdot \text{sr} \cdot \text{s}$ )

0.2 MeV

5 MeV

Jupiter - JUICE

$\sim 5 \times 10^7$

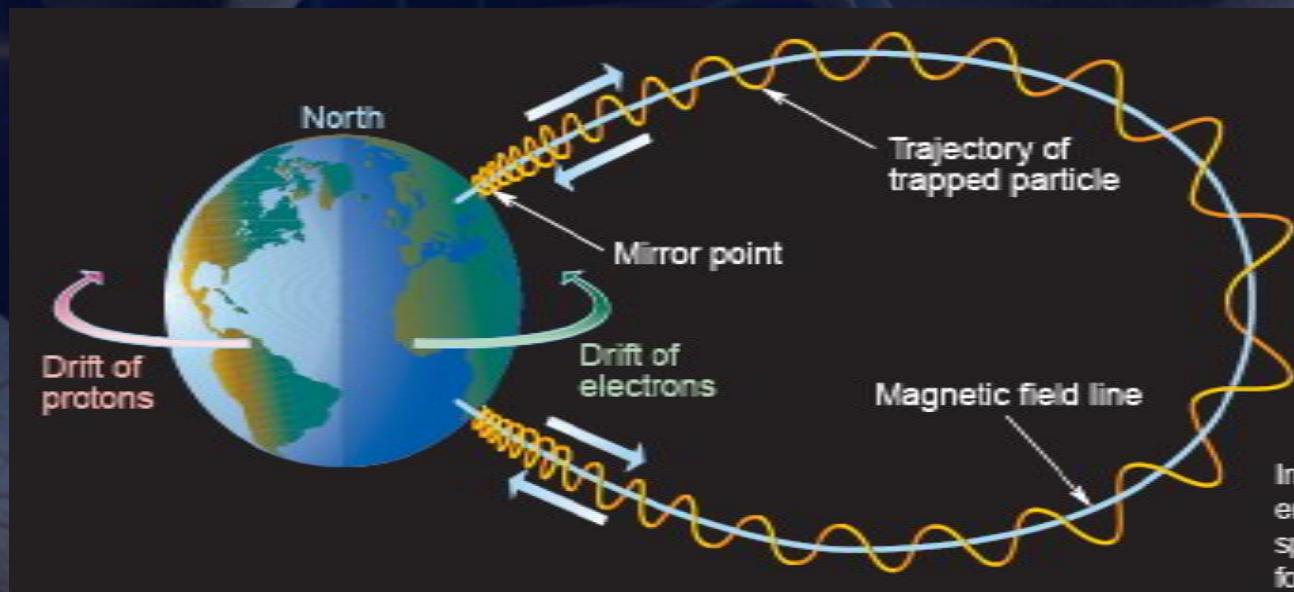
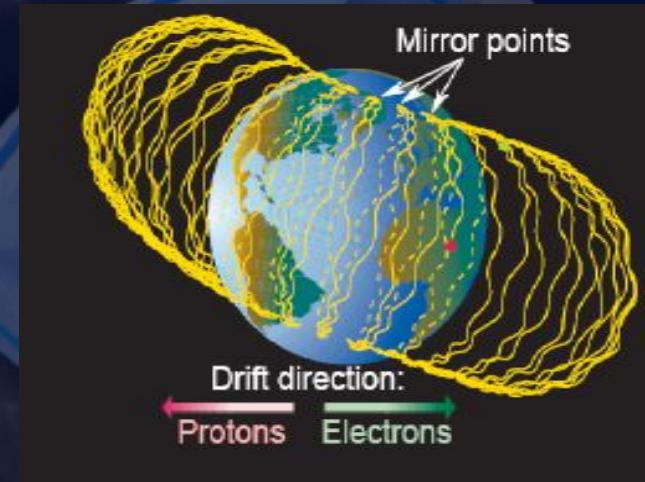
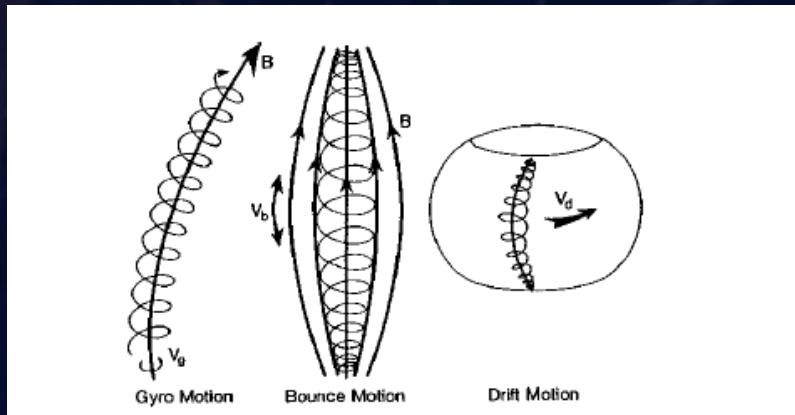
$\sim 5 \times 10^5$

Earth - GEO

$1 \times 10^7 / 4\pi$

$1 \times 10^1 / 4\pi$

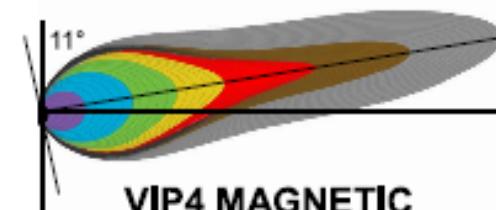
# Particles in the magnetosphere



# Jupiter's Magnetosphere

<b>Characteristics</b>	<b>Earth</b>	<b>Jupiter</b>
Equatorial radius (km)	$6.38 \times 10^3$	$7.14 \times 10^4$
Magnetic moment (G-cm <sup>3</sup> )	$8.1 \times 10^{25}$	$1.59 \times 10^{30}$
Rotation period (hr)	24.0	10.0
Aphelion/perihelion (AU)	1.01/0.98	5.45/4.95

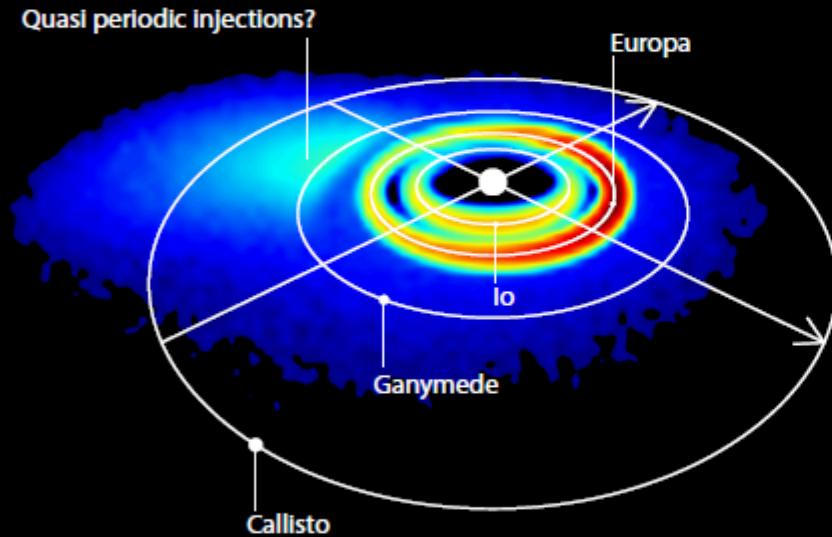
- Jupiter is roughly 10 times the size of the Earth while its magnetic moment is  $2 \times 10^4$  larger.
- As the magnetic field at the equator is proportional to the magnetic moment divided by the cube of the radial distance, the Jovian magnetic field is proportionally **20 times** larger than the Earth's.
- The energy and flux levels of trapped particles in the Jovian system can be much higher than those at the Earth or in the interplanetary space.



**VIP4 MAGNETIC  
FIELD MODELS**

## Global view of the giant accelerator and its interaction with the moons

(a) Two separate, asymmetric Europa and Io Torii



(b) One merged, symmetric Europa-Io Torus

