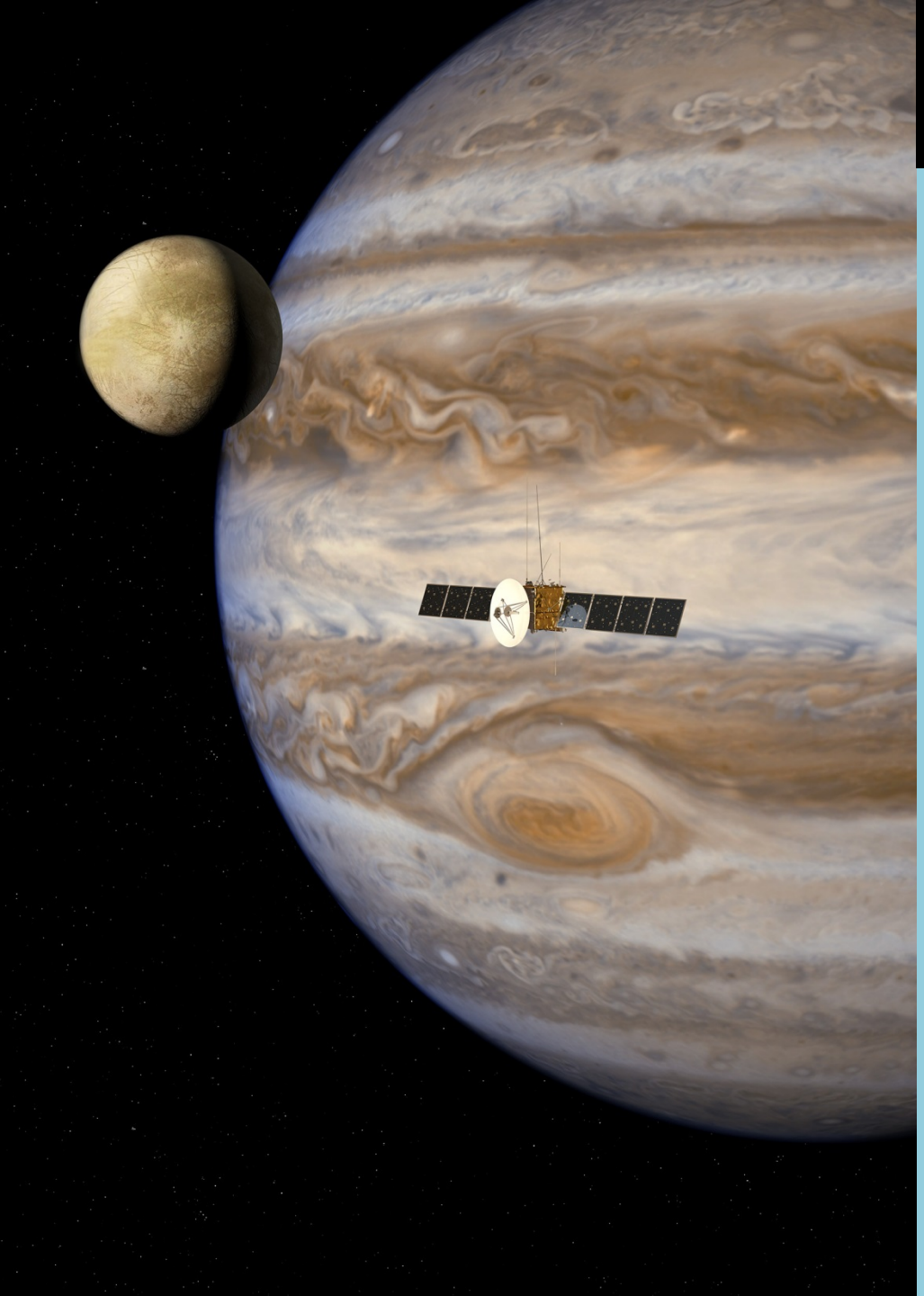


RADEM: a Rad-hard Electron Monitor for JUICE

Radiation and Plasma Monitoring Workshop, ESTEC 13-14 May 2014

Alessandra Menicucci,
Space Environment and Effects section (ESA) and RHEA
On behalf of RADEM consortium

Outline

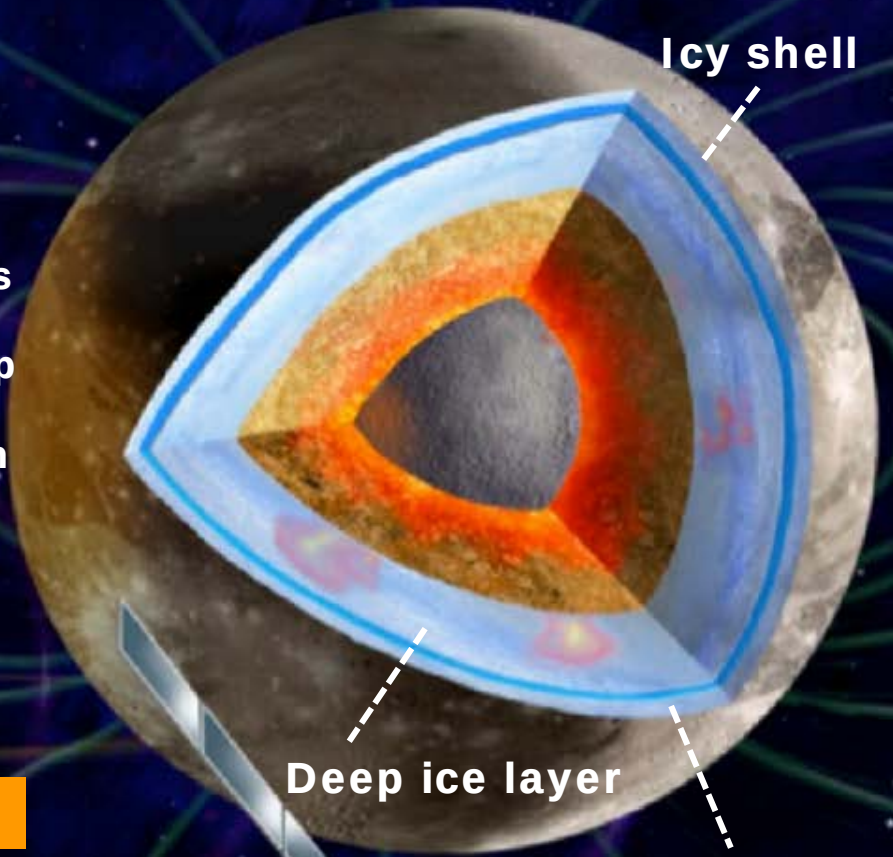
- JUPITER system and the JUICE Mission
- Radiation environment at Jupiter
- Rad-hard electron monitor
- RADEM Phase A-B results
- RADEM Phase C-D
- Conclusions

JUPITER

The largest body in the solar system after the sun

Ganymede

- The largest moon in the solar system bigger than Mercury, it is thought to have oceans stacked up in several layers.
- Only moon known to have a magnetosphere
- Fly-bys and orbit



JUICE

- Next L-class ESA mission to be launched in 2022.
- JUICE will explore Galilean moons in unprecedented detail.

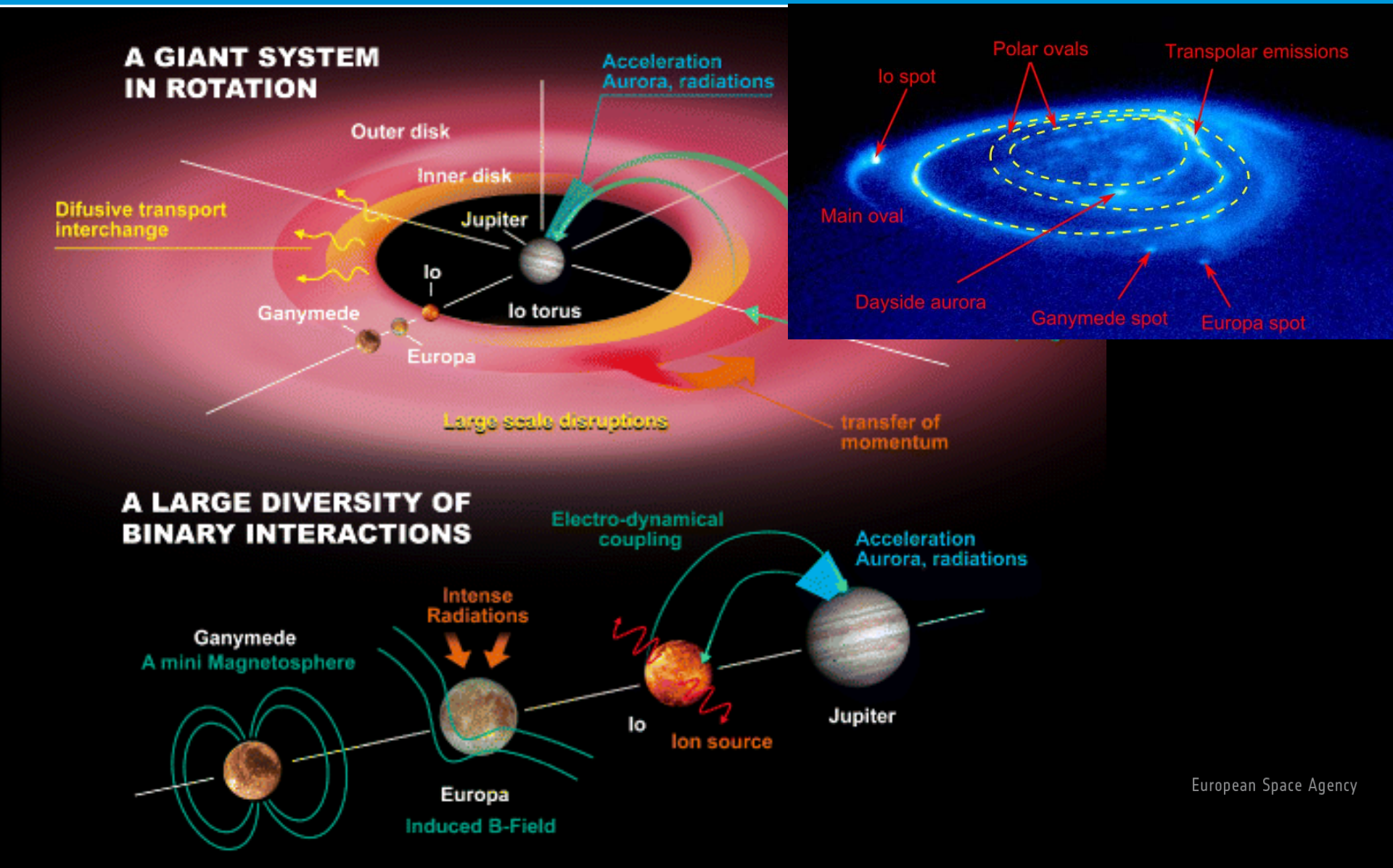
Europa

- It has the size of our moon, the surface composed of water-ice where life may lurk.
- 2 fly-bys

Kallisto

- Second largest Jovian moon, it might have subsurface ocean
- Multiple flybys

JUPITER SYSTEM: a giant magnetosphere and a mini solar system in its own



Past and future missions to Jupiter

Fly-bys

Spacecraft	Year	Distance
Pioneer 10	1973	130.000 km
Pioneer 11	1974	34.000 km
Voyager 1	1979	349.000
Voyager 2	1979	570.000 km
Ulysses	1992/2004	408,894 km/120,000,000 km
Cassini	2000	10.000.000 km
New Horizons	2007	2,304,535 km

Galileo orbiter

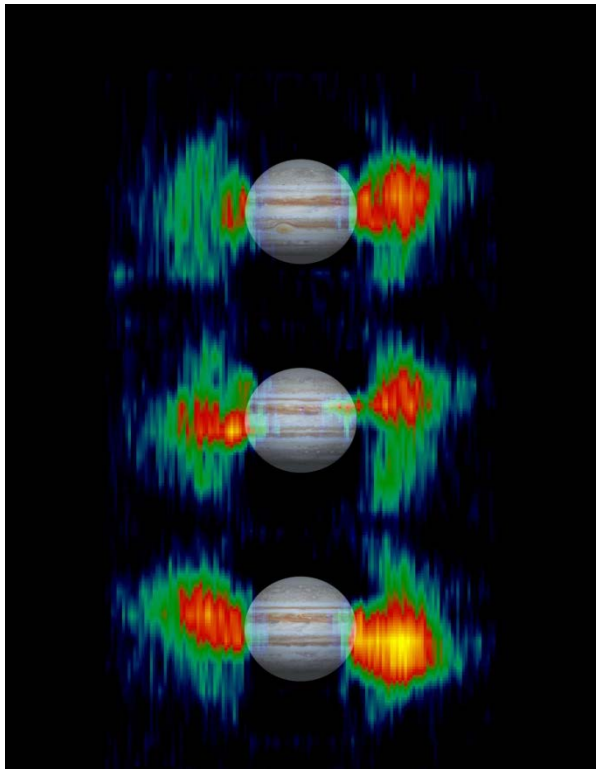
- Launched in 1989, arrived at Jupiter in 1995
- Orbited 35 times around Jupiter in elongated ovals designed for close-up fly-bys of the largest moons
- Orbits at different distances to sample the planet magnetosphere

Future missions

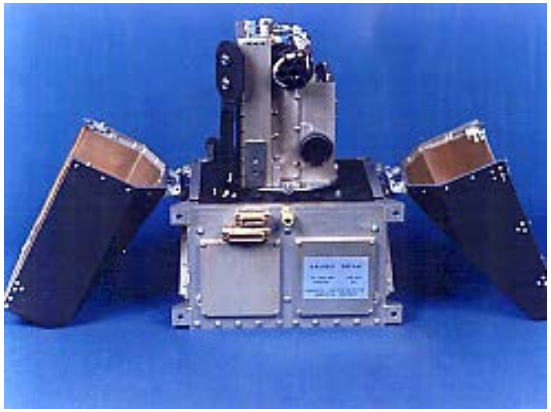
- JUNO (NASA) has been in 2011 will arrive in late 2016.
- JUICE (ESA) due to launch in 2022.

Modelling of the Jovian Radiation Environment

- Divine and Garret (DG83): first model based on Voyager/Pioneer in-situ data
- Galileo Interim Electron Environment (GIRE): Update of DG83 based on Galileo EPD data
- Salammbo- 3D: Developed by ONERA as a pure theoretical model
- JOE/JOP: Developed by ONERA is a combination of DG83, GIRE and Salammbo-3D
- JOSE: Developed by ONERA using all relevant data and realistic magnetic field



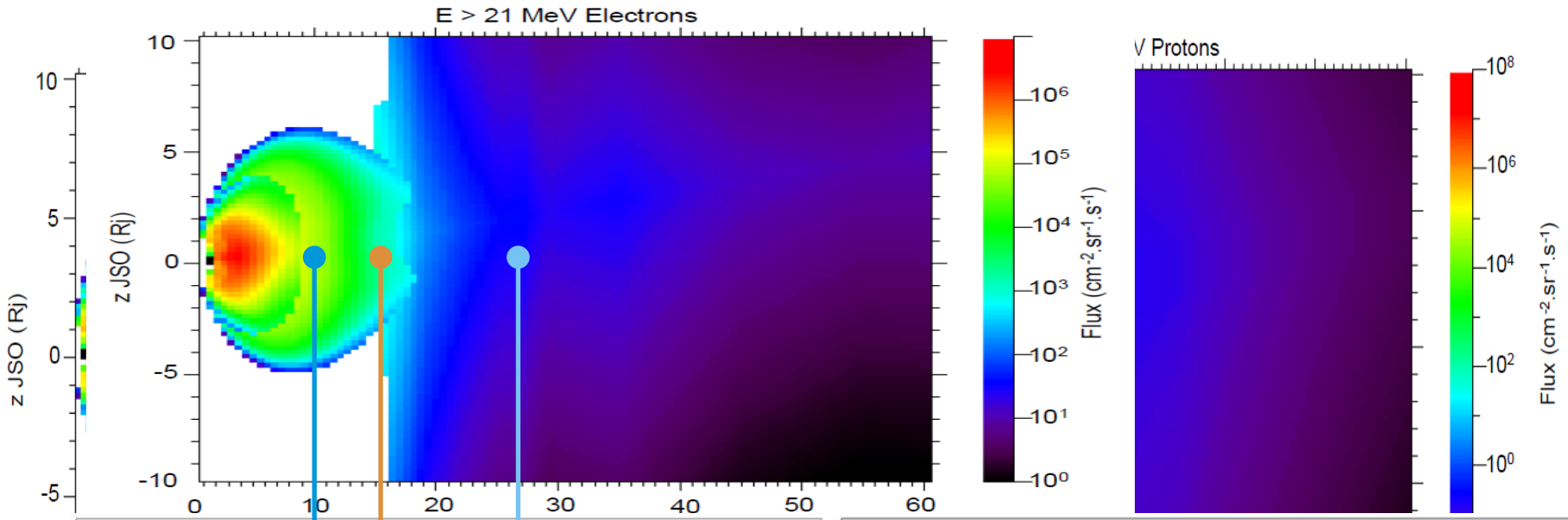
Observation of the synchrotron emission by Cassini at 3 different points in Jupiter 10 h rotation.

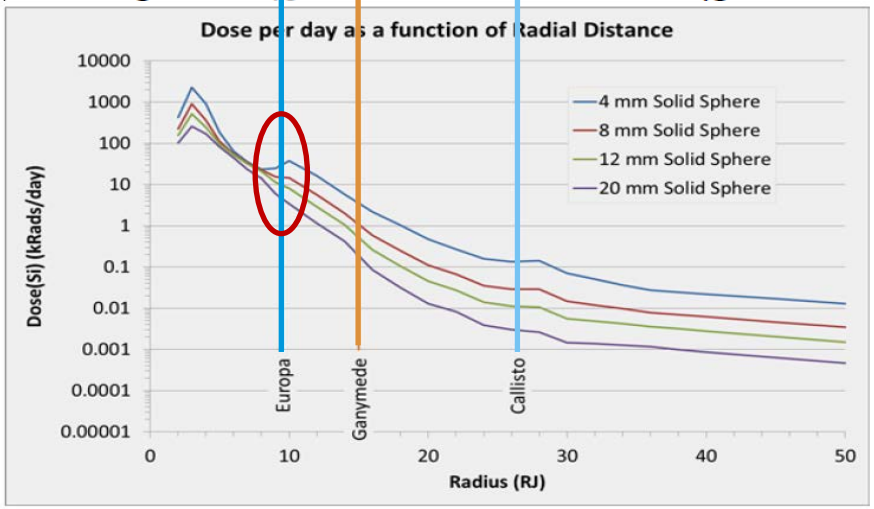


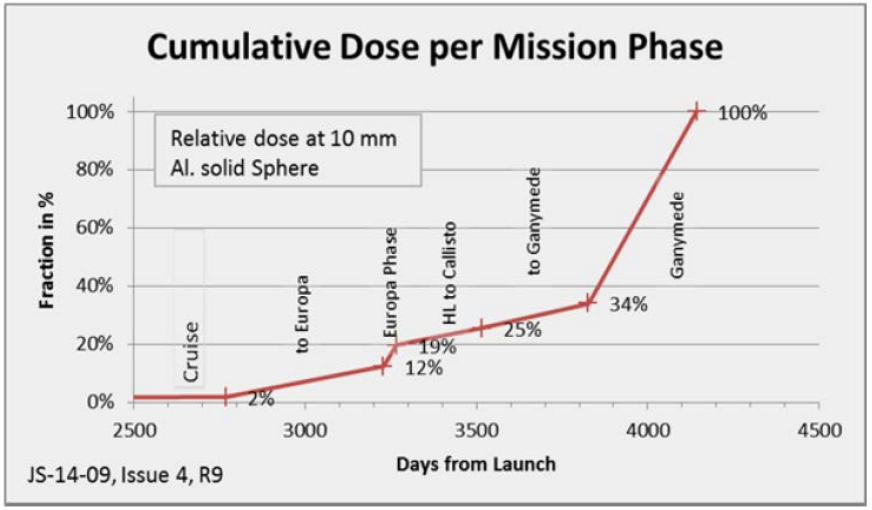
Energetic Particle Detector

- based on silicon detectors and TOF
- measured ions (Z >= 1) from 0.020 to 55 MeV and electrons from 0.015 MeV to more than 11 MeV

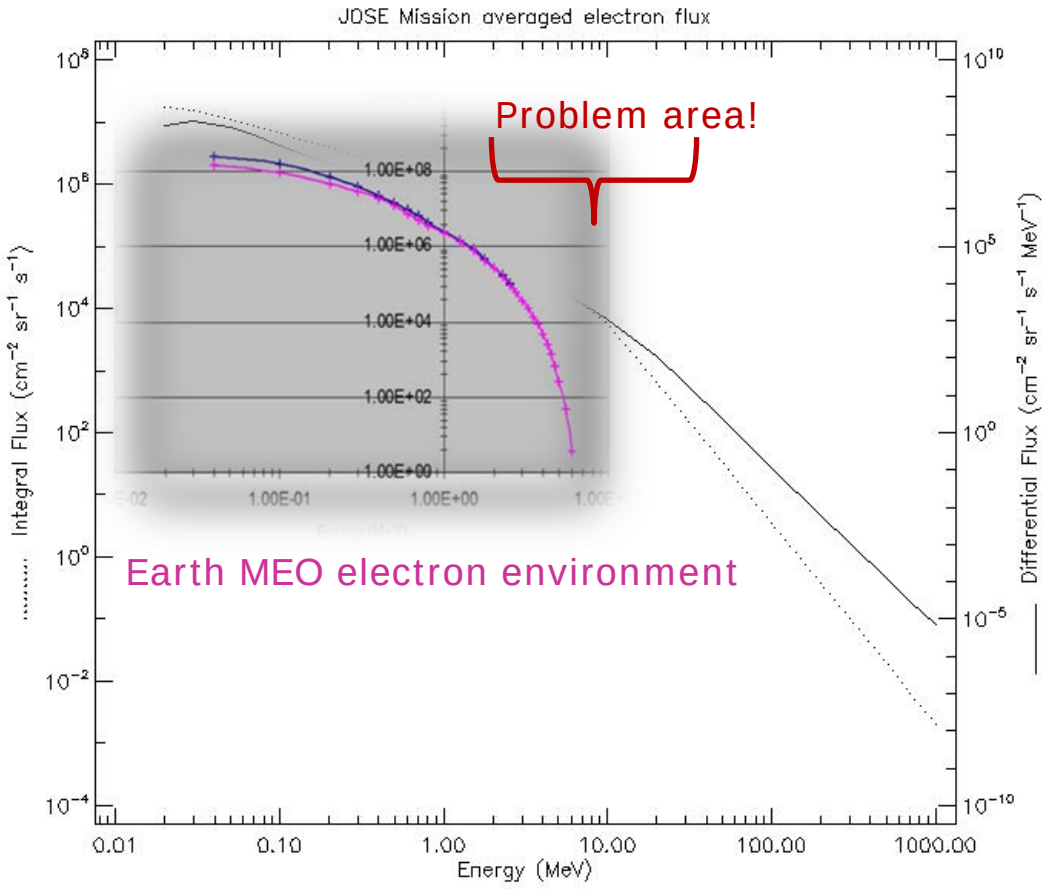
Severe radiation environment: Jovian Specification Environment Model (JOSE)

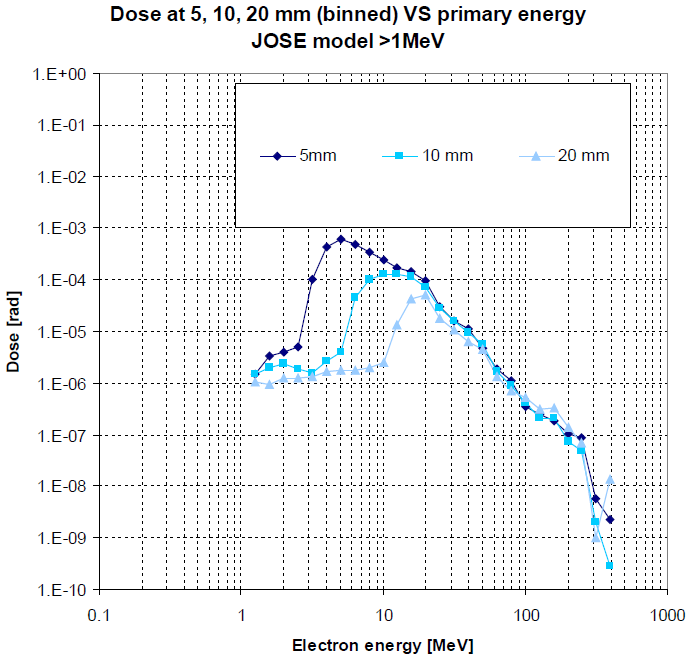






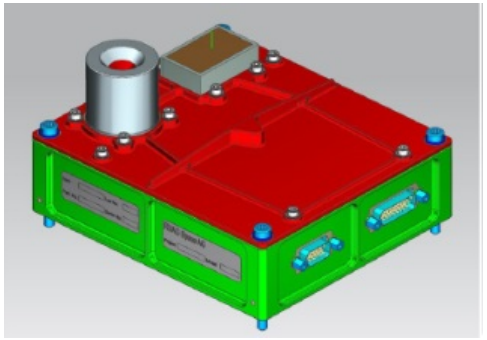
JUICE electron radiation environment





RADEM: a rad-hard electron monitor

- Phase A-B ESA TRP concluded in 2012 by RUAG (CH) and PSI (CH).
- Main objectives were:
  - Sensors + Front End Electronics design and breadboarding
  - Design of Back-End Electronics, PCU and mechanics
  - Simulations and calibration of the prototype



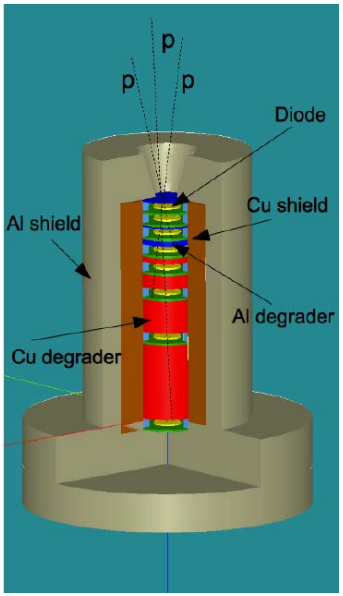
- Targeting specifically JUICE but suitable to fly also in other electron rich environments (i.e. MEO)
- Start TRL ~2; end TRL = 4
- 400k€, 18 months
- The most challenging requirement for RADEM is the ability to detect electrons up to MeV-GeV range and to measure accurately the flux while keeping the mass, power consumption and data rate low and being radiation hardened. Detection of electrons at those energies is made complicated by multiple-scattering processes.

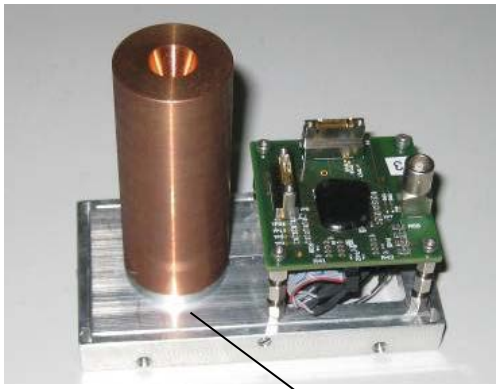
RADEM Key requirements

Compact, light, low resources radiation monitor	**Energy resolution**
Mass < 1 kg; Volume < 1 dm3, Power < 1 W, data rate < 100 bps	*8 quasi logaritmic bins*
Electron detection	**Radiation hardness**
Energy range 100 keV – 40 MeV *Peak flux 10^9 e/cm^2/s*	*1 Mrad at the exterior of the monitor* *Total dose determination and alarm function*
Proton detection	**Lifetime in operational mode**
Energy range 2 MeV – 200 MeV *Peak flux 10^8 p/cm^2/s*	*11 years*
Temporal Resolution	**Autonomous operations**
≥ 1 min	*7 days*
Sensitivity to ions from Helium to Oxigen (MeV.cm2/mg)	**Particle Identification**

RADEM Phase A-B prototype

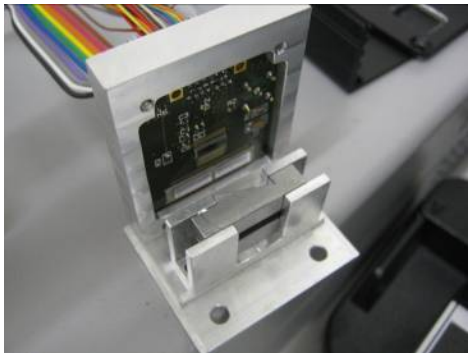
Proton telescope

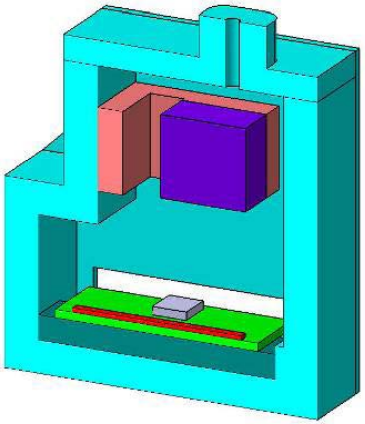




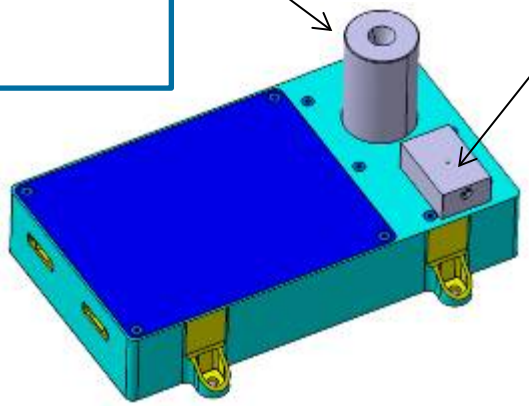
composed by 8 layers Si diodes interleaved by absorbers in a stack

Electron spectrometer



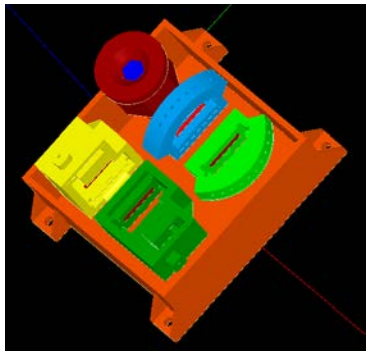


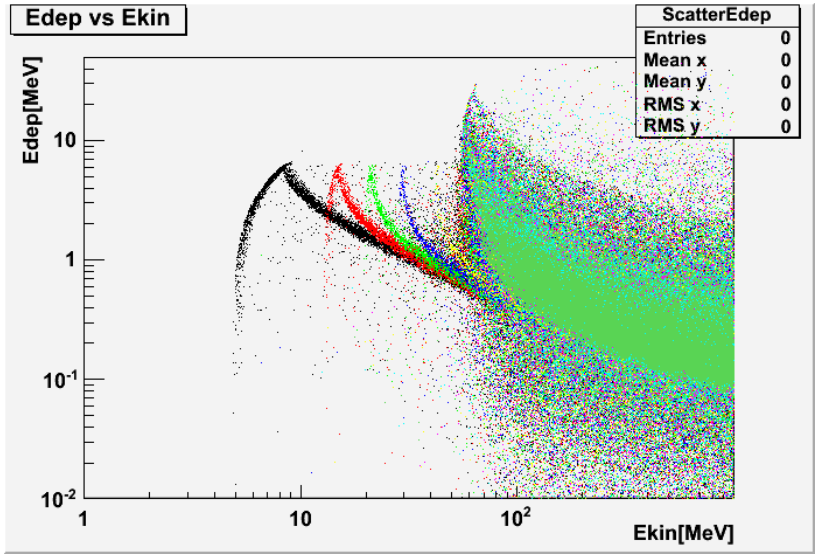
Based on magnetic deflection of electrons by a permanent magnet detected by Si microstrips

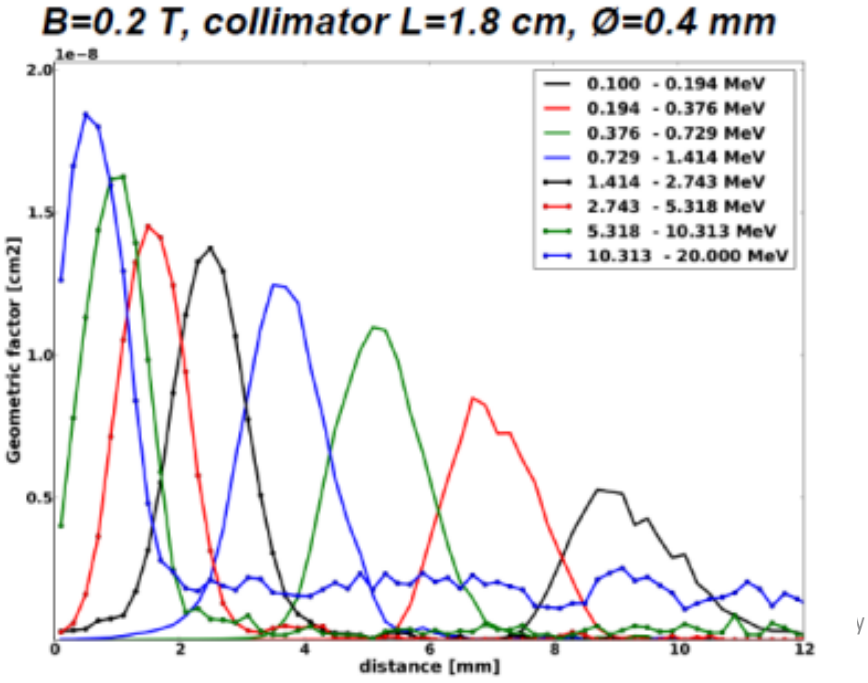


RADEM Geant4 Simulations

- Full mass model constructed with GEANT4 and GRAS based on CAD drawings performed by PSI (L. Desorgher and W. Hajdas)
- Responses for Jupiter environment simulated.
- Results used for optimization of both detector units and shielding.

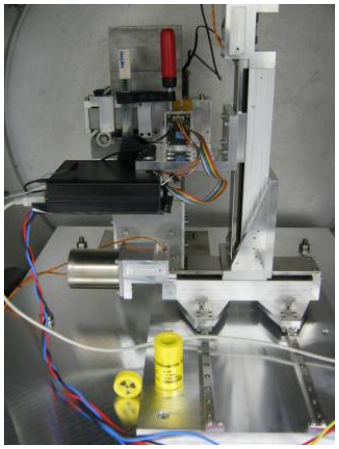


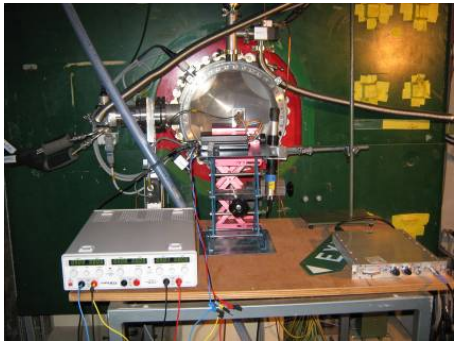


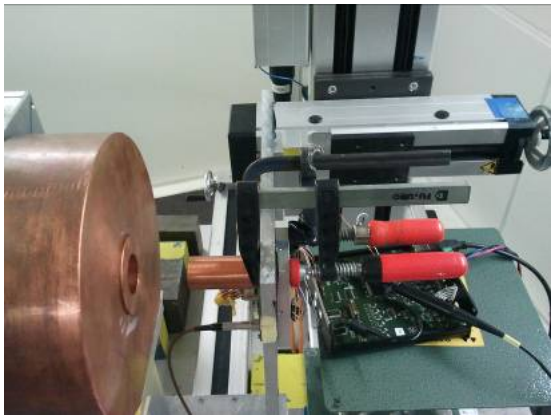


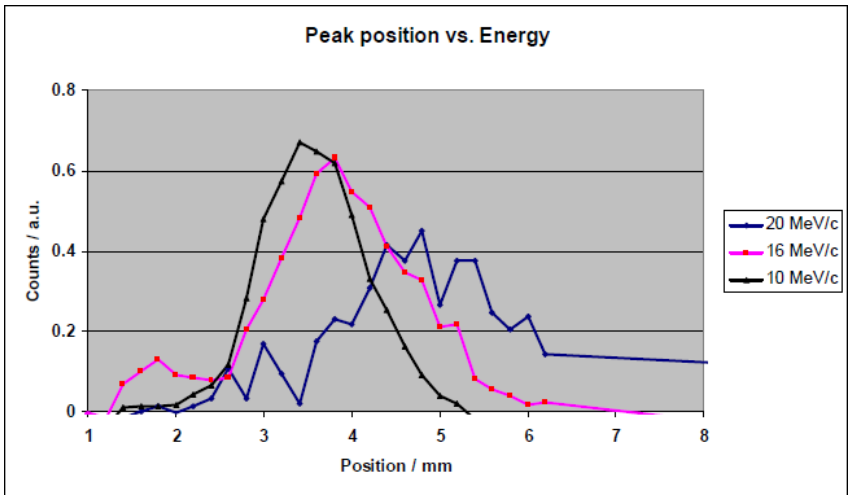
RADEM prototype testing at PSI

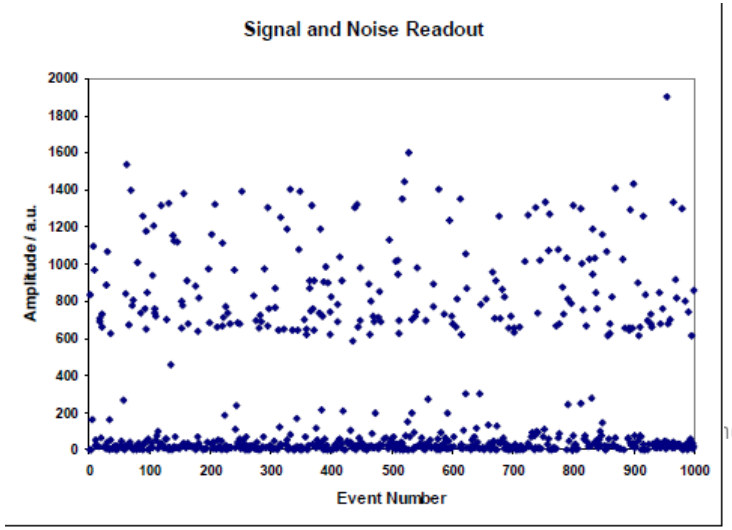
- Electron spectrometer tested with PSI electron monochromator and e- beamline (5-40 MeV)
- Proton telescope tested at PIF with protons from 5 to 230 MeV











RADEM Phase B2-C-D

- The RADEM Phase A-B TRP has produced the prototype of the 2 sensors heads and performed a preliminary calibration under electrons and protons beams that together the extensive Geant4 simulation have proven the concept and highlighted the challenges.
- A new CTP contract has just been kicked-off to design, manufacture and calibrate an EM, EQM and PFM of RADEM.
- The consortium is lead by Efacec (PT) with subcontractors RUAG (CH), PSI (CH), LIP (PT) and Gamma Medica Ideas (NO).
- The total budget of the Phase B2-C-D contract is 4 M €.
- The contract will include the design of an electron directionality detector and a new read-out ASIC (with heritage from NGRM) for the Si sensors.

Conclusions

- The JUICE mission will be launched in 2022 and will allow an unprecedented details to investigate the Jovian system and 3 of its major moons in search for signs of life and habitability.
- JUICE will fly in a very harsh radiation environment and the capability of monitoring this environment is of key importance.
- The Phase B1 of the RADEM development has just been kick-off and will address the challenges of flying on JUICE among which shielding and background rejection, high resolution radiation monitoring data acquisition with as low as possible resources.

Looking forward to the launch of JUICE …