The Ganymede Laser Altimeter (GALA) on ESA's JUICE mission: Overview of the instrument design.

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05. Nov. 2014, NASA GSFC

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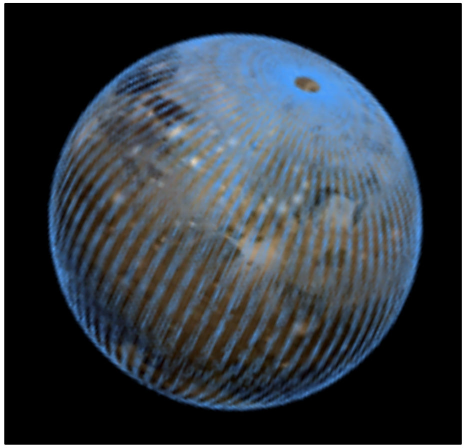
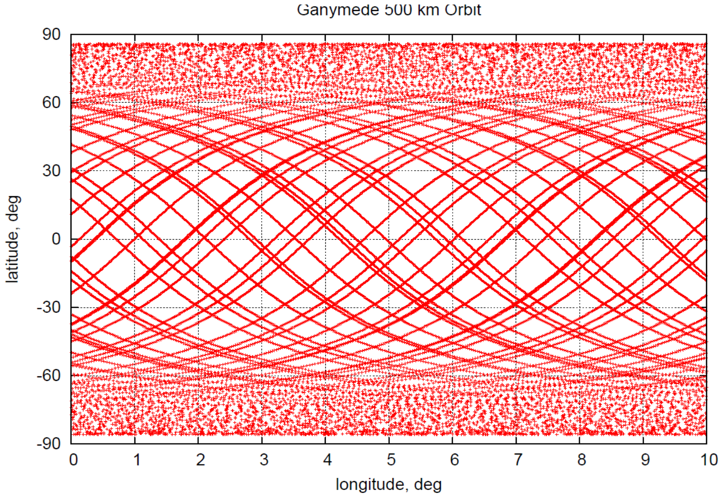
Ganymede: Global Shape and Topography

The 500-km altitude orbit allows for excellent global coverage of the entire satellite. Polar regions are well covered; resolution decreases for equatorial regions.





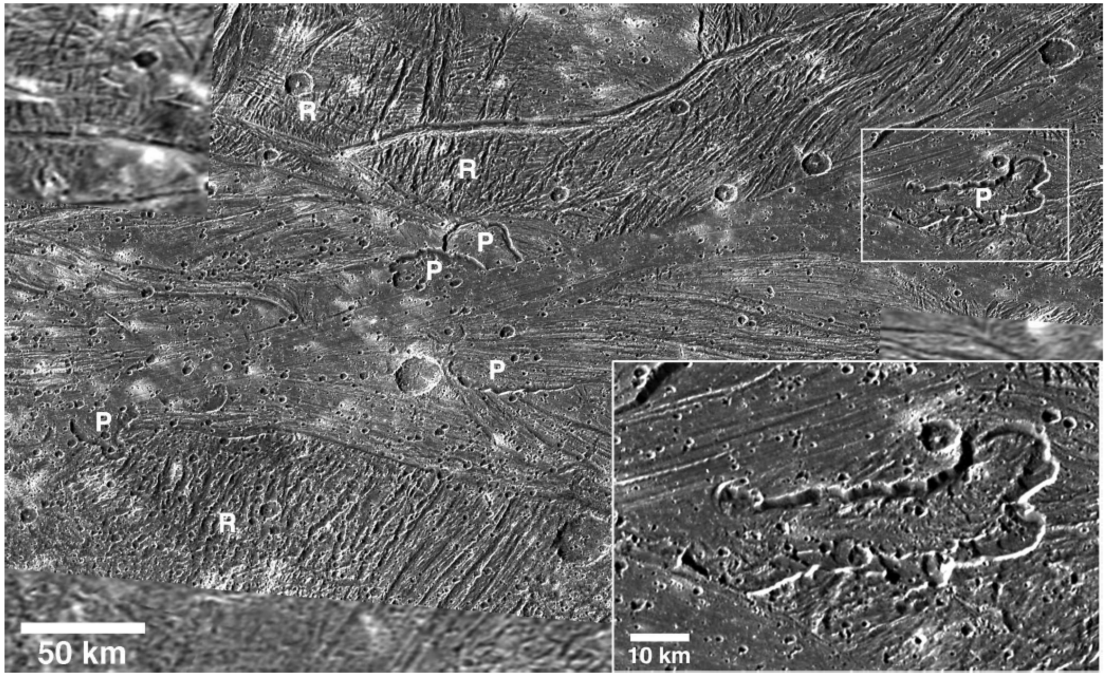
Ground-tracks from 0° to 10° longitude.
1° corresponds to 46 km at the equator.

Global topography up to degree and order 20 to 44 (depending on operation scenario).
Grid size between 2° (degree 44) and 4.3°(degree 20)

Providing a global topographic model by GALA is essential because of limited coverage with stereo imaging.

Ganymede: Regional and Local Topography

Pappalardo et al., 2004



Example:
Cryo-volcanism on Ganymede

The lack of topographic data and of the topographic relationships between different geologic units has prevented determining the relative roles of tectonic and volcanic resurfacing.

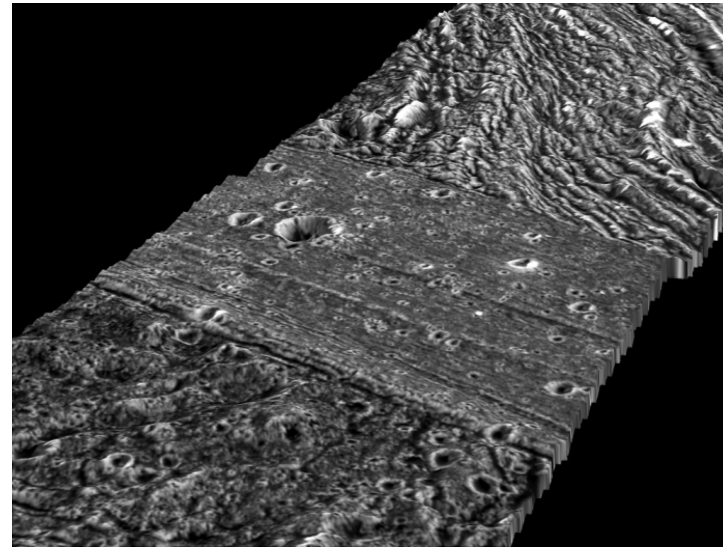
Topographic data is key in understanding the evolution of Ganymede (e.g. volcanically resurfaced areas on Ganymede have shown to be smooth and lower-lying w.r.t. to the surroundings in contrast to tectonically resurfaced areas).

Here GALA will essentially contribute to explore the evolution of this body.

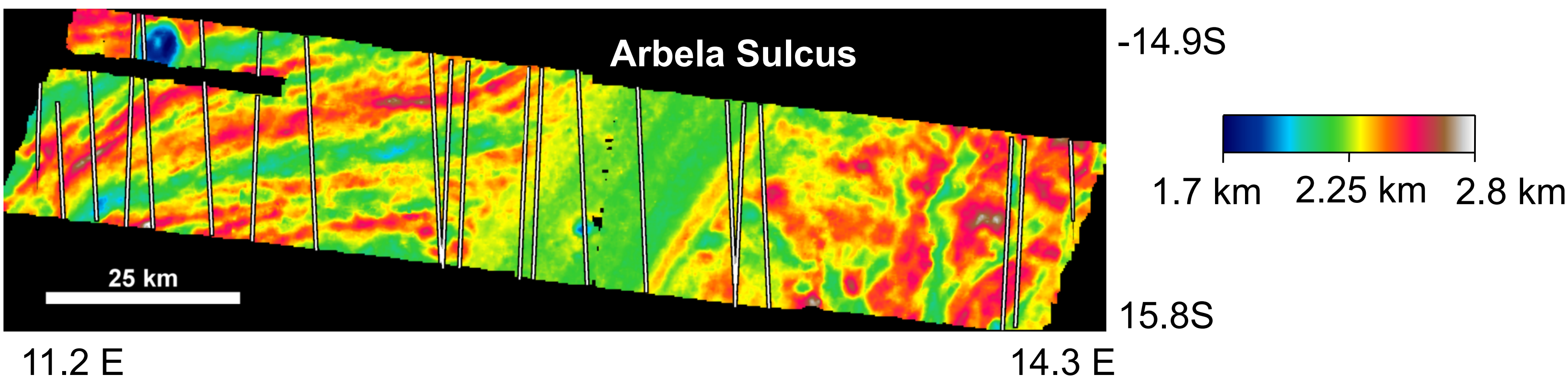
Ganymede: Regional and Local Topography

Characterize the different geologic units on Ganymede (and Europa) and study specific examples of their topography in terms of horizontal and vertical scale of the surface features

Example: Arbela Sulcus
(bright and dark-terrain boundary)
Tectonism on Ganymede



GALA coverage assuming continuous nadir operation

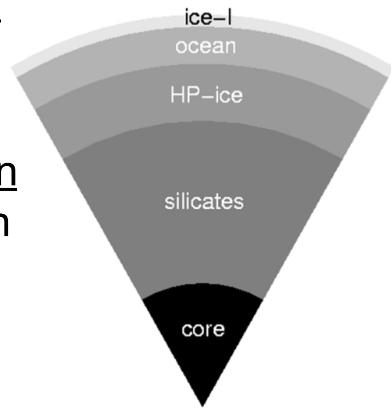


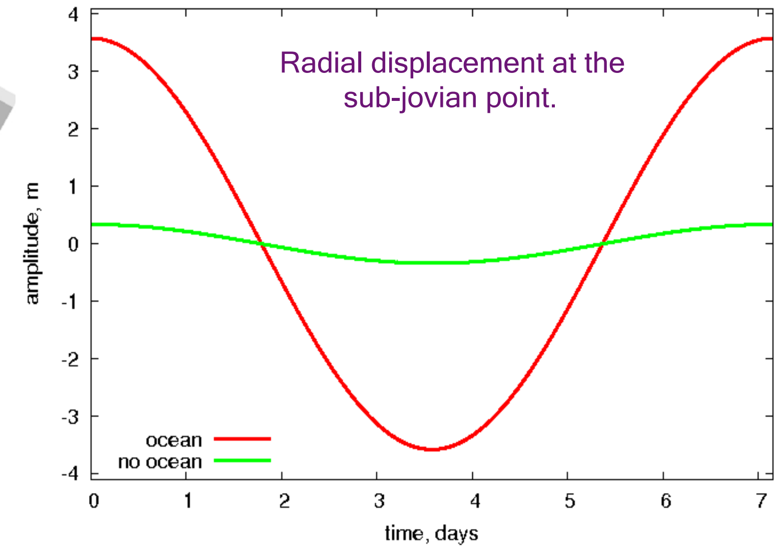
Ganymede: Tidal Deformation and Subsurface Ocean

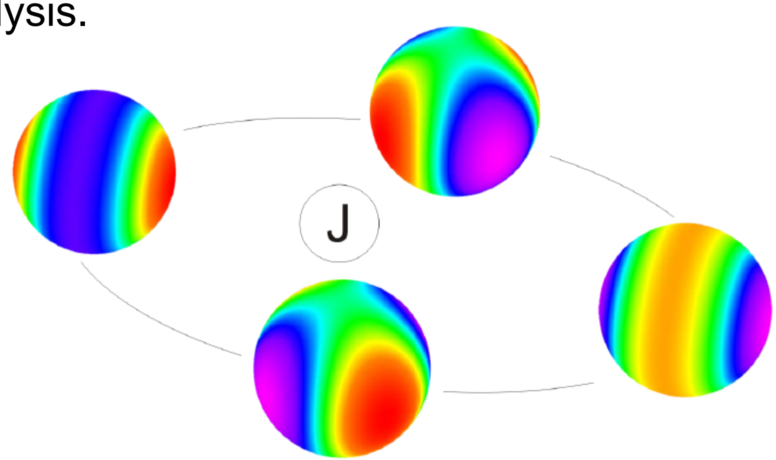
Does Ganymede have a subsurface ocean? What is its extension?

GALA will be able to detect an ocean and to constrain the ice thickness on the order of tens of km.

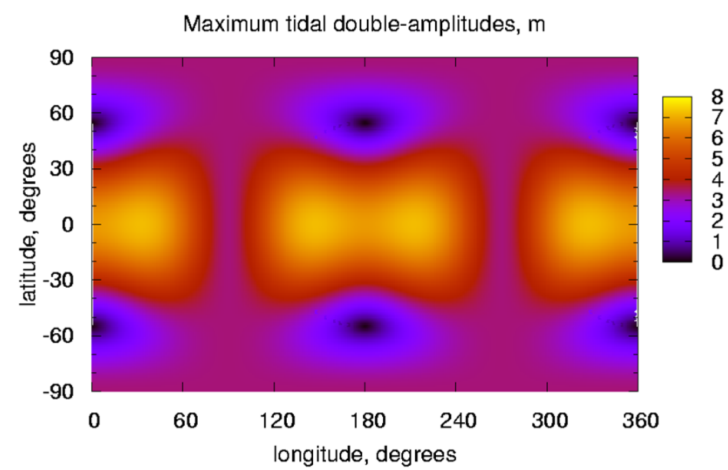
Improvement of ice thickness determination by combining h_2 and k_2 analysis.







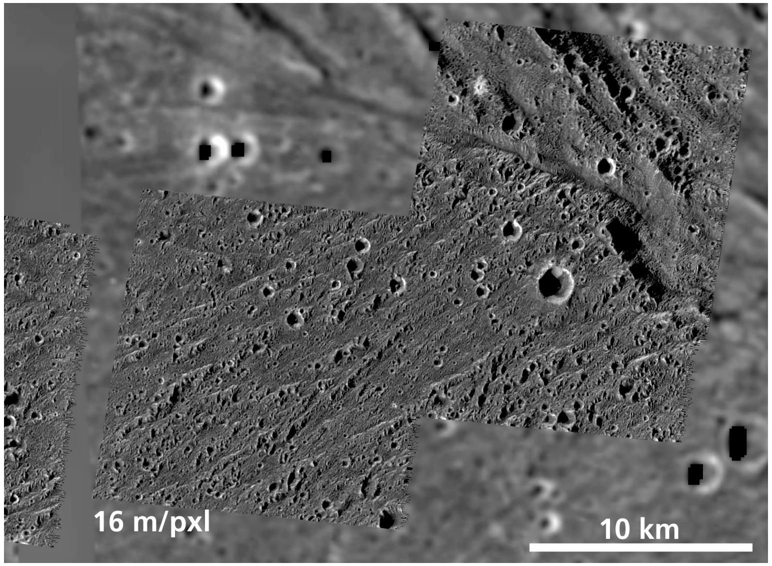
Periodic variation of the tidal potential during one tidal cycle (one orbit of 7.15 days around Jupiter).



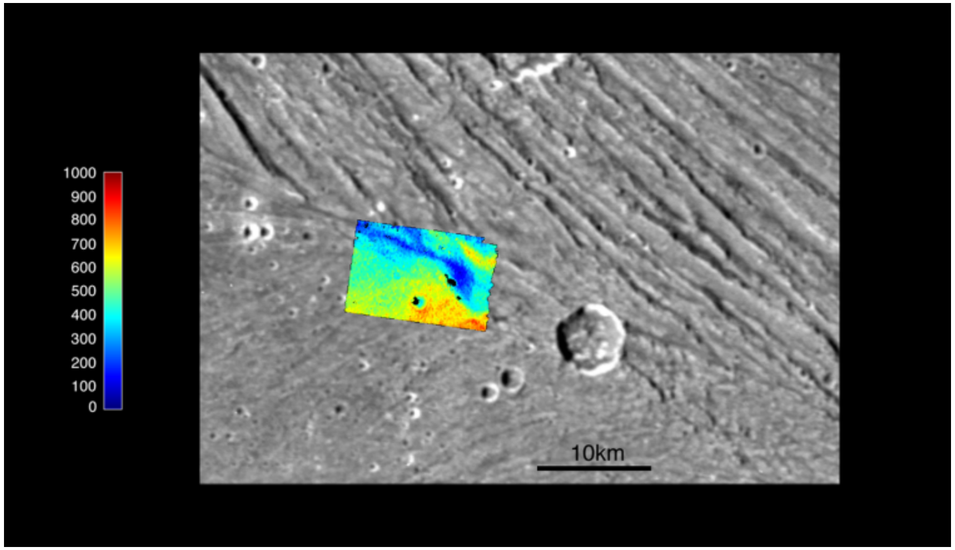
Surface Roughness and Local Slopes

Ganymede‘s surface is very rough. Regional and local differences and their relation to geologic features and surface age are widely unknown.

GALA will determine the surface roughness on a few 10s of meters scale.
This is also essential data for selection of possible future landing sites.



Ganymede‘s rough surface



Example for smooth terrain on Ganymede

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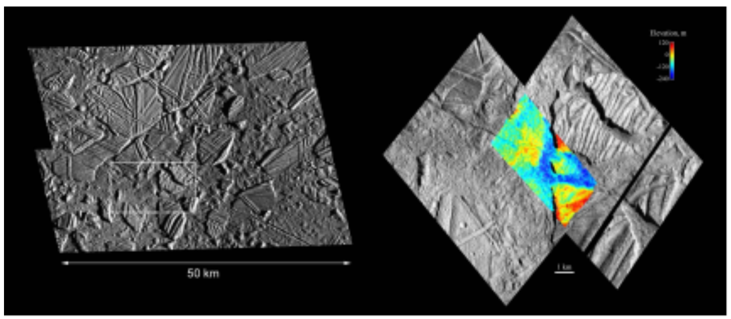
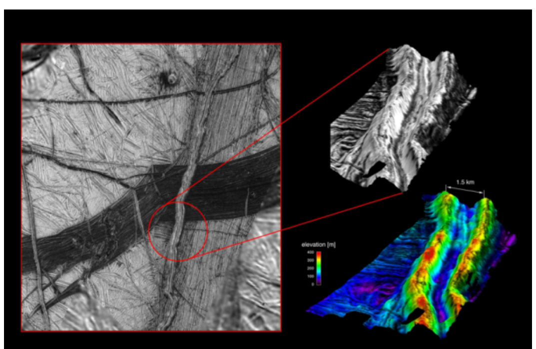
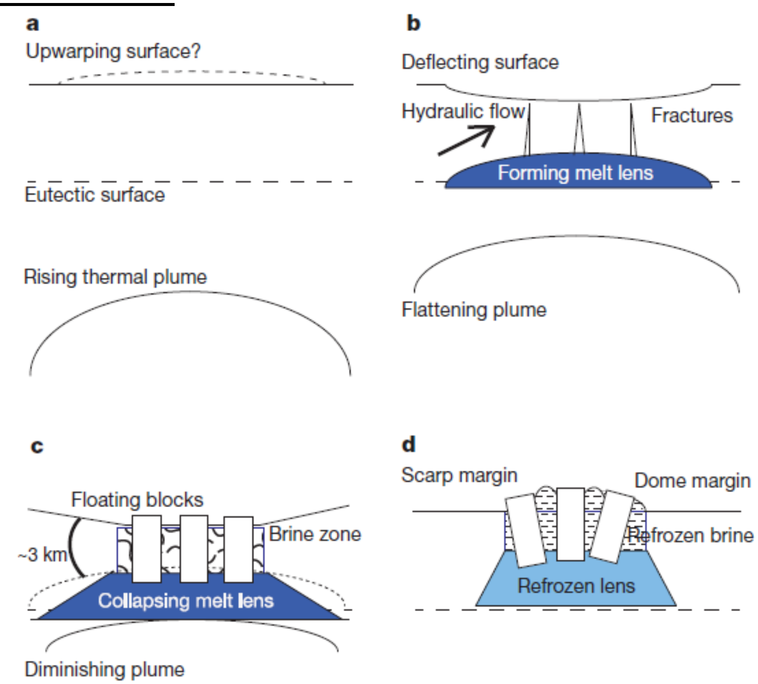
Europa flybys

- Search for regional topographic depressions, in particular for chaos terrain and regions which might contain liquid water in the shallow subsurface
- Obtain height profiles along possibly active regions
- Determine slopes and tilts of ice blocks in chaos terrain
- Obtain profiles of double-ridges and triple-bands



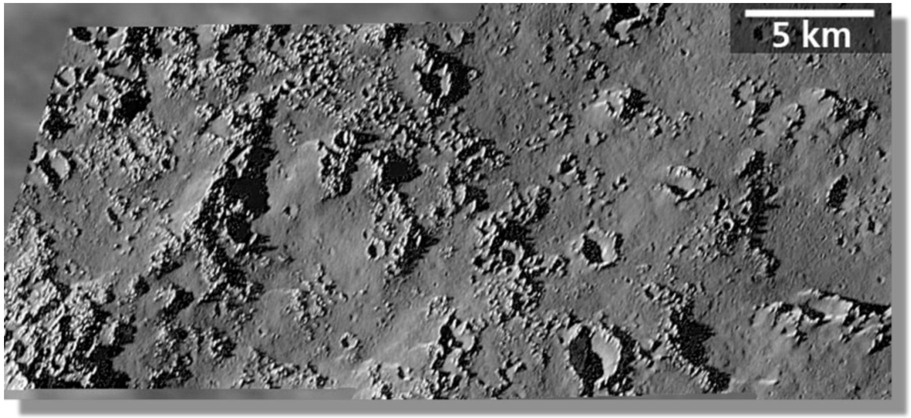


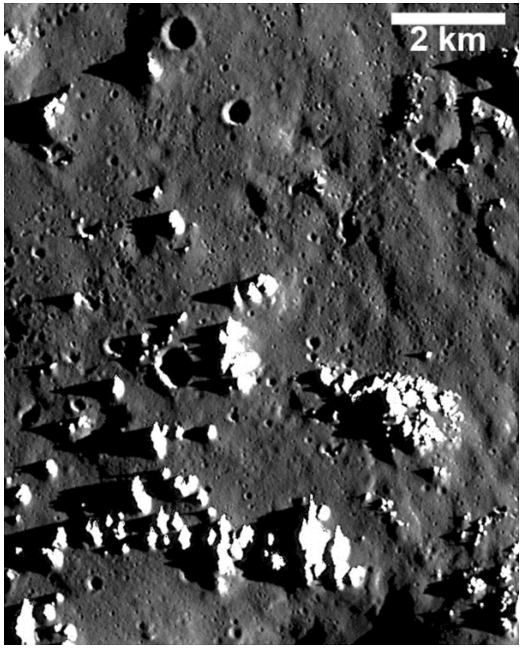


Liquid reservoirs and the formation of chaos terrain (Schmidt et al., 2011)

Callisto flybys

- Determine global shape parameters
- Search for regional topographic depressions, in particular for ring basins and large craters
- Obtain height profiles along different terrains (mainly different types of craters)
- Correlate surface roughness with degradation and erosion of craters
- Correlation between albedo and elevation





GALA coverage

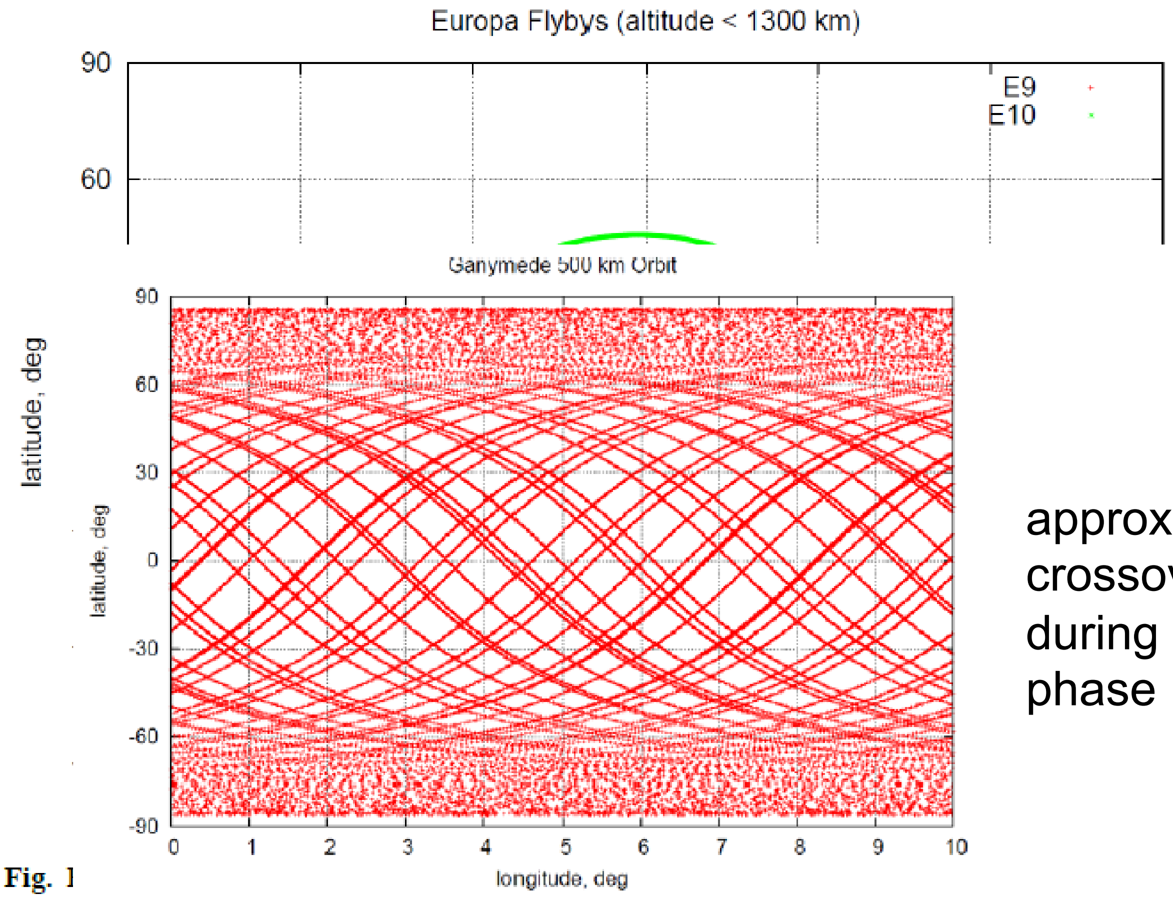


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Fig. B-8: Ground-tracks of the entire 500-km altitude phase from 0° to 10° longitude. 1° corresponds to 46, 40, and 23 km on the surface of Ganymede at latitudes 0° (equator), ±30°, and ±60°, respectively.

approx. 1 million crossover points during GCO-500 phase

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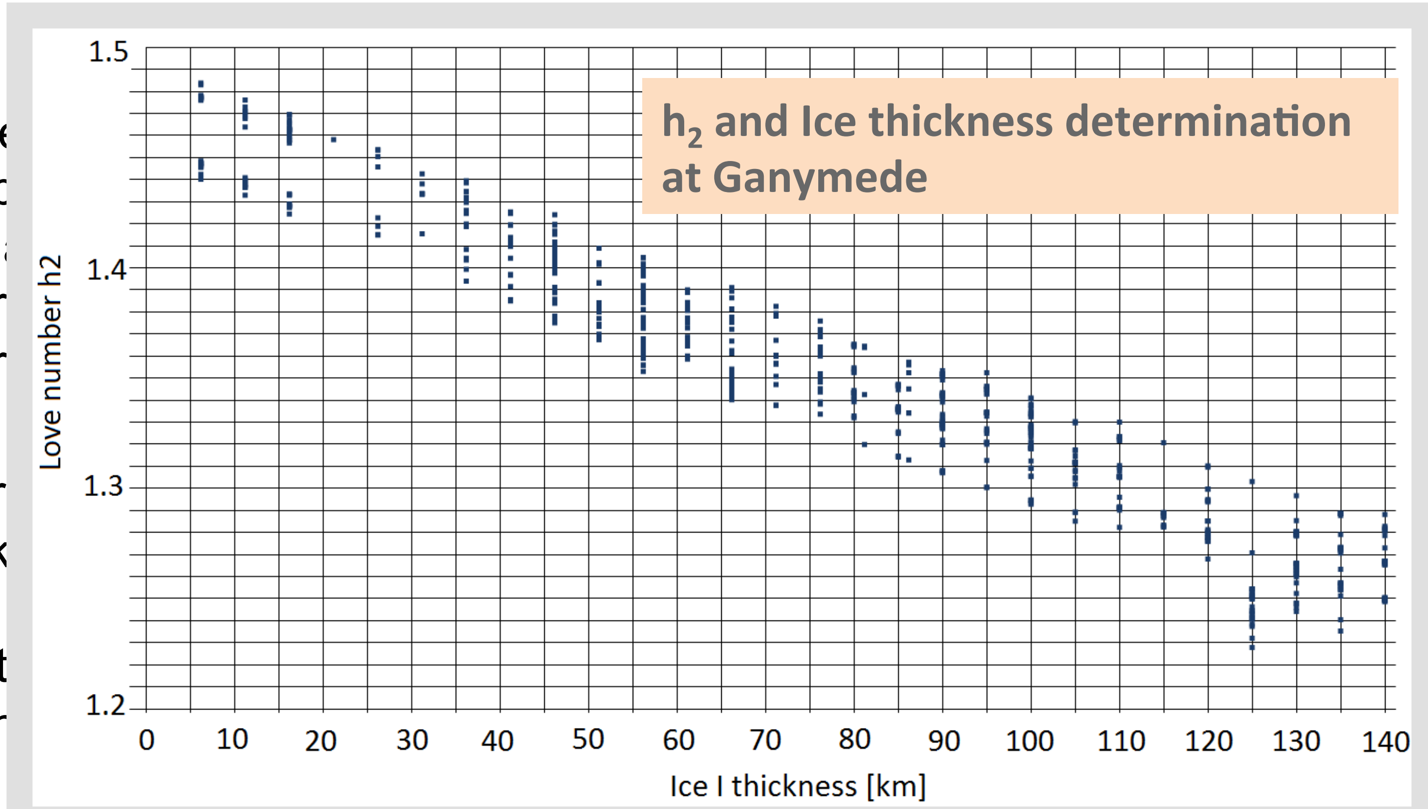
JUICE Mission timeline & GALA activity

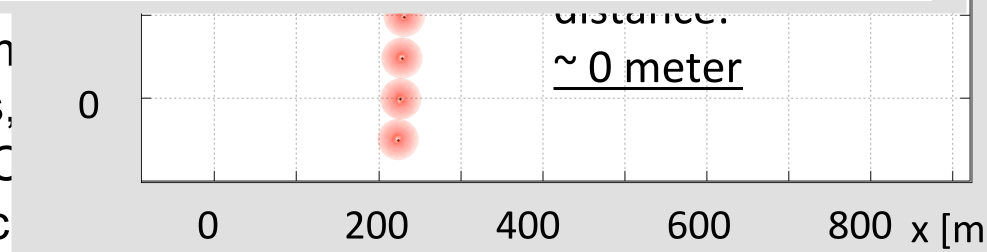
Launch	June 2022	
Interplanetary transfer (EVEE)	7.6 years	Ranging from & to Earth during cruise
Jupiter orbit insertion	Jan. 2030	
Jupiter equatorial phase #1	11 months	
2 Europa flybys	36 days	GALA can operate at altitudes < 1600 km*
Jupiter high-latitude phase incl. Calisto flyby's	6 months	GALA can operate at altitudes < 1100 km*
Jupiter equatorial phase #2	11 months	
Ganymede phases:		
Elliptic #1	30 days	GALA can operate at altitudes < 1400 km*
High altitude (5000 km)	90 days	
Elliptic #2	30 days	
Circular GCO-500 (500 km)	130 days	

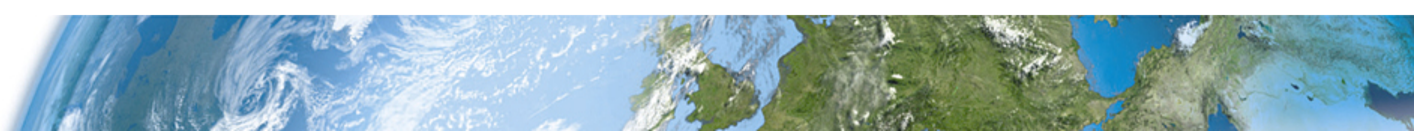
* under optimal conditions (0° slope, high albedo) and for high SNR

Instrument Key Parameters for Science Return

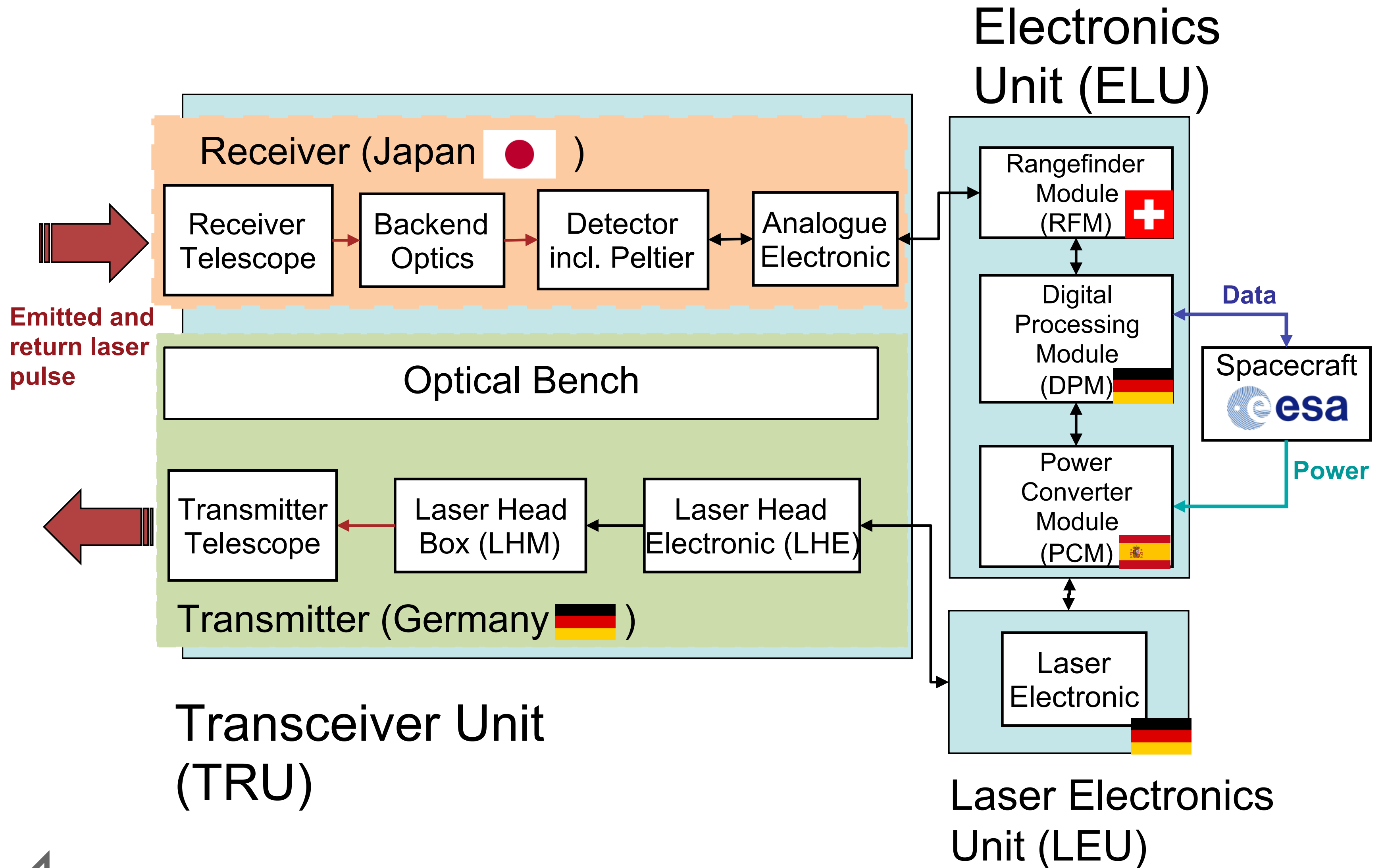
- Pulse Repe
  - for sub
  - Small
    → incr
    → incr
- Pulse ener
  - for link
  - 17 mJ
  - Detect
    → h
- High accuracy of range measuren
  - for determinig tidal variations,
  - 200 MHz APD, 200 MHz ADC
  - 8 cm optimal conditions, 15 c



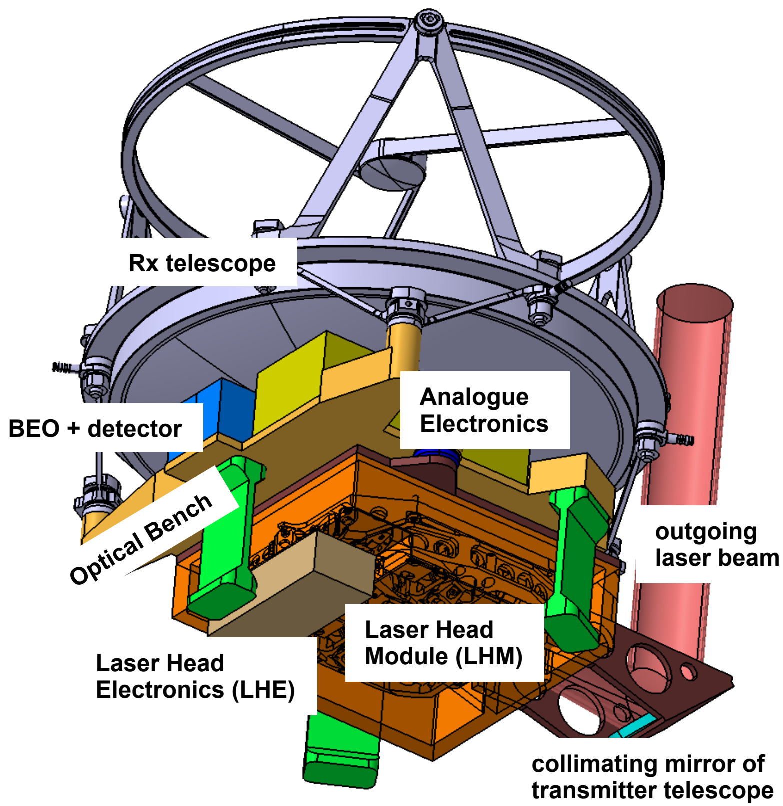


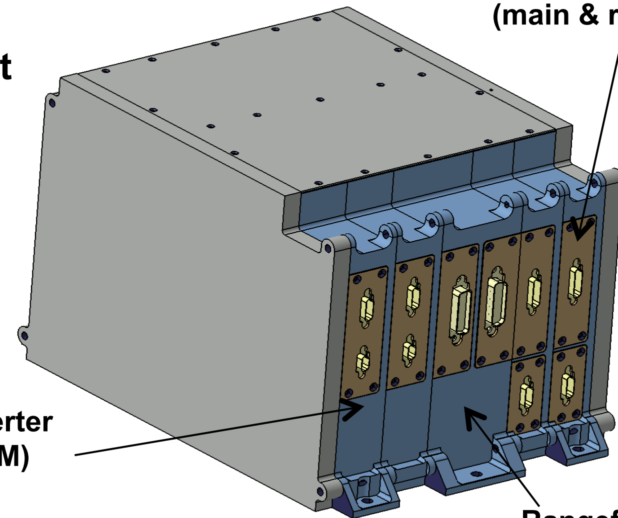


Block Diagram of the GALA Instrument



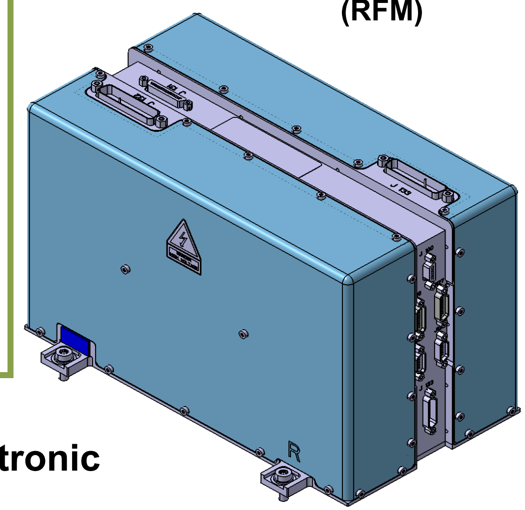
Instrument Overview and description





TRU:
compact, self-shielding design

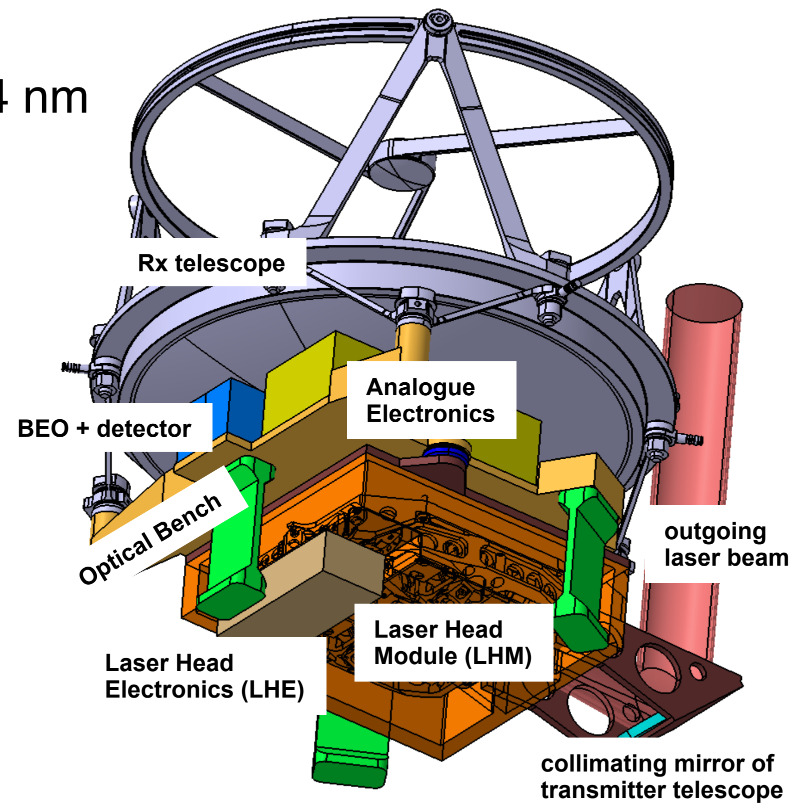
ELU and LEU:
Placed in shielded S/C vault



Instrument Performance

- Transmitter
  - Transversal pumped Nd:YAG laser at 1064 nm
  - Two cold-redundant laser resonators with 17 mJ at 30 Hz nominal, active Q-switch
  - Pulse width: 5.5 ns; Divergency: 100 µrad
- Receiver
  - Cassegrain telescope, 30 cm diameter
  - Backend-Optics, Bandpass filter, SiAPD
  - Analogue pre-amplifier w/ digitizer
  - Digital rangefinder for ToF measurement, waveform analysis etc.
  - Several data modes
- Electronics with digital processing module and power converter
- Resources: 52 W Power, 15 kg

Transceiver Unit (TRU)



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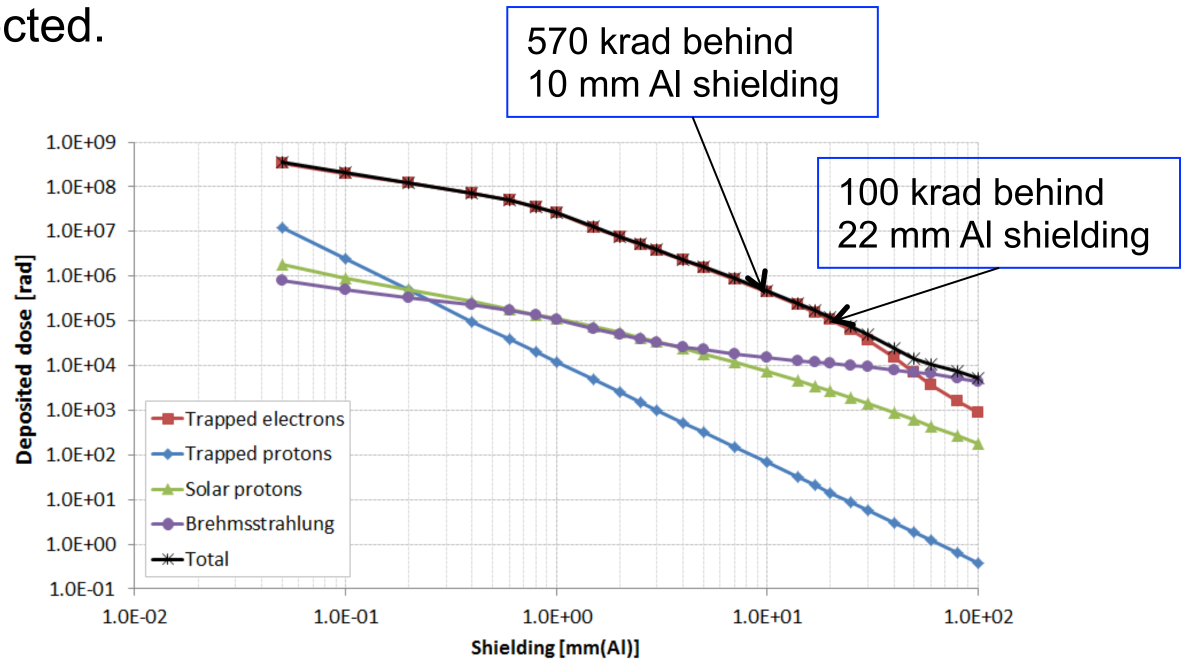
Radiation environment is challenging

- JUICE is a „radiation mission“: instrument design is constrained by radiation aspects
- In contrast to other missions, radiation is dominated by electrons. New techniques for analysis and shielding design are needed.
- Selection of EEE parts, detector and optics is affected.

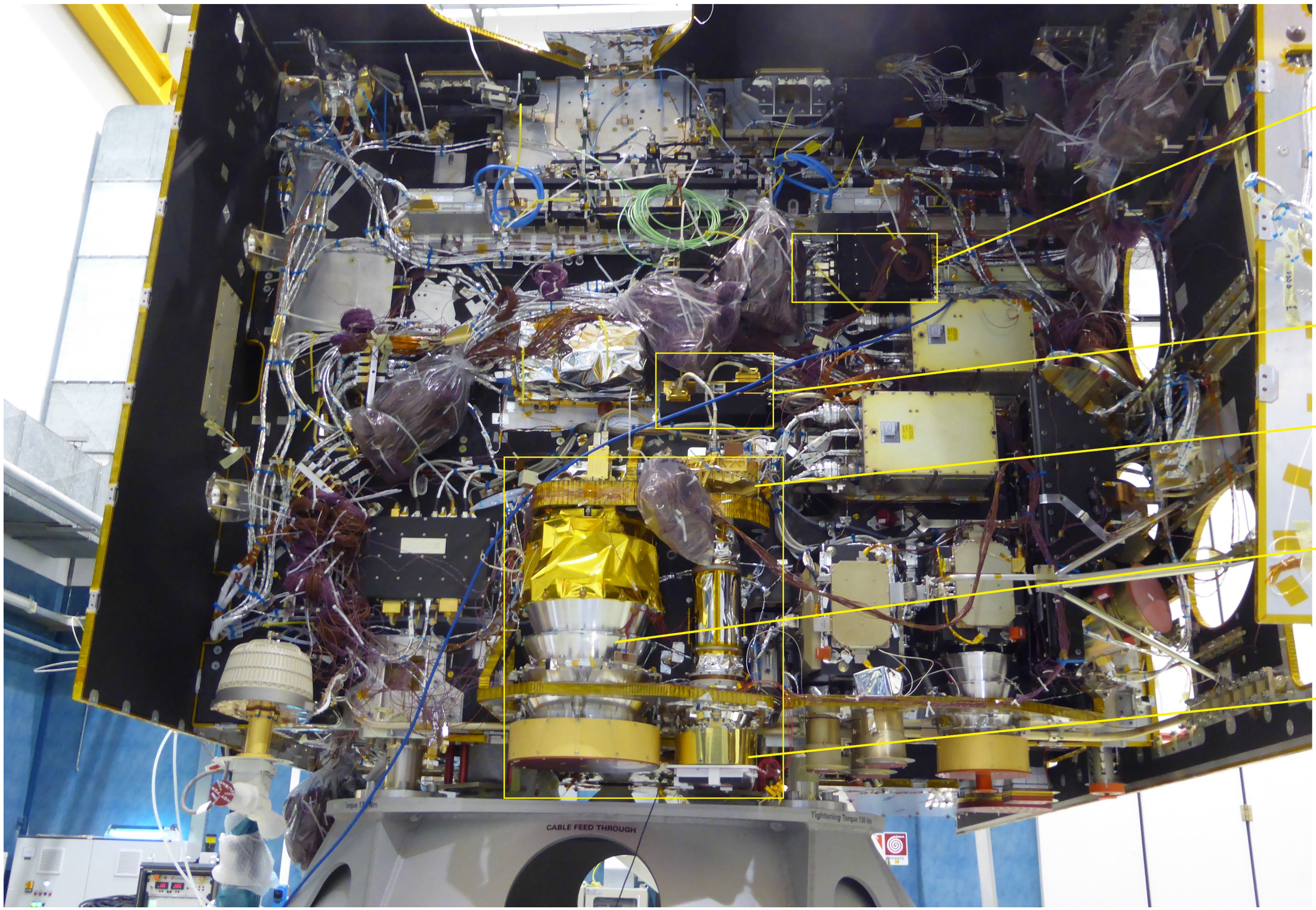
- Distance from the Sun → low energy budget

- Distance from the Earth → low data budget



TID depth dose for the entire JUICE mission incl. Factor of Safety of 2

GALA Heritage: BELA onboard BepiColombo



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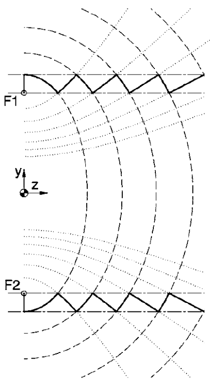

Fig. 5 Hyperbolas (dotted) and ellip
the two focal points F1 and F2, locat
(left side). The baffle contour (thick l
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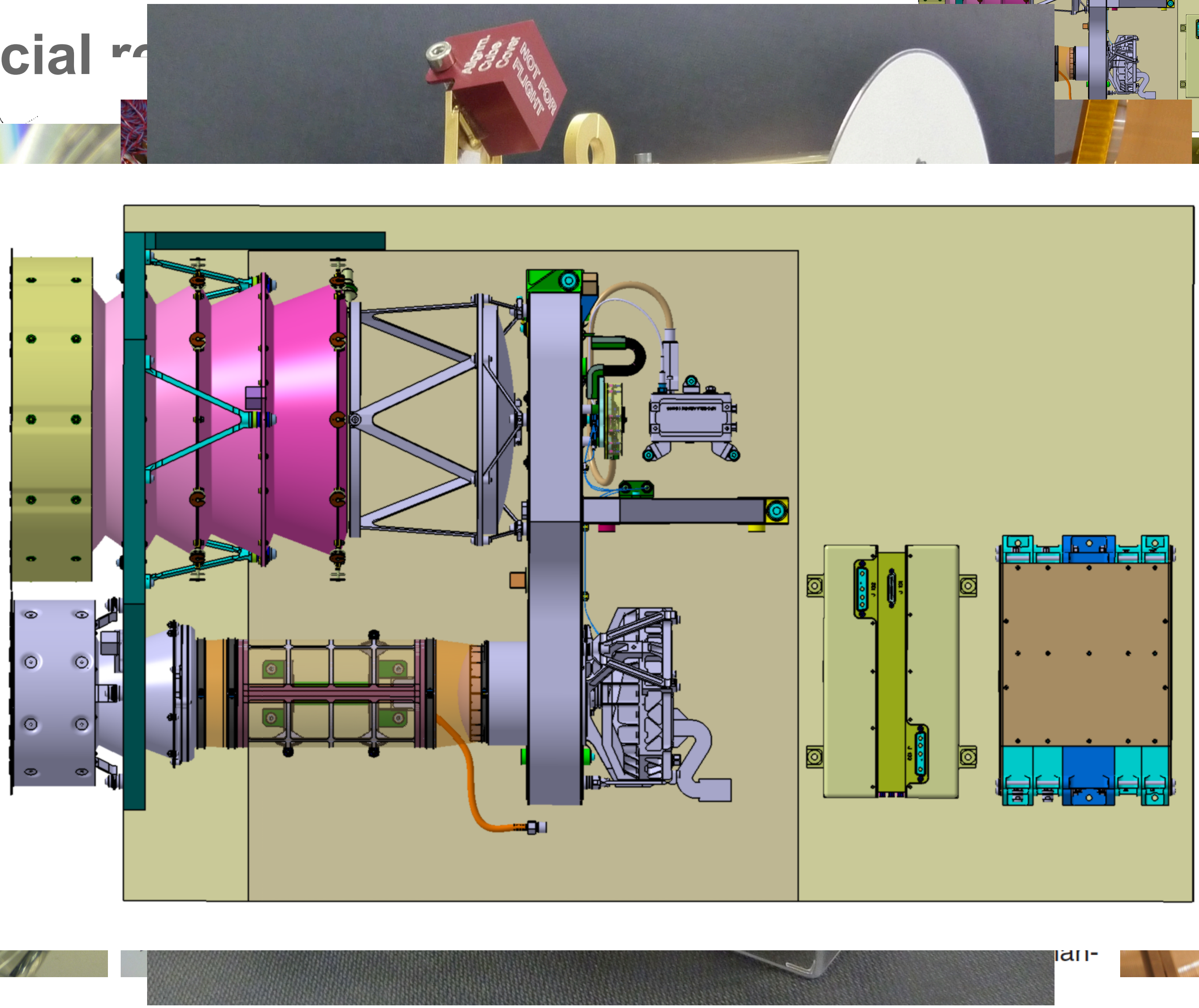
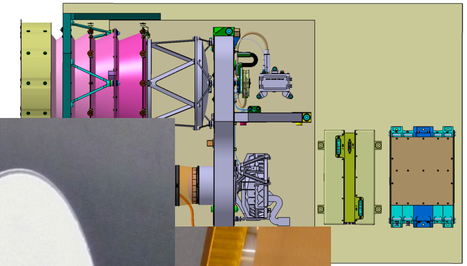
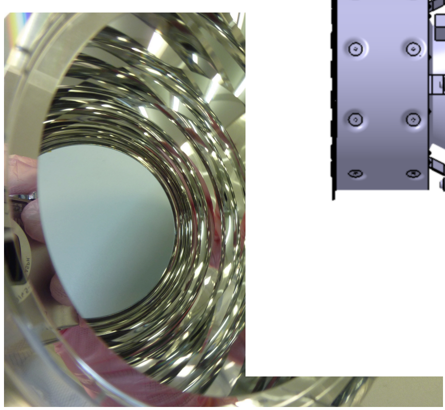
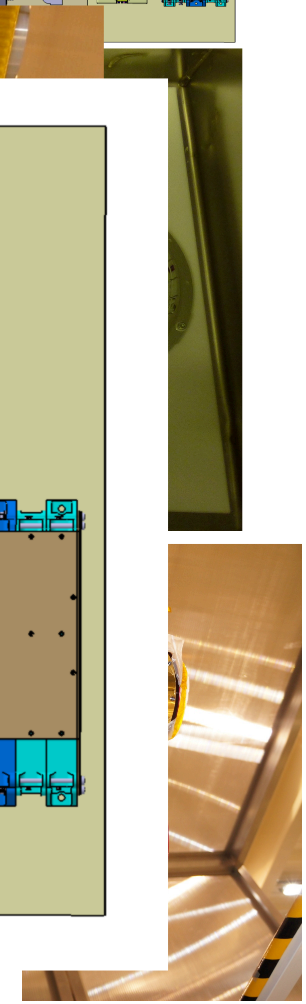
nel (parallel dashed-dotted lines).



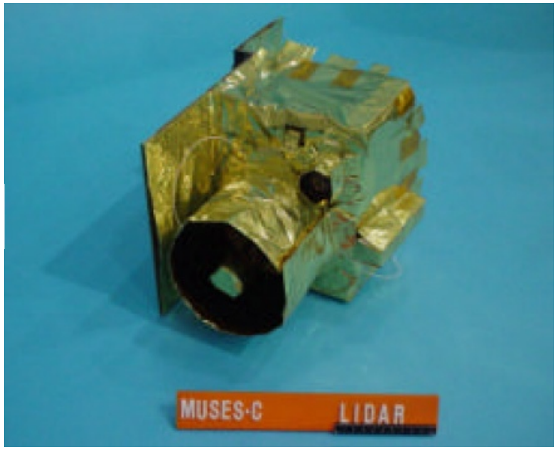




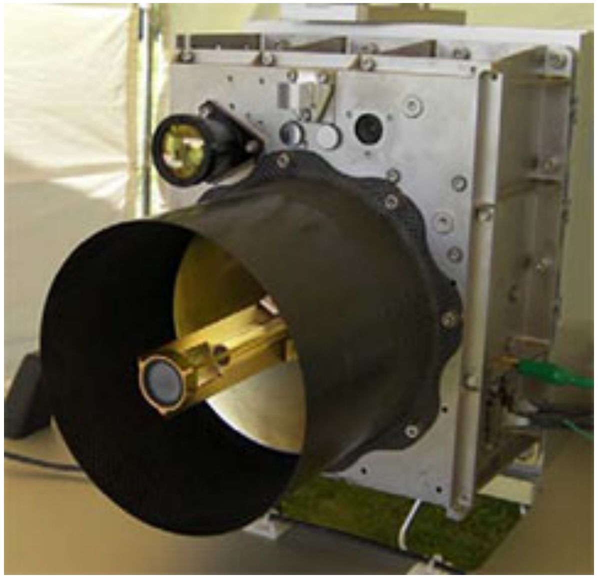


GALA Heritage: Japanese Laser Altimeters

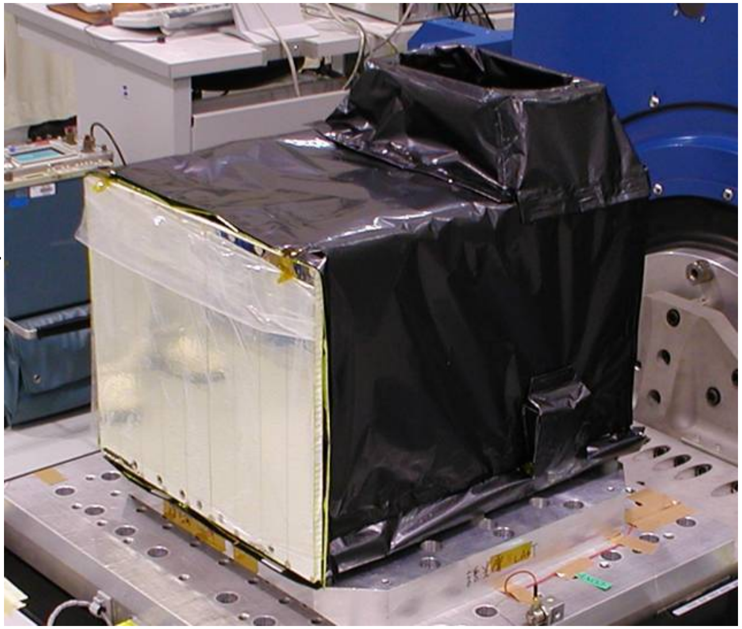
- Hayabusa Lidar
  2003 – 2010, NEA mission
- Kaguya Laser Altimeter
  2007 – 2009, Lunar mission
- Hayabusa2 Lidar
  Launch 2015, NEA mission



Hayabusa LIDAR



Hayabusa2 LIDAR



Kaguya LALT

Summary

- GALA uses the classical laser altimeter design (ToF measurement of sub-sequent pulses)
- Obtain Ganymede’s global shape and topography on different scales, surface roughness, local slopes. Global coverage of Ganymede’s surface
- Measure Ganymede's tidal deformation and determine h_2 up to an accuracy of better than 1%.
  → quantify the thickness of ice shell and depth of the ocean beneath with an accuracy of approx. 10 km.
- Flyby’s at Europa and Callisto
- Interplanetary laser-ranging

- Next steps
  - PDR in Mid 2016, CDR in Oct. 2017
  - Flight Model Delivery in Mid 2019
  - Launch in June 2022