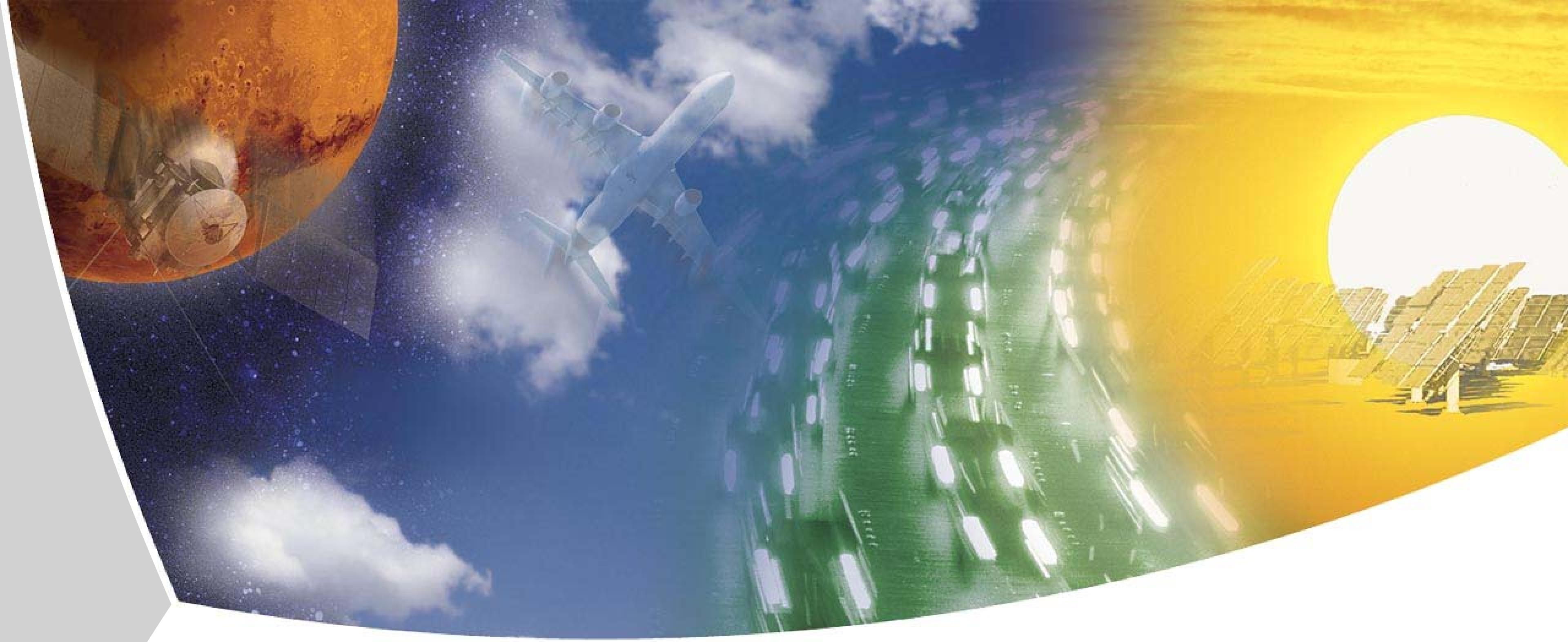

A Laser Altimeter Study for the Europa-Jupiter System Mission (EJSM)

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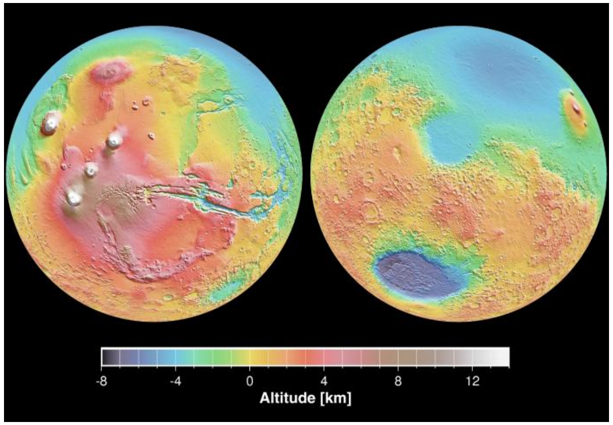
Laser Altimetry

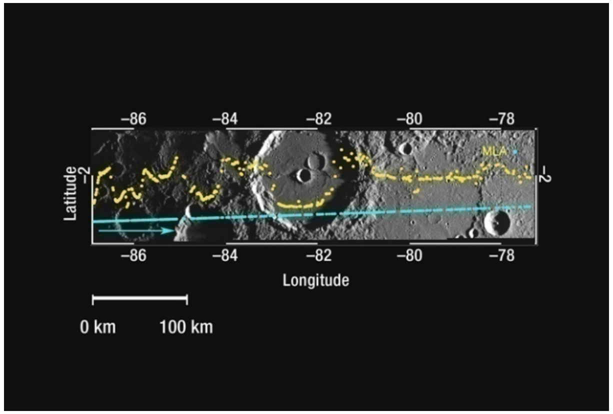
Geodesy:
- Radius, shape and rotational state of the Galilean Moons
- Reference Systems
- Tracking from Earth by Laser ranging

Geology:
- Regional and local height profiles for geomorphologic characterization of surfaces
- targeted profiles of sites of interest

Geophysics:
- Tidal deformation (evidence for oceans in Europa, Ganymede and Callisto)
- Global and regional topography for interpretation of gravity signal
- Improvement of gravity solution by cross-over point analysis
- Surface characteristics (local slopes, roughness, albedo)

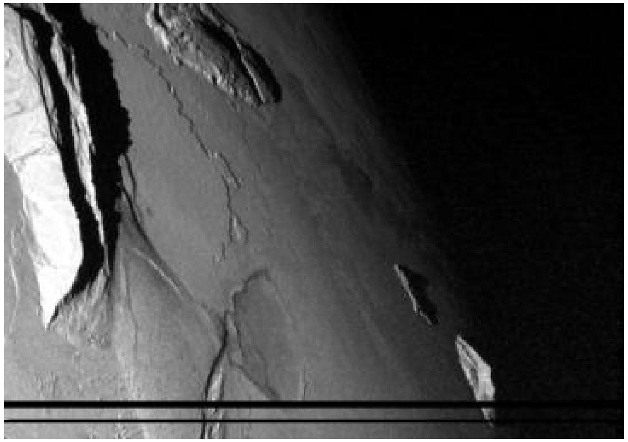


Topography of Mars (MOLA)

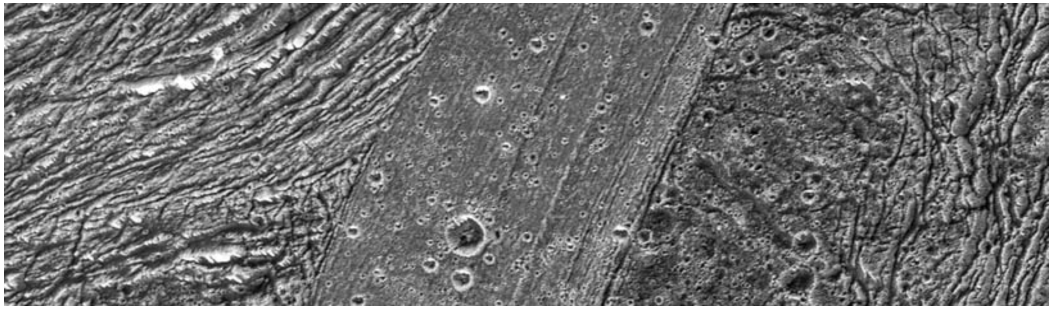


Mercury (MLA Data): Laser ground-track and height-profile. Note the crater in the middle and the 'flooded' crater of same size right beside it.

Geology in the Jovian System: very diverse targets

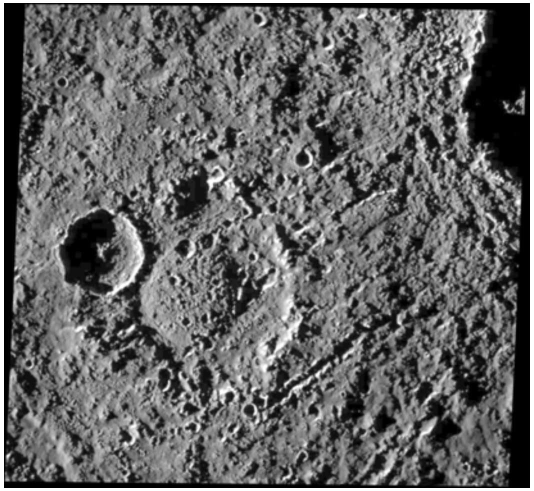


Mountains on Io



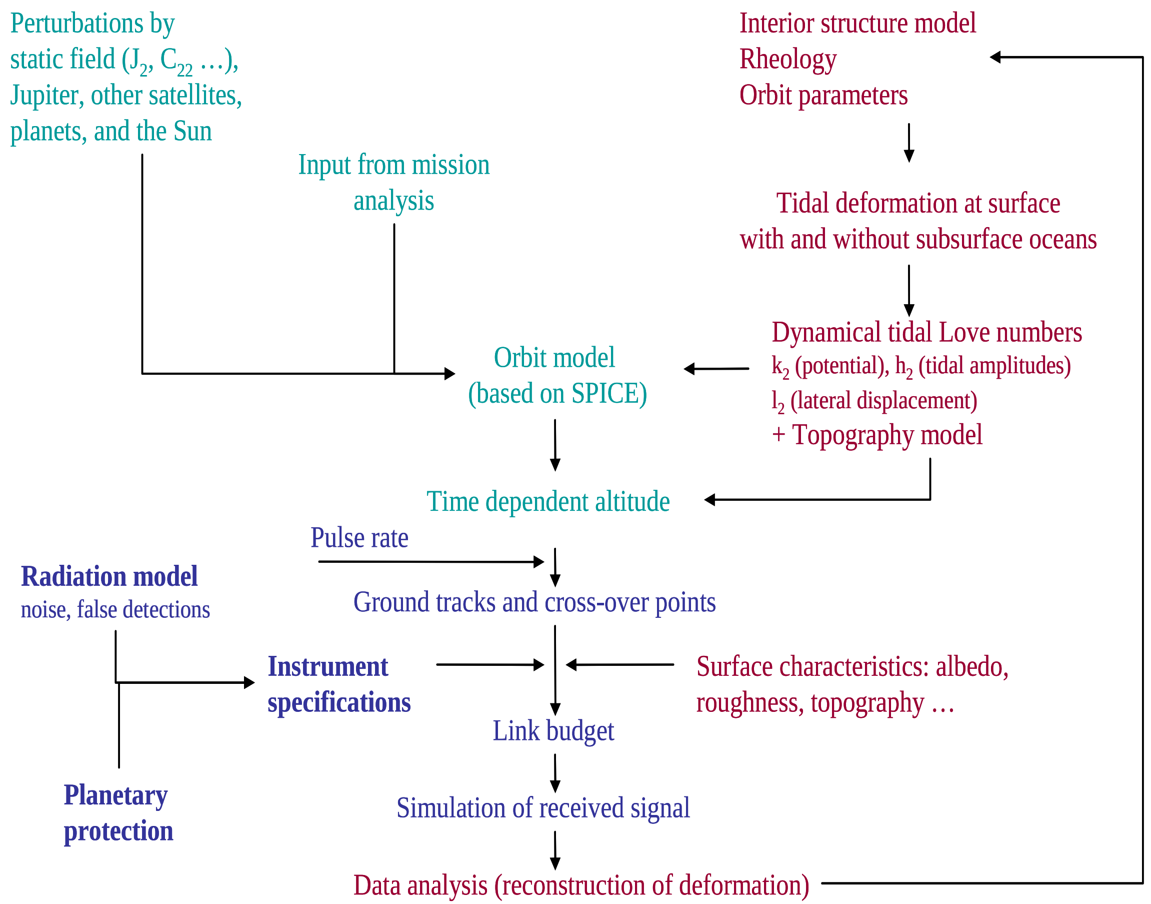
Grooves on Ganymede

Ridges on Europa



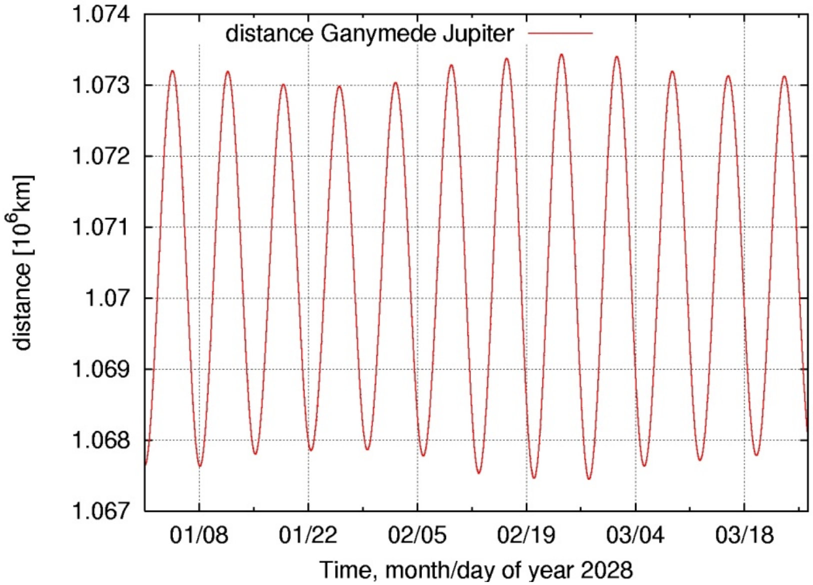
Craters on Callisto

Study Approach (Example: Tidal Deformation)

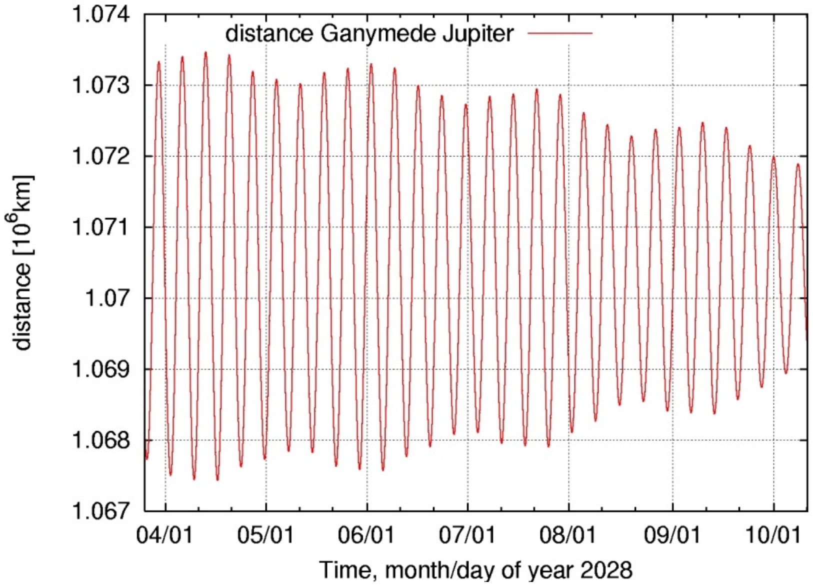


Tides in the Jovian System

Periodic variations of Ganymede's distance to Jupiter because of its elliptical orbit (shown here in the time-frame of EJSM for 2028).

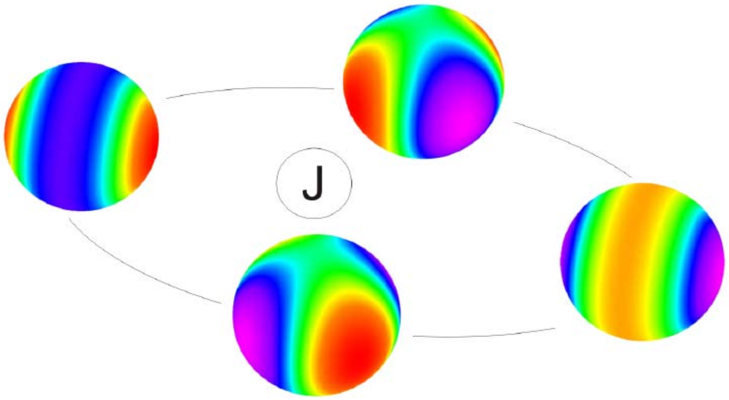


During elliptical phase (80 days)

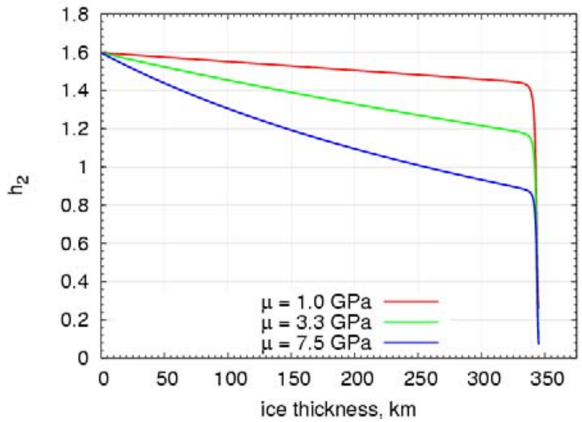


During circular phase (200 days)

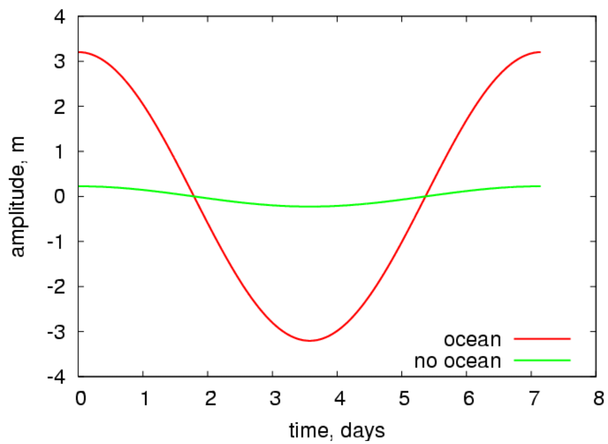
Tidal Deformation of Ganymede



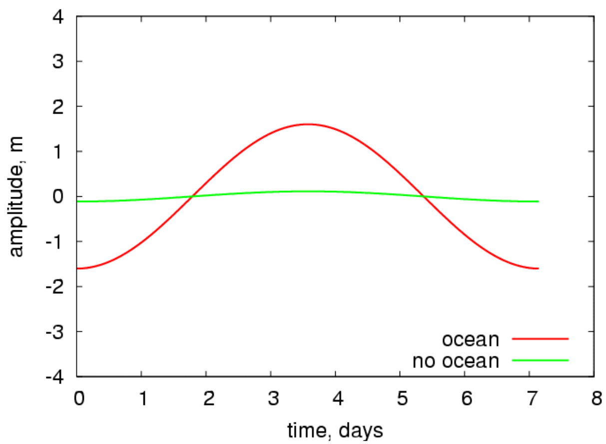
Tidal potential along an elliptical orbit



Elastic Love number h2 of Ganymede for different ice rigidities.

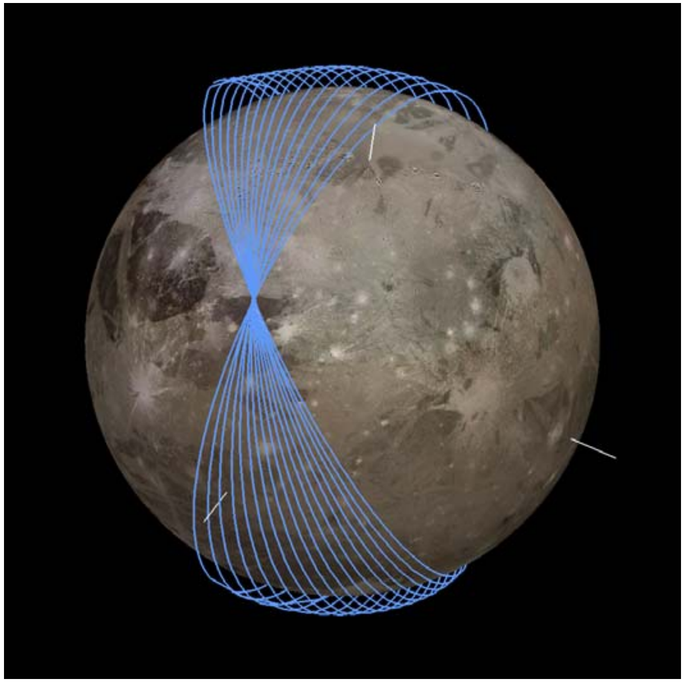


Tidal amplitudes for Ganymede at sub-jovian point

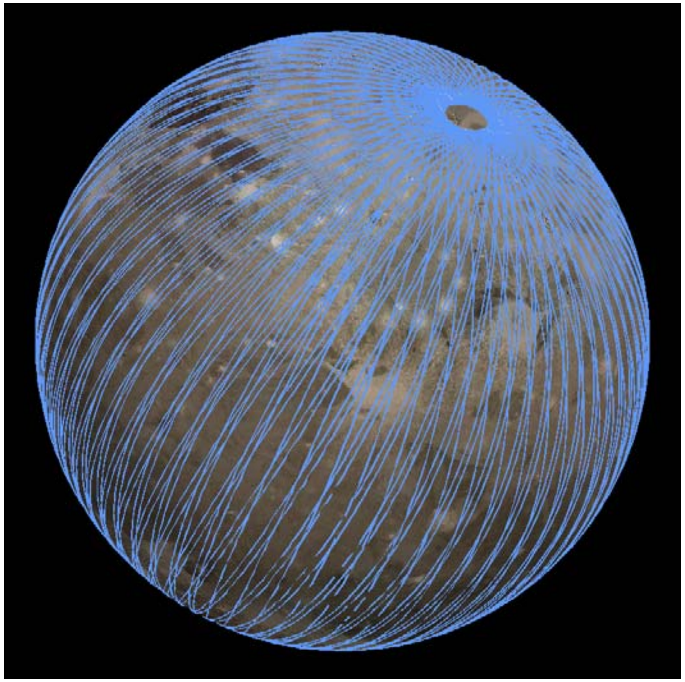


Tidal amplitudes at Ganymede's pole.

Orbit Coverage



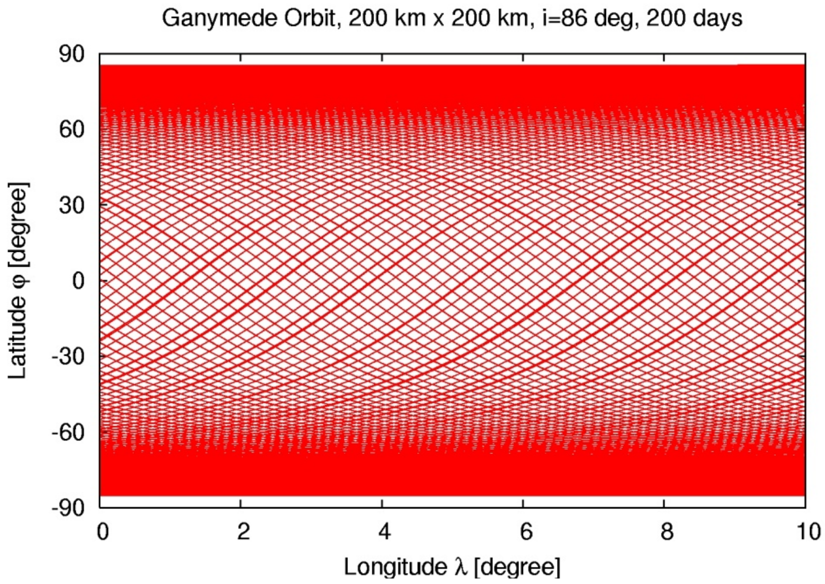
Shift of orbit mainly due to J2 of Ganymede

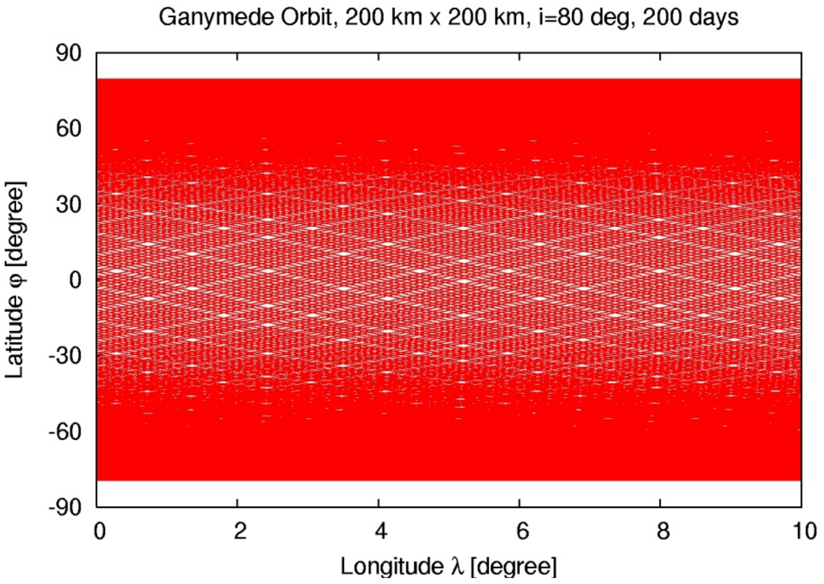


Laser Tracks on Ganymede after 12 days in 200 km circular orbit, inclination 86°

Orbit Coverage (circular phase)

Influence of inclination



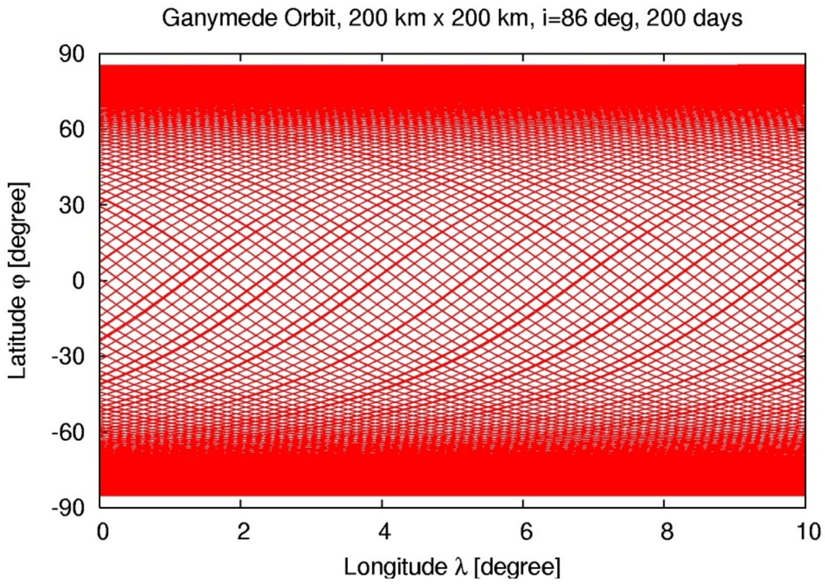


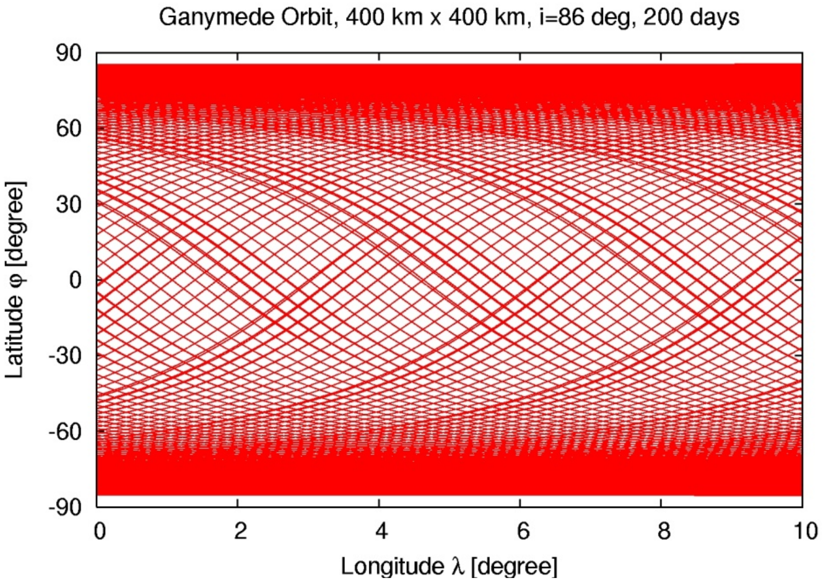
Inclination 86°, altitude 200 km

Inclination 80°, altitude 200 km

Orbit Coverage (circular phase)

Influence of altitude

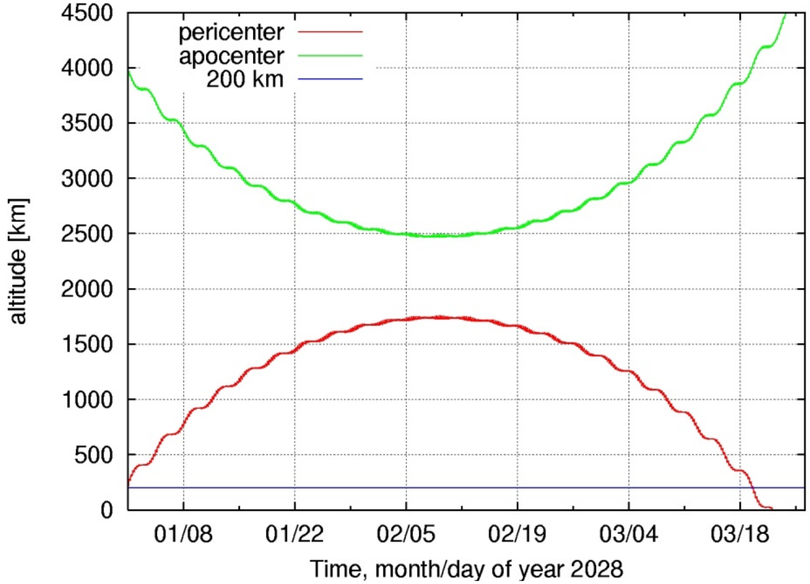


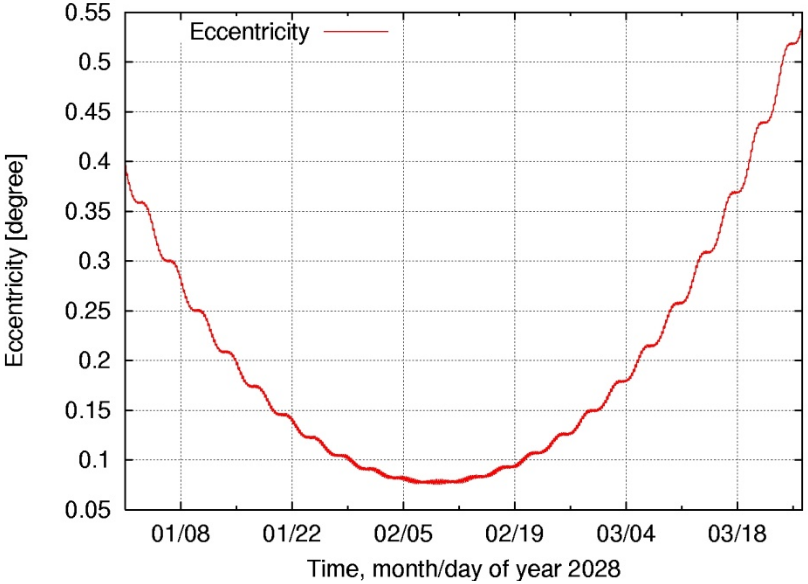


Inclination 86°, altitude 200 km

Inclination 86°, altitude 400 km

Orbital Evolution (elliptical phase)



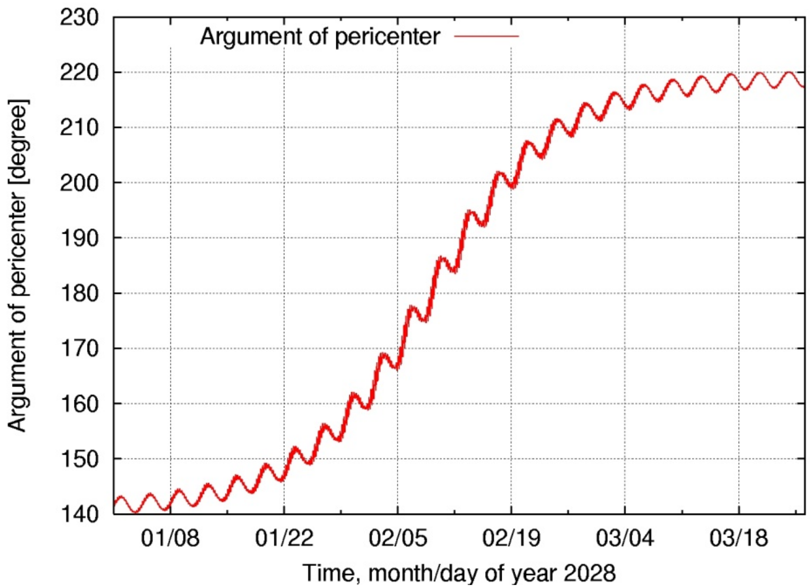


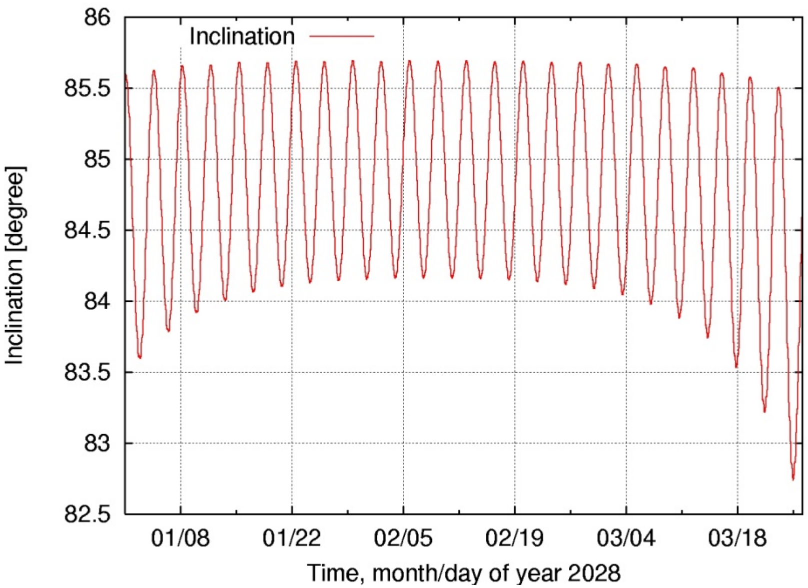
Altitude of pericenter and apocenter during elliptical phase.

Eccentricity

Perturbations mainly by J2 of Ganymede and Jupiter

Orbit Coverage (elliptical phase)



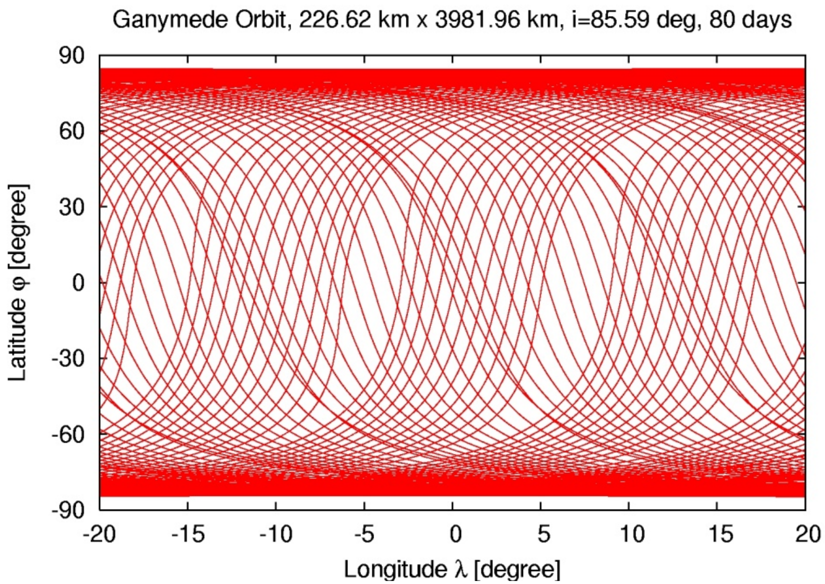


Argument of pericenter.

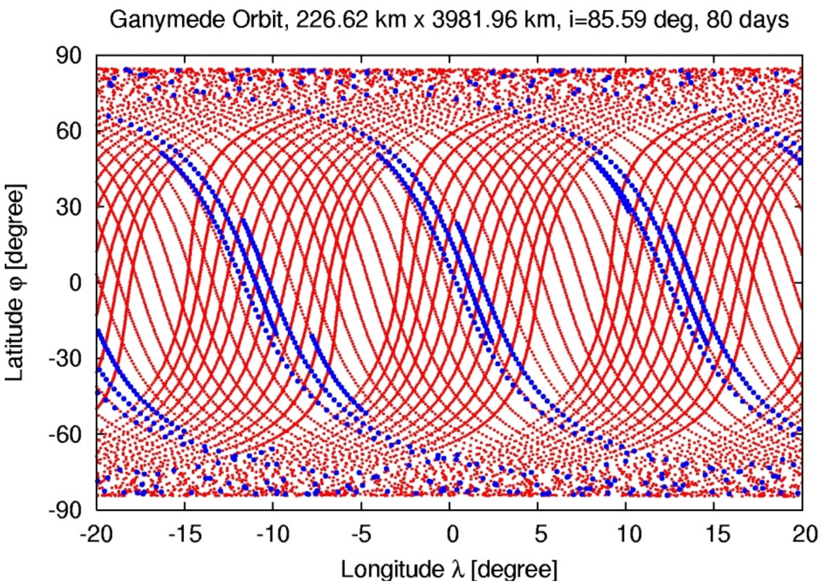
Inclination.

Perturbations mainly by J2 of Ganymede and Jupiter

Orbit Coverage (elliptical phase)

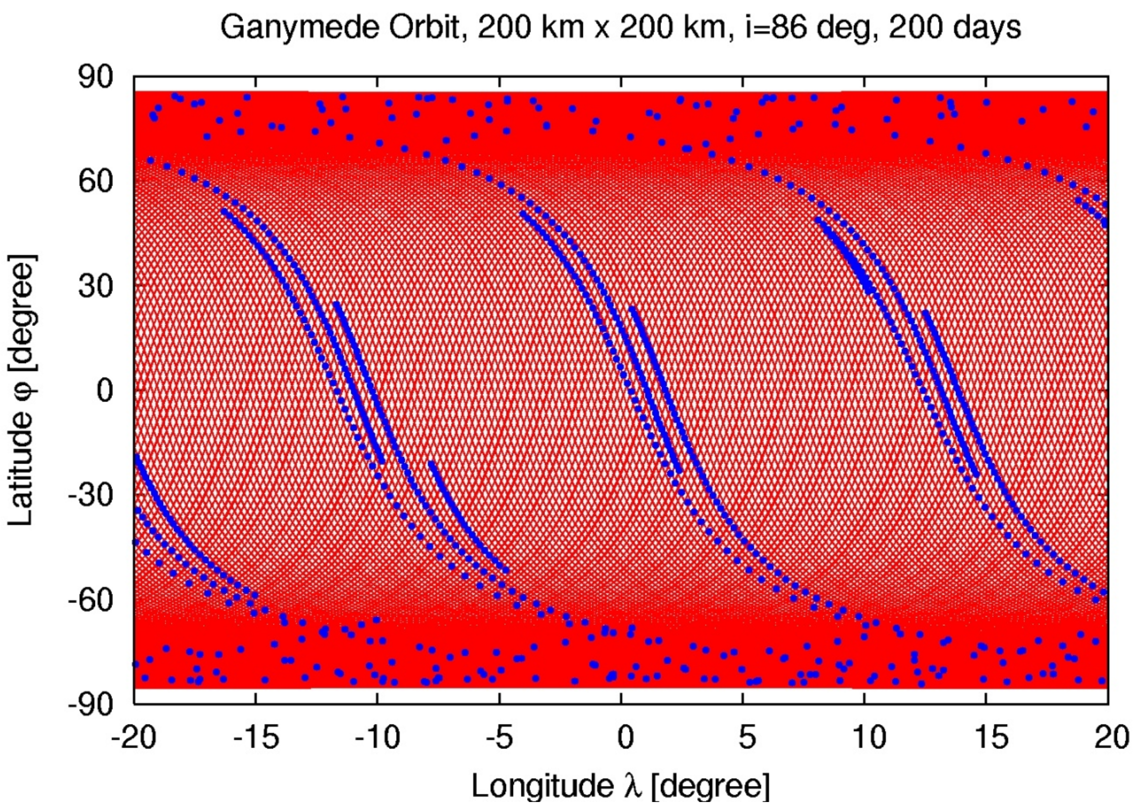


Elliptical Phase



In blue: JGO closer than 1000 km

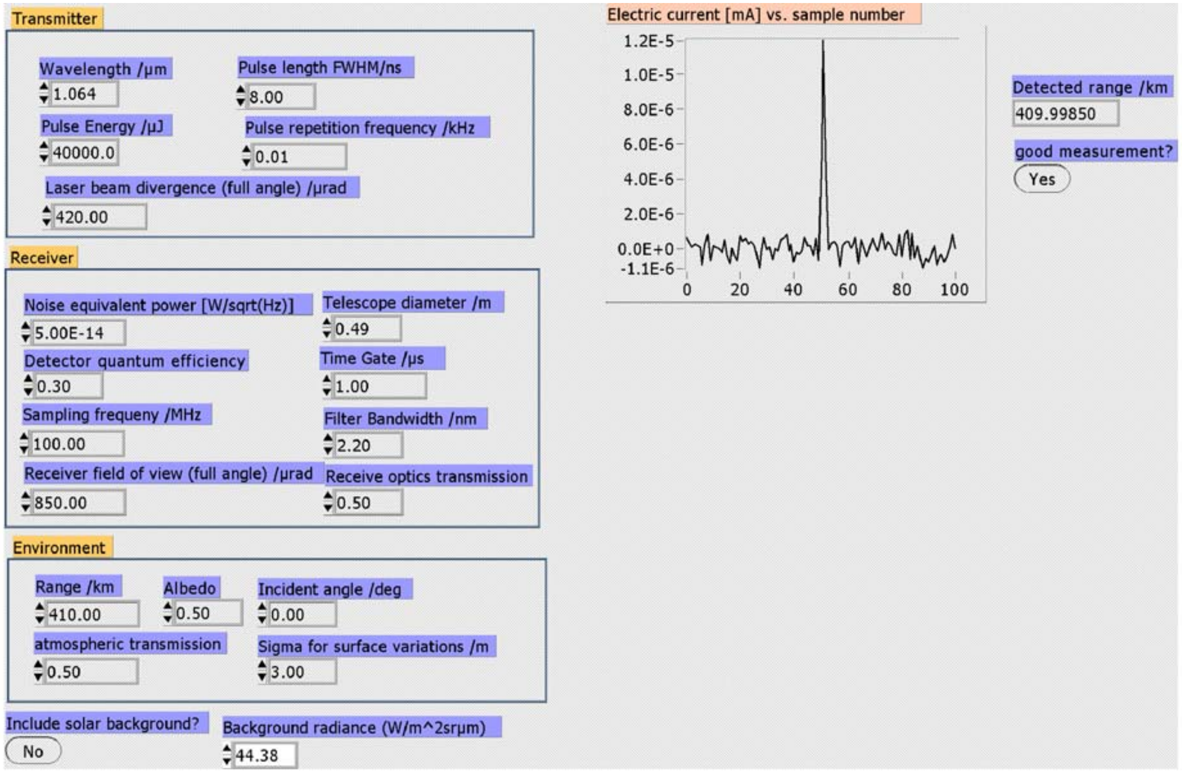
Orbit Coverage



The blue dots indicate 50s time-steps, not the laser shots itself which have a much higher frequency.

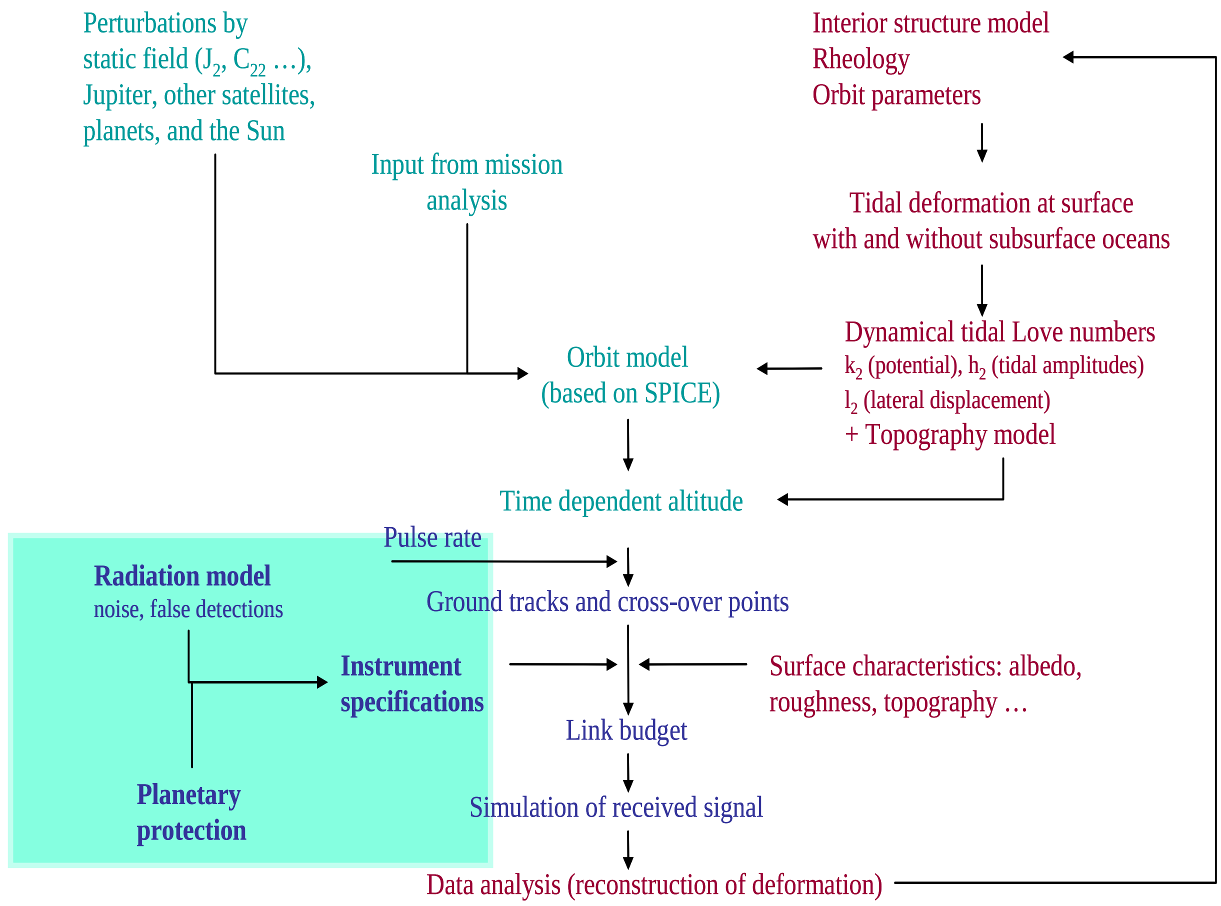
Tracks in circular phase complemented by elliptical phase near pericenter.
Improvement of coverage, especially in the equatorial regions.

Simulation: Laser Signal, Pulse Detection and Noise



Software to analyse the Laser pulses including technical parameters (e.g., laser power etc), surface characteristics (e.g., albedo) and noise.
Next step: implement false detections due to radiation

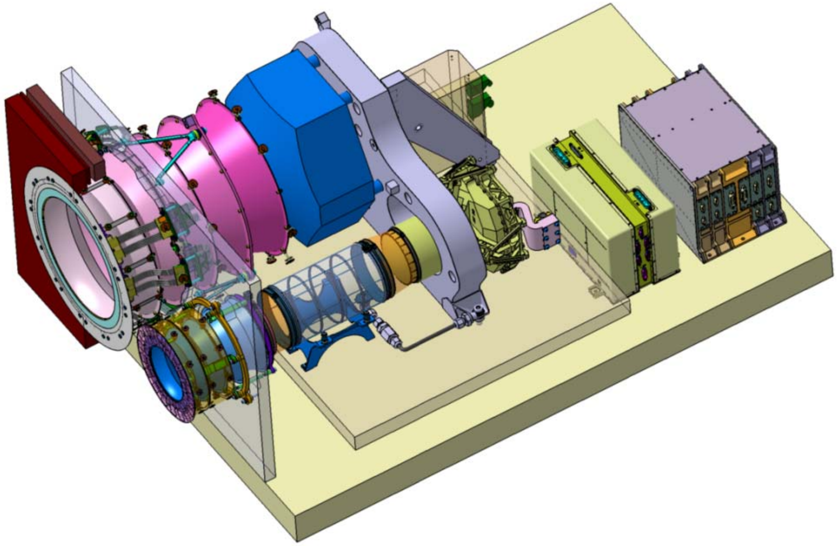
Study Approach (Example: Tidal Deformation)



Technical Overview

- Time-of-flight measurement of an emitted laser pulse and digital waveform analysis of the received pulses.
- Transmitter: actively q-switched ND:YAG laser. Pulse energy and pulse repetition rate are adjustable
- Receiver: Telescope with analog Si-APD, digital rangefinder
- Cold redundancy on sub-system level

Heritage: “BELA”
BepiColombo Laser Altimeter
- STM: June 2010
- EQM: October 2011
- FM: September 2012
- Mercury orbit: 2020

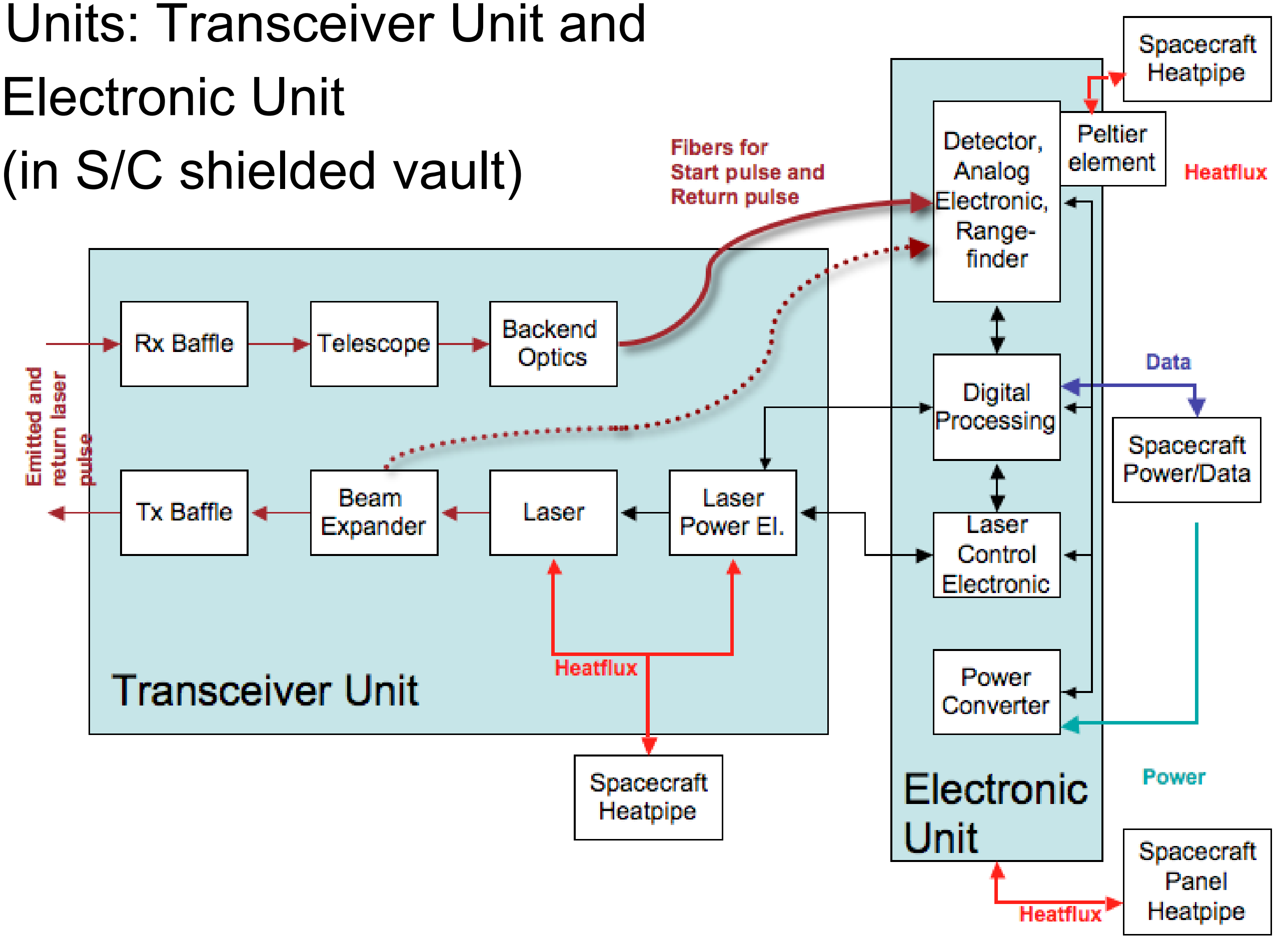


Different Targets, different environments

- The required performance in terms of pulse energy, range, range accuracy, pulse repetition rate etc. is at least quite similar.
- The differences are more in the technical side
  - Radiation
  - Parts & Materials
  - S/C technical interfaces
  - Different formalisms for NASA and ESA
- Find a compromise between synergies and “individual instrument designs”

Block Diagram

2 Units: Transceiver Unit and Electronic Unit (in S/C shielded vault)



Status

- Drafts of Science Req. Document, Instrument Req. Document
- Ranging possible < 1000 km, < 1m range accuracy
- Performance of the instruments is not fixed yet, since there are still relevant changes in Orbits and Operations. The design is still flexible.
  - Ganymede & Callisto:
    Pulse energy between 15 and 26 mJ, Rx aperture dia between 10 and 25 cm, Range between 400 and 1300 km (at Ganymede)
  - LA for Europa:
    5 - 15 mJ, 10 - 15 cm, 225 to 625 km range
  - Mass 7 kg (excl. shielding), Power 24 W operational

- Laser ranging from Earth to the S/C is still under study:
  - Requires a small optical receiver in the HGA and a powerful laser on Earth.
  - Improvement in Orbit determination

Technology Development Activities

- Positive pre-decision on funding by the German space agency (DLR)
- Main aspects:
  - New laser design for EJSM missions
  - Rad-hard electronics: parts, support of ESA's ASIC develop.
  - Rad-hard detector diode
  - Rad-hard laser optics

- The laser pump diodes used for BELA are already tested up to 180 krad TID(Si) with < 5% degradation. Tests will continue.