Gravity Science at Ganymede
Ganymede Circular Phase Simulation

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SIMULATION SETUP

- 180 days split in 45 arcs lasting 4 days each.
- Nominal altitude: 200 km
- Gravity field up to degree 15.
- Non-gravitational accelerations:
  - Solar radiation pressure
  - Planetary radiation from Ganymede (Albedo, Infrared thermal emission)
  - Ganymede atmosphere (from Marconi model)
- AWGN Allan deviation = 10^{-14} @ 1000 s integration

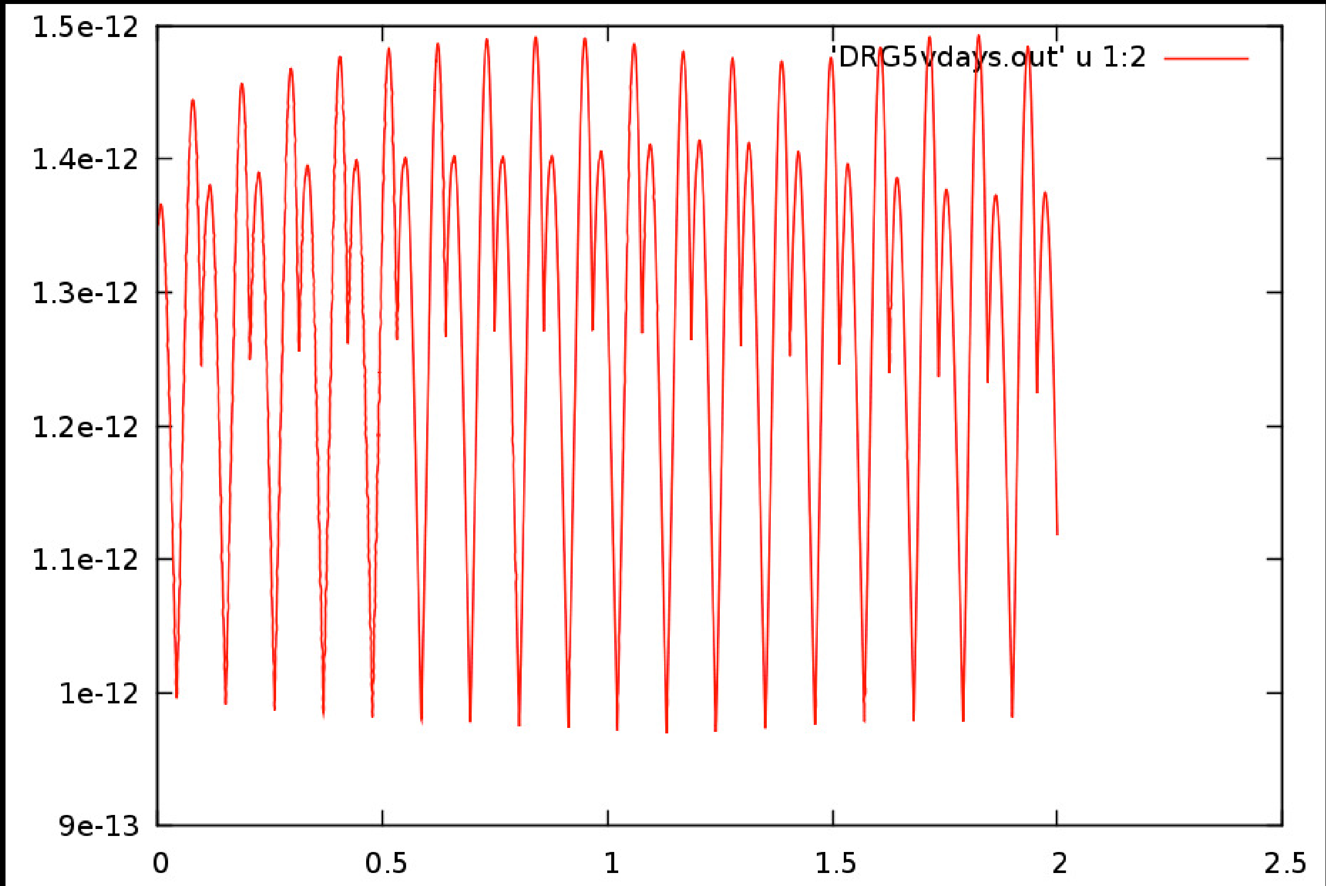
Estimation Setup

- Estimated parameter set:
  - State vector
  - 10 x 10 Ganymede gravity field

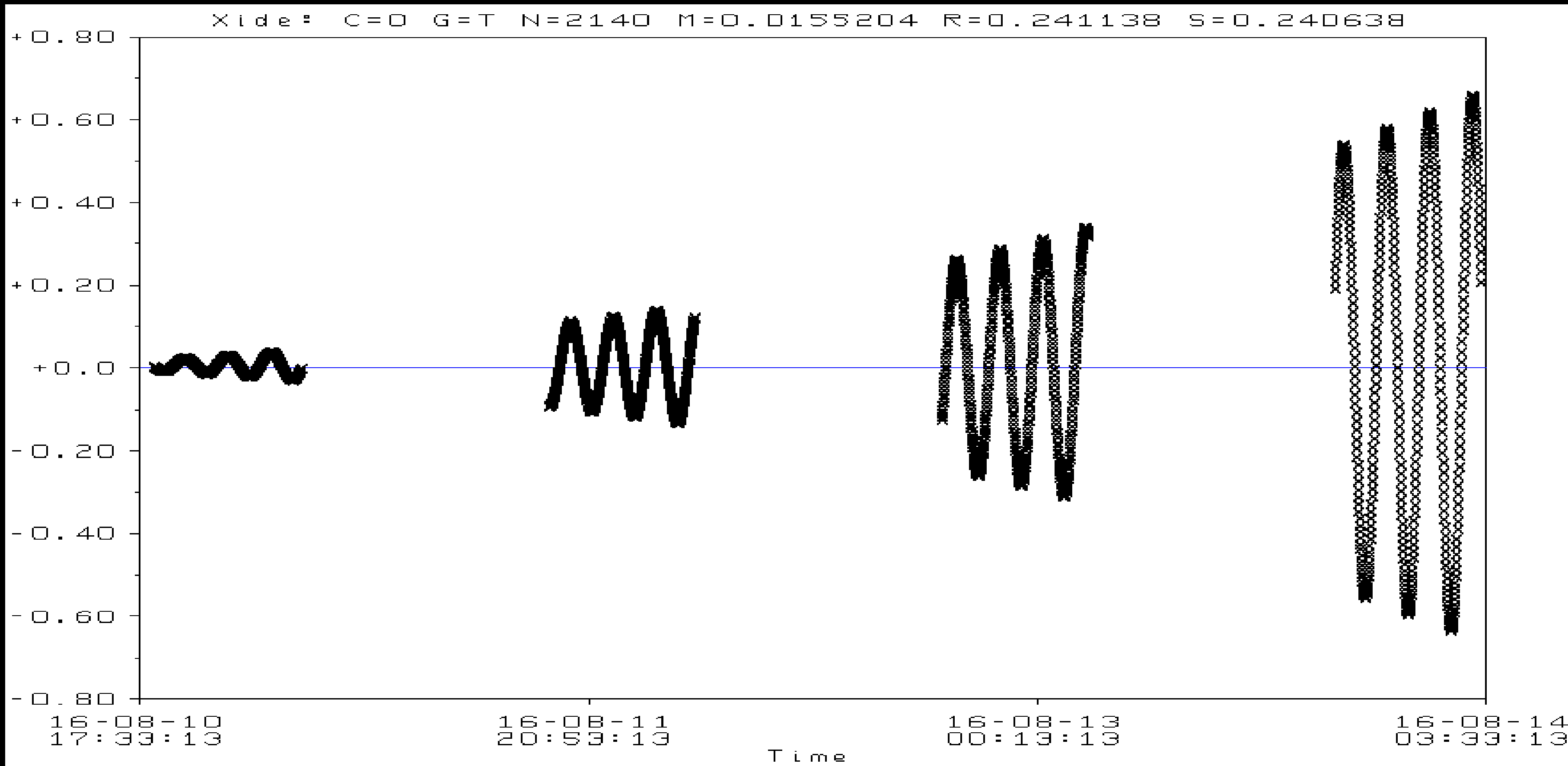
Ganymede Atmosphere simulation

- Simulated by a simplified Marconi model
- Density depends on angle from subsolar point
- The density has a maximum at the subsolar point, then decreases symmetrically as a function of the subsolar latitude and longitude.
- Peak spacecraft accelerations about 10^{-12} km/s^2.

Atmosphere – Acceleration vs Time



Atmosphere – Doppler signature

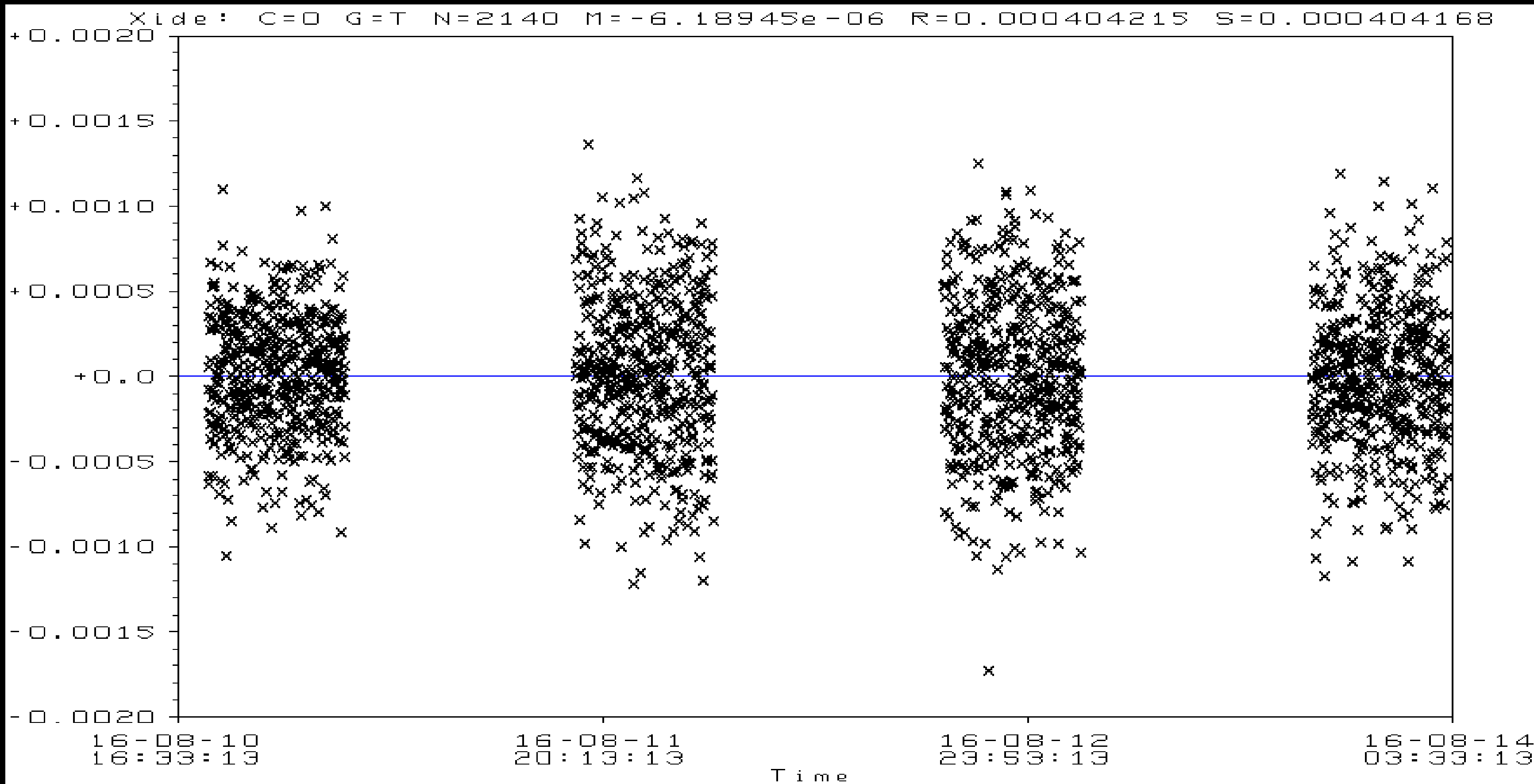


Atmosphere – Estimation strategy

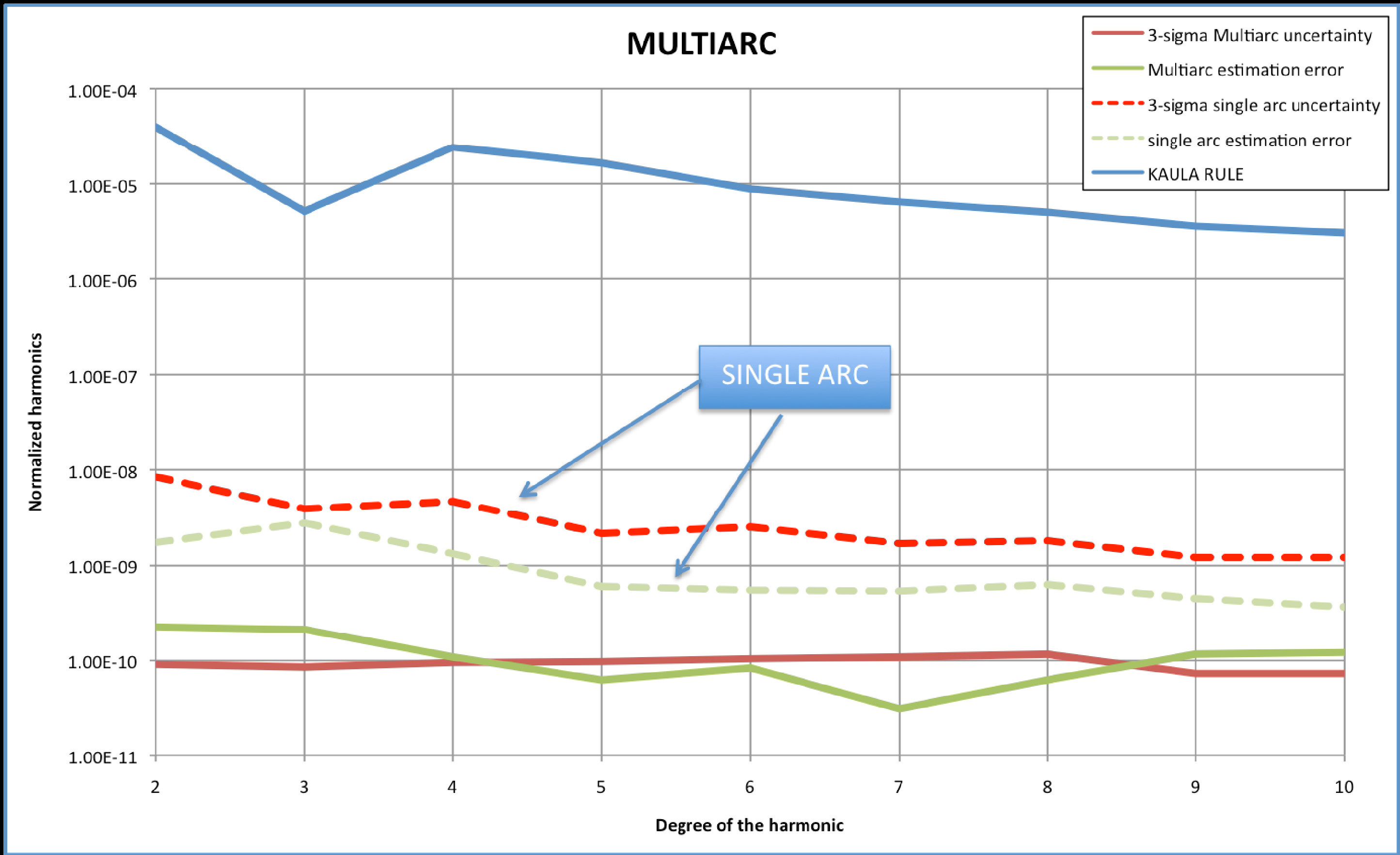
- In order to absorb the signature due to the atmospheric drag, stochastic accelerations are introduced in the integration of the trajectory at the same order of magnitude of the expected perturbation (update time 10 mins).

- 45 single arc solutions are combined in a multiarc solution.

Single Arc Data Fit



Estimation - Results

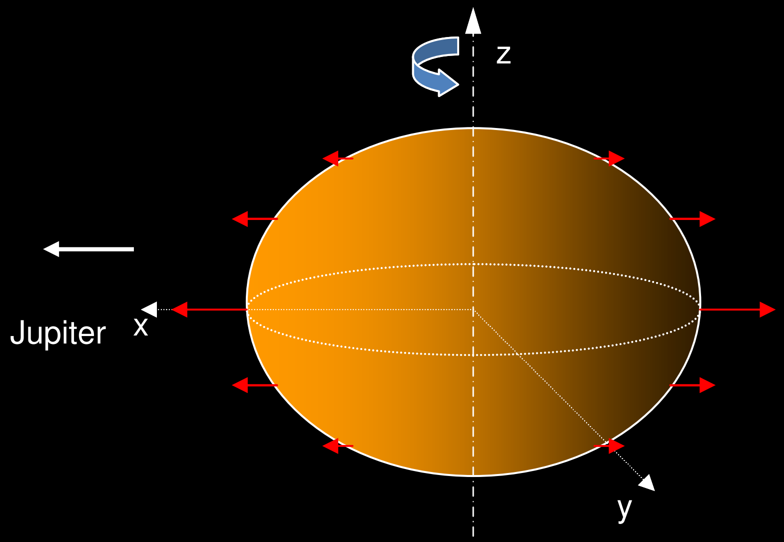


Remarks

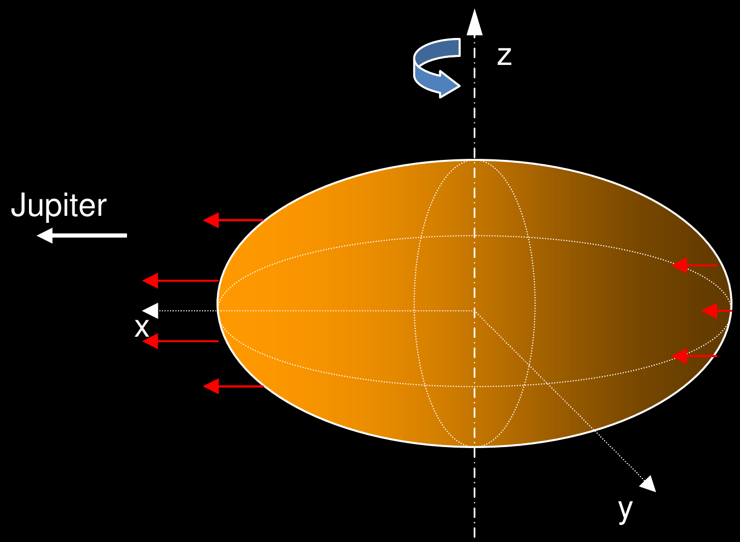
- The atmospheric perturbation is absorbed by the stochastic dynamical model at a level compliant with the scientific requirements of the mission.
- Low degrees are the most affected.
- The atmospheric drag decreases with the altitude of the spacecraft orbit. Moving to 300 km would reduce the estimation errors quite significantly.
- Montecarlo simulations are planned to assess the real uncertainty in the low degree harmonics.

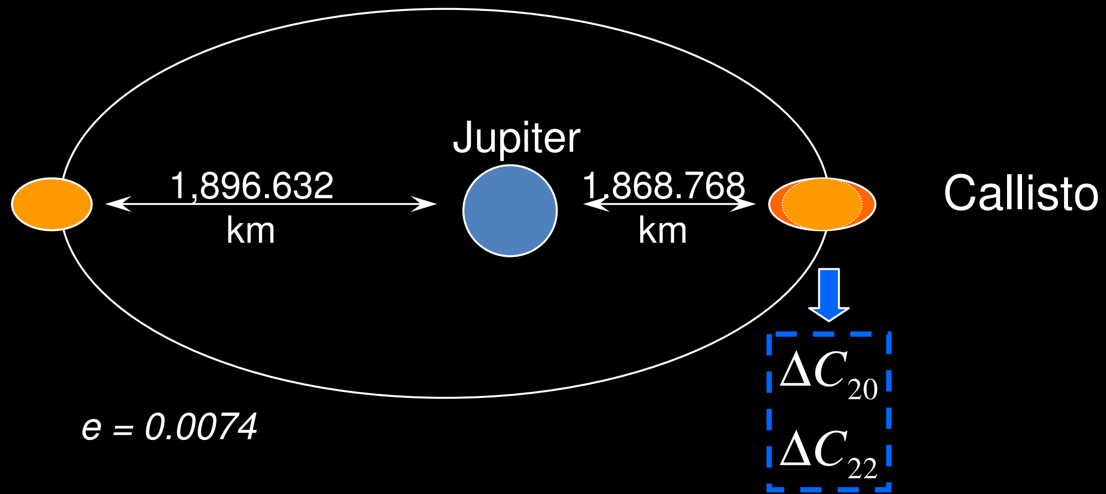
Elastic Deformations of Tidally Locked Satellites

Centrifugal deformation



Tidal deformation





Gravity field of Medicean moons is poorly know.

Galileo's determination of quadrupole field based on a priori assumptions

Galileo Doppler data severely affected by plasma noise

SATELLITE PUTATIVE QUADRUPOLE FIELD

$$J_2 = J_{2,s} + J_{2,p} = J_{2,s} - \frac{1}{2} k_2 q_t e \cos M$$

$$C_{22} = C_{22,s} + C_{22,p} = C_{22,s} - \frac{1}{4} k_2 q_t e \cos M$$

$$S_{22} = S_{22,s} + S_{22,p} = S_{22,s} - \frac{1}{3} k_2 q_t e \sin M$$

$$J_{2,s} = \frac{1}{6} k_f (2q_r - q_t)$$

$$C_{22,s} = -\frac{1}{12} k_f q_t$$

$$S_{22,s} = 0$$

$$q_t = -3 \frac{M_J}{M_S} \left(\frac{R_S}{a} \right)^3$$

$$q_r = \frac{\omega^2 R^3}{GM_S} = -q_t / 3$$

Titan flybys 1-sigma formal accuracy in J2 and C22: ~ 1 10^{-7} (X-band Doppler)

		a	e	R	GM	n_deg/d	J2	dJ2
Io		421800	0,0041	1821,6	5959,916	203,49	1,43E-03	3,16E-06
Europa		671100	0,0094	1560,8	3202,739	101,37	4,15E-04	2,11E-06
Ganymede		1070400	0,0013	2631,20	9887,834	50,32	1,59E-04	1,11E-07
Callisto		1882700	0,0074	2410,3	7179,289	21,57	3,09E-05	1,23E-07

Tidal variations of the gravity field accessible to Ka-band Doppler with SNR >~ 100

$k_f = 1$

$k_2 = 0.3$

Hydrostatic equilibrium → $J_2 / C_{22} = 10/3$

Gravity Science Summary

- JGO radio system under consideration will provide an unbiased estimate of the quadrupole and higher degree gravity field.
- Atmospheric drag can be estimated without significantly affecting the gravity field estimation (@ 200 km altitude)
- k2 Love number is observable with good accuracy
- Two-way Ka-band Doppler is the main observable quantity Information content from range (10 cm) and VLBI (phase ref. @ 5 m every 300 s) is negligible.
- Frequency stability at a level of 1×10^{-14} @ 1000 s is adequate for gravity science goals of the mission
- Fixed high gain antenna impairs the determination of Callisto gravity field and the orbit reconstruction for laser altimetry while in Ganymede orbit.