Prospects for measurements of Mercury’s solid body tides with the BepiColombo Laser Altimeter

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Motivation

Does Mercury have a solid inner core? And if yes, how large is it?

This is an important question for models of Mercury‘s thermal history and dynamo [1]. It can be answered by combining precise measurements of the Love numbers h_2 and k_2 [2].

- h_2 and k_2 quantify the deformation caused by tidal forces
- h_2 and k_2 depend on rheologic properties of the interior
- k_2 has been measured by radio science [3]
- h_2 will be measured by the BepiColombo Laser Altimeter (BELA) [4]

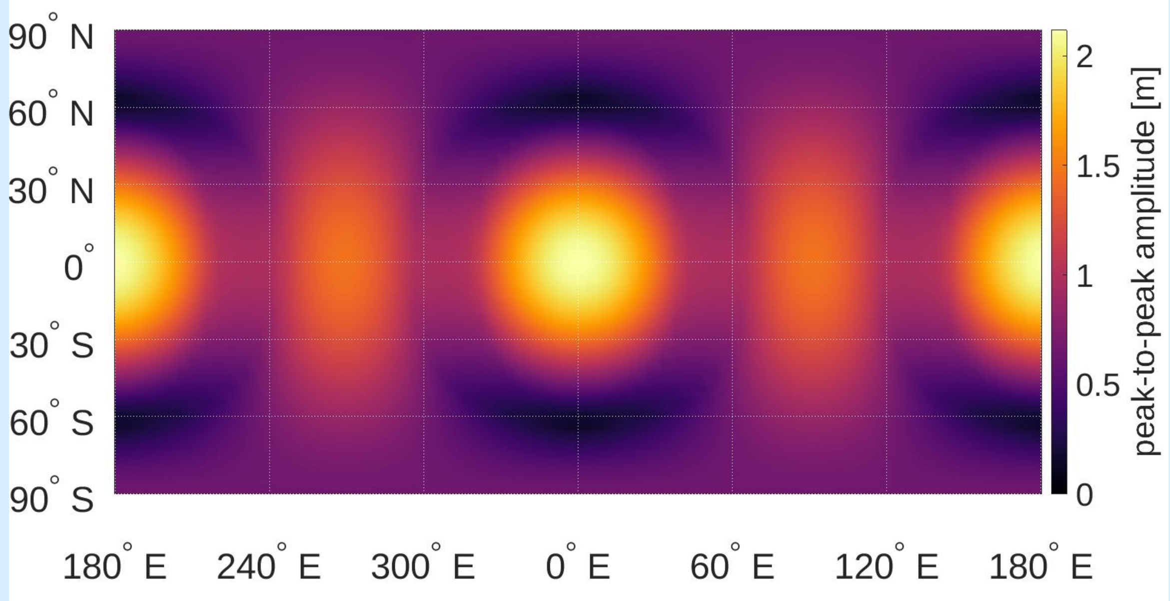


Fig. 1: Map of the peak-to-peak amplitude of tidal deformations on Mercury.

Method

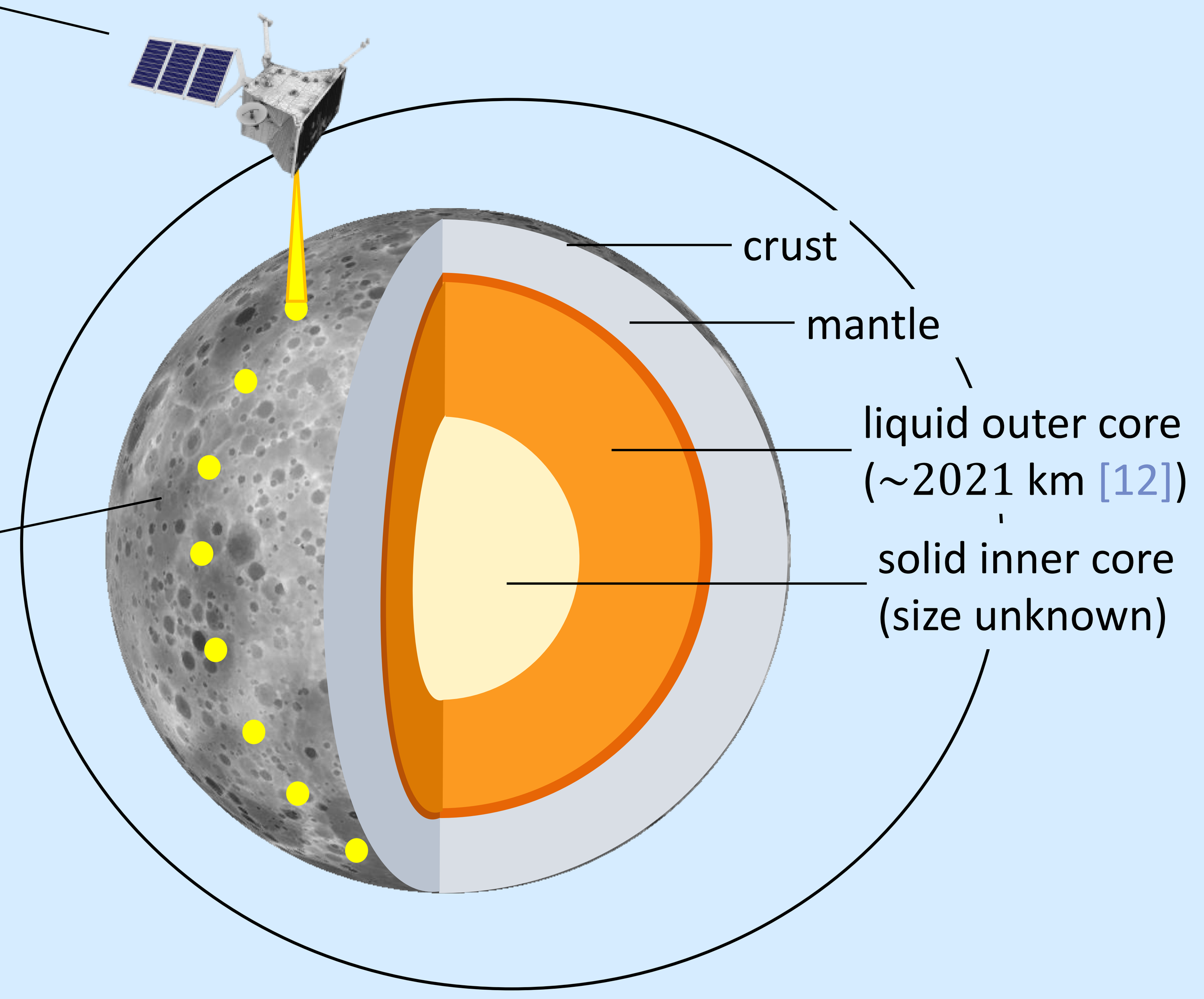
- Simultaneous solution for h_2 and global topography
- parametrization of topography as an expansion in 2D cubic B-splines on an equirectangular grid keeps computational effort manageable [6]
- Mercury’s slow rotation causes highly acute-angled altimeter ground track intersections (unfavorable geometry for a local solution, but manageable in a global approach) [10]

The Mercury Planetary Orbiter (MPO)

- arrival at Mercury in 2026
- 1-year nominal mission
- 400 x 1500 km orbit

The BepiColombo Laser Altimeter (BELA) [4]

- 10 Hz shot frequency (here simulated 2 Hz)
- highest measuring altitude ~1050 km
- $> 150 \cdot 10^6$ (here $30 \cdot 10^6$) topographic observations
- ~2 m range error for each individual measurement



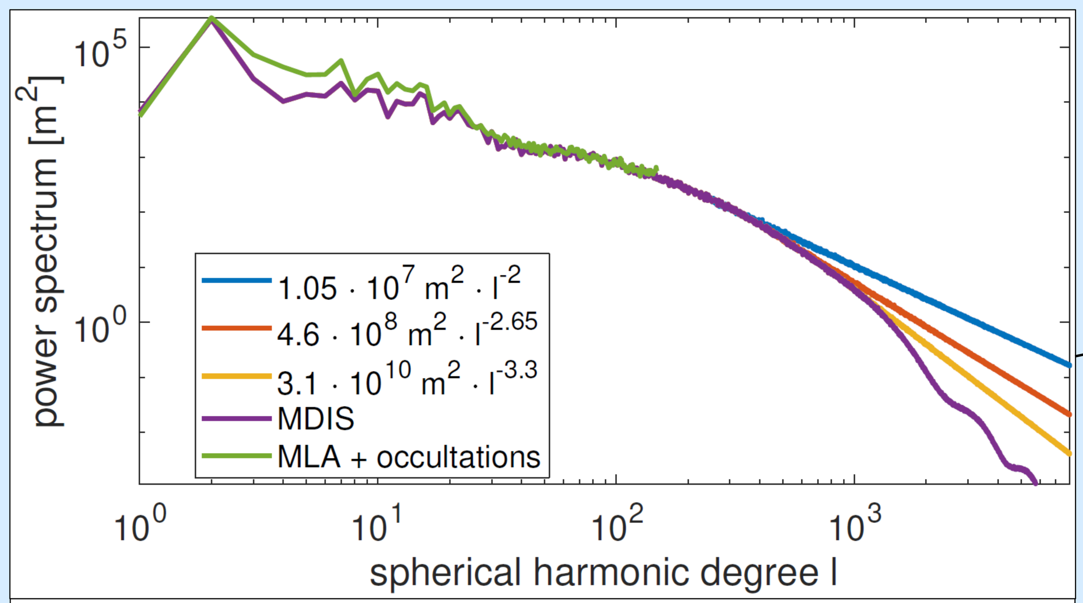


Fig. 2: Power spectrum of Mercury’s topography by MDIS [8], three simulated spectra based on power laws that extrapolate the MDIS spectrum, and the power spectrum from MLA data and radio science occultations [9].

Results from 100 sets of simulations

for topography power law $l^{-3.3}$, maximum altitude 1050 km, 1-year mission

Source	h_2 uncertainty
Large-scale topography	0.0064
Random noise	0.0032
Radial orbit determination	0.0013
Lateral orbit determination	0.0002
Systematic pointing error	0.0093
Pointing jitter	0.0003
Libration	0.0044
total	**0.0115**

Topography power law $l^{-2.65}$	0.017
Topography power law l^{-2}	0.041
Maximum altitude 1500 km	0.012
2-year mission	0.010

Simulation of BELA measurements

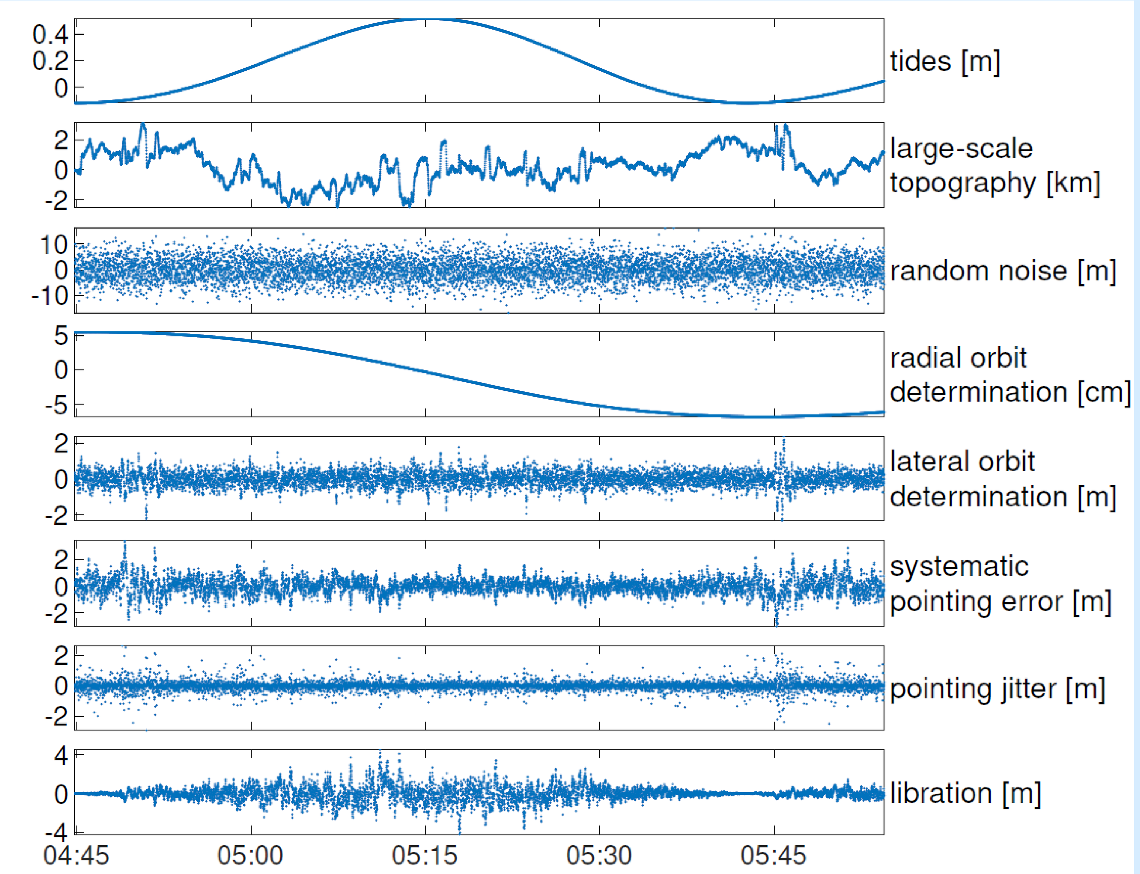


Fig. 3: Contributions of each of the simulated signals to range measurements of the altimeter for the time span of one orbit of the MPO.

- tides: can be computed precisely using ephemerides and a priori $h_2 = 0.8$ (see **Fig. 1**)
- large-scale topography: based on power law extrapolated from MDIS topography (see **Fig. 2**) to degree $l = 7999$ ($\hat{=}$ ~1 km)
- random noise: contains range error and power contained in topography at scales < 1 km
- orbit determination: full covariance analysis based on expected performance of MORE and ISA instruments [5]
- pointing error: 20 arcsec systematic error correlated with distance to Sun (temperature); 2 arcsec jitter
- libration: 1.3 arcsec uncertainty [11]

Implications

- $\sigma_{h_2} \approx 0.05$ permits distinction between small and large inner core
- $\sigma_{h_2} \approx 0.01$ allows determining size of inner core to ± 150 km, if inner core radius > 800 km [2]

➢ BELA will detect or reject a large inner core [7]

➢ if Mercury’s surface is smooth at small scales, BELA can also determine the size of a large inner core

➢ thermal effect on pointing is a major error source

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