PROSPECTS FOR MEASUREMENTS OF MERCURY'S SOLID BODY TIDES WITH THE BEPICOLOMBO LASER ALTIMETER. R. N. Thor[1; 2], R. Kallenbach[3], U. R. Christensen[1], A. Stark[3], G. Steinbrügge[4], A. Di Ruscio[5], P. Cappuccio[5], L. Iess[5], H. Hussmann[3], and J. Oberst[2; 3], [1] Max Planck Institute for Solar System Research, Justus-von-Liebig-Weg 3, 37077 Göttingen, Germany, e-mail: thor@mps.mpg.de, [2] Technische Universität Berlin, Institute of Geodesy and Geoinformation Science, Straße des 17. Juni 135, 10623 Berlin, Germany, [3] DLR Institute of Planetary Research, Rutherfordstraße 2, 12489 Berlin, Germany, [4] Department of Geophysics, Stanford University, 397 Panama Mall, Stanford, CA 94305, USA, [5] Department of Mechanical and Aerospace Engineering, Sapienza University of Rome, Via Eudossiana, 18, 00184 Roma, RM, Italy

Introduction: Tidal forces exerted by the Sun cause a periodic deformation of planet Mercury, the magnitude of which is characterized by the tidal Love number h_2. This quantity can constrain interior structure models, when combined with other geodetic measurements, such as the mean density, the moment of inertia, and the Love number k_2. Specifically, on Mercury, the combination of precisely determined values of h_2 and k_2 allows inferring the size of its solid inner core [1], which is crucial for the understanding of Mercury's thermal history and dynamo. Upon arrival of the Mercury Planetary Orbiter in 2026, the onboard BepiColombo Laser Altimeter (BELA) [2] will acquire $> 150 \cdot 10^6$ topographic observations at meter-level precision, including the radial tidal displacement. Here, we simulate these observations to determine the expected accuracy of h_2 retrieval from the BepiColombo mission.

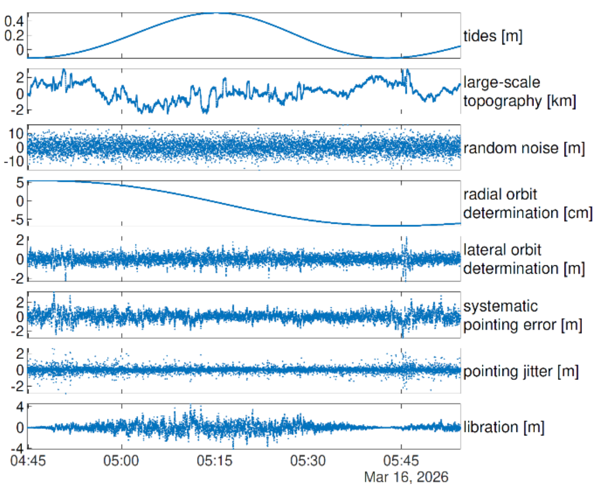

Figure 1: One random realization of the contributions of various signals and errors to the measured range of the altimeter.

Simulation: We aim at generating synthetic BELA measurements that are as realistic as possible and take into account various effects. We base the propagation of the spacecraft orbit on the Hgm005 model of Mercury's gravity field [3], including perturbations by the Sun, tides, and solar radiation pressure as per the latest nominal trajectory. The MPO will be in a 400x1500 km polar orbit with its periherm close to the equator. In our simulation, the altimeter emits laser pulses at a 2 Hz frequency whenever the spacecraft altitude is lower than 1050 km. We note that the nominal ranging frequency of BELA is 10 Hz, but we performed our simulation at a lower frequency to decrease the computational load. We also generate synthetic topography for Mercury, for which we use a model based on a power law that extrapolates the known large-scale power spectrum of the planet's shape [4] with exponent -3.3 down to a scale of 1 km. Topography at even smaller scales is combined with the range error of the instrument and represented by a Gaussian random noise.

The orbit of the spacecraft will be determined by the Mercury Orbiter Radio Science Experiment to a level of tens of meters in the transverse and normal directions and to a level of tens of centimeters along the radial direction [5]. Orbit solutions will benefit from the Italian Spring Accelerometer [6], which will measure non-gravitational forces acting upon the spacecraft. We generate a synthetic orbit determination error based on the expected position and velocity covariance of the spacecraft at each measurement epoch. For the error of the instrument pointing, a periodic thermal signal with an amplitude of 20 arcsec and a small jitter of 2 arcsec are assumed. Finally, the current best estimate of the amplitude of Mercury's 88-day libration is adopted, having a standard deviation of 1.3 arcsec [7]. The radial effect of all these error sources is shown in Fig. 1.

Method: Previous studies used an approach where the misfit between pairs of altimetric profiles at their intersections is minimized [8]. This approach is unsuitable for the BepiColombo mission [9], because, due to the nearly polar orbit, the crossovers will occur at high latitudes, where tidal displacements are relatively small, and, due to Mercury's slow rotation, altimeter tracks intercept at grazing angles, prohibiting an accurate retrieval of the tidal signal. Instead, we solve simultaneously for h_2 and the global topography of Mercury, parametrized as an expansion in 2D cubic B-splines on an equirectangular grid [10, 11].

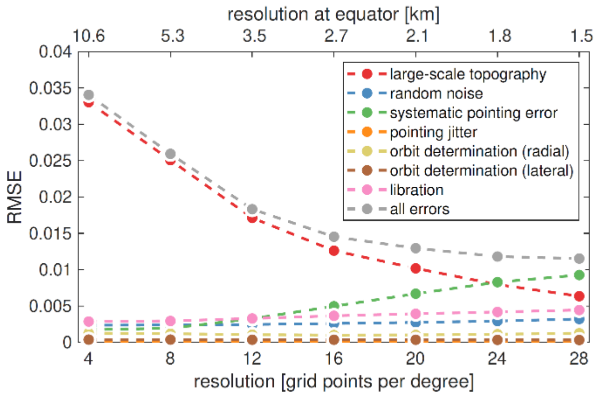

Figure 2: Root-mean-square error (RMSE) from 100 random realizations as a function of topographic grid resolution, split up into the contributions of various error sources.

Results: We generate 100 random realizations of topography, libration amplitude as well as range, pointing, and orbit determination errors. We independently apply the retrieval algorithm to each of the realizations to obtain an estimate on the obtainable h_2 retrieval accuracy. We find that the uncertainty strongly depends on the resolution of the topographic grid which is solved for during the retrieval. The uncertainty reaches a minimum of ± 0.012 at a resolution of 28 grid points per degree, the highest that could be computationally reached (Fig. 2). The main contributors are the topography at scales, which are too small to be modelled by the topographic grid, and the pointing error of the instrument. The former does not come as a surprise because our initial aim was to detect dm-range radial displacements in measurements taken at different, not perfectly known locations on the surface. A determination of h_2 with an uncertainty of ± 0.012 would enable a determination of the radius of Mercury's solid inner core up to ± 150 km, if the core is large, and assuming a perfectly known k_2 [1].

Acknowledgments: R. Thor is supported by grant 50 QW 1401 on behalf of the DLR Space Administration while preparing his PhD thesis in the framework of the International Max Planck Research School on Solar System Science at the University of Göttingen. A. Stark was supported by a research grant from Helmholtz Association and German Aerospace Center (DLR) (PD-308). The work of A. Di Ruscio, P. Cappuccio, and L. Iess was supported in part by the Italian Space Agency under contract 2017-40-H.0.

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