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Bepicolombo Laser Altimeter (BELA) contributions to MPO orbit improvement towards a better determination of Mercury geophysical parameters

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Abstract

Laser altimetry is the main source of information to improve planetary topography. However, it is also possible to use it in the form of crossovers to significantly improve the spacecraft orbit [1] and infer geophysical properties [2, 3]. In this study we will present our latest results on modeling BELA instrument [4] in flight and the potential improvement of MPO orbit. The impact of using altimetry crossovers on Mercury geophysical parameters is one of the final goals of this study and will be the object of future talks.

1. Introduction

BepiColombo is Europe's first mission to Mercury [5]. It will set off in 2018 on a journey to the smallest and least explored terrestrial planet in our Solar System, Mercury. When it arrives, it will study and understand the composition, geophysics, atmosphere, magnetosphere and history of the planet. The mission comprises two spacecraft: the Mercury Planetary Orbiter (MPO) and the Mercury Magnetospheric Orbiter (MMO). The BepiColombo Laser Altimeter (BELA) is one of the instruments of MPO and is being developed by a consortium led by Physikalisches Institut, Universitat Bern and the DLR Institute of Planetary Research Berlin. It will provide an accurate digital terrain model and improve our knowledge about the geophysical parameters of the planet Mercury.

2. The model of the instrument in flight

To know the possible scientific developments that can be achieved using BELA, we need to have a model of the instrument in flight. In our orbit propagation, we use the d/o 50 gravity field Hgm005 (derived from NASA Messenger data) as background field. Moreover, we model the gravitational effect of the Sun and of other planets on the orbit of MPO. We also assume a cannonball model for the spacecraft to take into account the effect of solar radiation pressure. A more accurate macromodel of MPO and the effect of IR radiation and albedo from the surface of Mercury on the orbit of the spacecraft are being implemented to improve the quality of our simulation. With these assumptions, the MPO orbit has been propagated and verified against orbits provided by DLR and ESA as shown in Fig. 1. Here we present our latest model which has been developed using the planetary extension of the Bernese GNSS Software (BSW [6]). The latter is an advanced space data processing software developed at the Astronomical Institute of the University of Bern (AIUB).

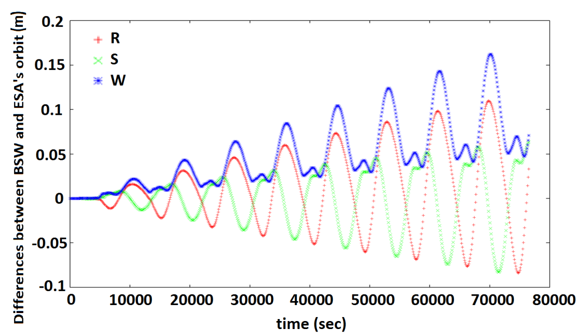

Figure 1: Orbit differences between BSW propagation and ESA SPK orbit, not exceeding 15 cm over 1 day.

To model the BELA instrument within our simulation, we use the end-to-end test results of BELA calibration in the "Starsim" laboratory of the University of Bern. Hence, to test our instrument in flight model, we simulate a series of laser altimetry observations around Mercury based on a full coverage Mercury DTM from Messenger camera data [7] and we add both random and systematic errors to the observables to have a realistic simulation. An example of our simulation results is shown in Fig. 2.

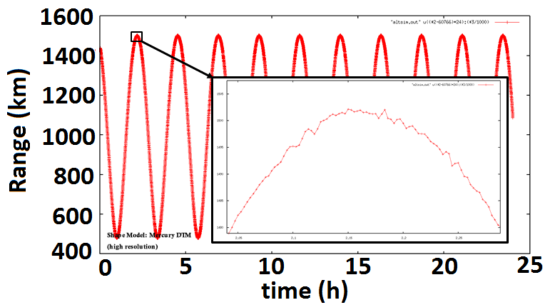

Figure 2: Measured range as a function of time in altimetry simulations.

3. Study of the orbit improvement using laser altimetry

An accurate orbit determination for MPO can be performed by using data from radio tracking. Cicalò et al [8] modelled range and range-rate data from MORE (Mercury Orbiter Radio science Experiment) Ka-band antenna and showed that it is possible to reconstruct the orbit with an accuracy of the order of one meter. Since the amplitude of Mercury tidal deformations is in the order of less than one meter, their determination will benefit from a more accurate orbit. Therefore, we study the impact of using laser altimetry observations as additional contribution to the orbit improvement as well as to the determination of other geophysical parameters. For this study, we simulate both Doppler and laser altimetry data based on MPO nominal orbit (see Fig. 3) and we reconstruct the orbit using both observation types with an appropriate weighting. Then, we compare the results to both the nominal orbit and the one only based on Doppler observations. We will present our latest advances on this topic.

4. Summary and Conclusions

We modelled the orbit of the MPO spacecraft and simulated the Doppler and laser altimetry observations to study the impact of using laser altimetry on orbit determination. We present our latest advances on this topic, including sensitivity studies w.r.t. the impact of uncertainties on Mercury gravity field, non-gravitational forces ($e.g.$, solar radiation pressure) and instrument related noises. The final goal of this study is to contribute to improve the determination of Mercury geophysical parameters ($e.g.$, tidal deformations and librations).

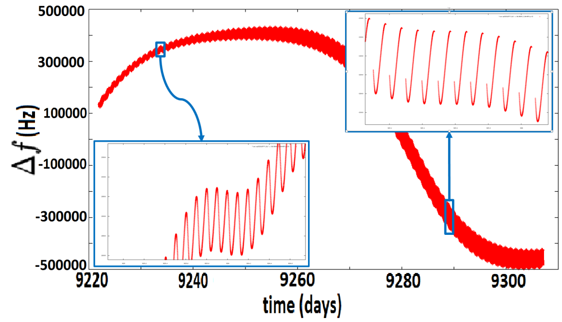

Figure 3: Simulated Doppler observation of MPO spacecraft as a function of time.

Acknowledgements

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