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Orbit simulations for BepiColombo using MESSENGER-based high-order Mercury gravity field data

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Introduction

We developed a tool to simulate the orbital motion of the BepiColombo spacecraft, scheduled for arrival at Mercury in 2022. The mission will consist of two spacecraft, the MPO (Mercury Planetary Orbiter, ESA) and the MMO (Mercury Magnetospheric Orbiter, JAXA). We simulate the orbital evolutions of the considering perturbing forces for a time of 2 years from arrival. This study was undertaken for mission planning purposes and estimates of surface coverage for the on-board mapping instruments.

The knowledge of the evolution of the two orbits for the BepiColombo Mission is important to know, because there will be no active attitude corrections for both spacecraft after orbit insertion.

Orbit Perturbations

Perturbing forces acting on the Keplerian MPO and MMO orbits include Mercury's non-spherical mass distribution parameters, the gravitational force of other planets, the Sun and the solar radiation pressure SRP (Fig. 1). Because of the perturbing accelerations, semi-major axis, eccentricity, inclination, ascending node, argument of pericenter, show complex variations. The program simulates the evolution of all these elements over a period of 2 years. The software was programmed using SPICE subroutines.

Numerical Integration

Starting from initial values for the state vector (i.e., position and velocity) or a set of orbital elements at time t0 given in [2], we obtain the spacecraft trajectory with an accuracy of the order of 1 m by choosing a step-size of 50 s [1]. The results of the numerical calculation were verified against the results of a similar BepiColombo orbit simulation by ESOC [2] and showed very good agreement.

Gravity Field Coefficients

With MESSENGER in science operations since March 2011, there are new gravity field coefficients available [5]. In particular, accurate data are available for: J2, J3, C21, J4. Previous orbit predictions had to be done with a variation of the coefficients, because of the lower precision of MARINER 10 and MESSENGER gravity field data from flybys [3], [5].

Results (Examples)

Fig. 1 shows the accelerations in detail (5 days) for the MPO. As expected, the gravity field terms of Mercury cause significant perturbing accelerations on the MPO. Perturbations by other planets are small. The J3 term mainly influences the altitude at pericenter. The altitude lowers from 400 km at the beginning of the science mission to about 240 km. This would be an advantage for BELA (lower altitude better measurements) but a disadvantage for the MPO in terms of thermal radiation from the Mercury. J3 reflects an asymmetry between the northern and southern hemisphere in the gravity field of Mercury. Therefore, the longitude of pericenter is important because the effect of J3 decreases with increasing distance from Mercury. Shifting the argument of pericenter from the nominal initial value of 16° to lower values reduces the decrease of pericenter altitude significantly [Fig. 2].

Likewise the coverage was analysed [Fog. 3]. The coverage with BELA tracks assuming a maximum altitude of 1055 km to obtain a reasonable signal of the return pulse.

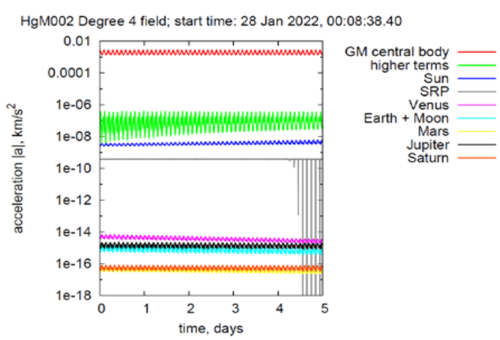

Fig. 1 Accelerations acting on the MPO (5 days)

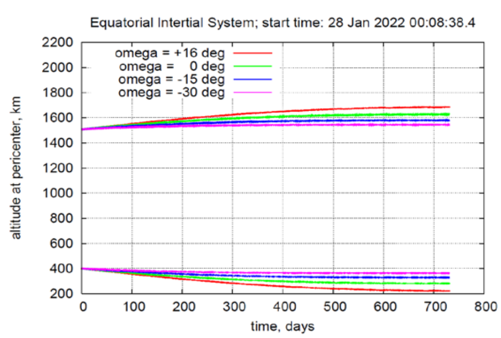

Fig. 2 Pericenter and apocenter altitudes of MPO for different values of initial argument of pericenter

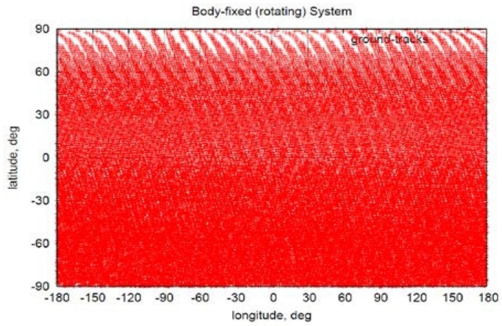

Fig. 3 Coverage with ground-tracks on Mercury's surface. Initial argument of pericenter -15°

Outlook

With the MESSENGER mission continuing, we expect that improved gravity field models of Mercury will become available. Then, additional coefficients will be included in our software to improve the BepiColombo orbit predictions.

References

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