EPSC Abstracts
Vol. 9, EPSC2014-548, 2014
European Planetary Science Congress 2014

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

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1. Introduction

We developed a tool to simulate the orbital motion of the BepiColombo spacecraft, scheduled for arrival at Mercury in 2023. The mission will consist of two spacecraft, the MPO (Mercury Planetary Orbiter, ESA) and the MMO (Mercury Magnetospheric Orbiter, JAXA). We simulate the orbital evolution of MPO, considering perturbing forces for a period of 2 years following arrival. This study was undertaken to support operational planning for the on-board mapping instruments, especially BELA (BepiColombo Laser Altimeter), currently being developed by DLR/UBE.

The knowledge of the evolution of the two orbits for the BepiColombo Mission is important, because active orbit- and attitude corrections are not possible after orbit insertion. Also due to the harsh thermal radiation from Mercury, which has implications on the thermal design of the spacecraft, the evolution of the periherm is of particular importance.

The results base on the ones represented at the EPSC 2012 with the following improvements:

- Usage of the actually Mercury Gravity Field (50 x 50, Messenger)
- New MPO Orbit Parameters
- Influence of reflected Sun-light
- New calculated coverage

1.1 Orbit Perturbations

Perturbing forces acting on the Keplerian MPO and MMO orbits include Mercury's non-spherical mass distribution, the gravitational force of other planets, and the Sun as well as radiation pressure from direct sunlight and sunlight reflected from Mercury (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.

1.2 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 an independent BepiColombo orbit simulation by ESOC [2] and showed very good agreement.

1.3 Gravity Field Coefficients

With MESSENGER now being in science operations since April 2011, new Mercury gravity field parameters have become available [5]. In particular, coefficients are available for a spherical harmonics model of order and degree of 50. Previous orbit predictions had to be done using crude gravity field data obtained by MARINER 10 or during the early MESSENGER Mercury flybys [3], [5] assuming wide error margins for the gravity field coefficients.

1.4 Results (Examples)

Fig. 1 shows the accelerations in detail for the MPO. As expected, the gravity field terms of Mercury cause significant perturbing accelerations. Perturbations by other planets are small. The J3 term mainly influences the spacecraft altitude at pericenter. The altitude decreases from 400 km at the beginning of the science mission to about 250 km. This would be an advantage for BELA (lower altitude: higher signal levels) but a disadvantage for the MPO in terms of increased 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 to lower values reduces the decrease of pericenter altitude significantly [Fig. 2].

2. Figures

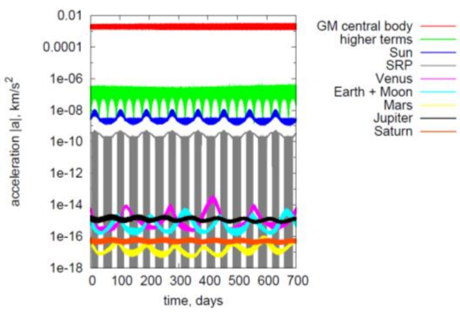

Figure 1: Accelerations acting on the MPO.

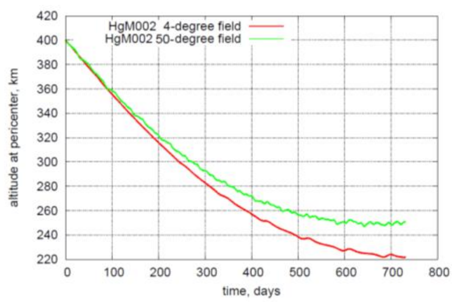

Figure 2: Pericenter altitudes of MPO.

3. References

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