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Simulation of global GM estimate of Asteroid (469219) 2016 HO3 for China's future asteroid mission

Weitong Jin (1,2), Fei Li (1), Jianguo Yan (1), Xuan Yang (1), Mao Ye (1), T.P. Andert (2) and González Peytaví(2)
(1) Wuhan University, Wuhan, China (jwt_whdx@whu.edu.cn), (2) Bundeswehr University Munich, Munich, Germany

Abstract

Asteroid (469219) 2016HO3 (hereinafter called HO3) is the most stable (known) quasi-satellite of Earth. China plans to launch a sample return mission to this target, called Zhenghe, consisting of an orbiter and a nano-lander addressing several scientific issues. The orbiter with full instrumentation will perform radio science experiments during the gravity field mapping phase. Precise radio tracking from Earth and onboard optical measurements will provide large data sets. From these it will be possible to study the global GM of the asteroid, which is a key factor to explain the internal structure of the asteroid.

In order to obtain a realistic assessment of the attainable accuracy in the determination of the asteroid GM, full numerical simulations of the radio science experiment have been performed with our own software ASGREAS. Simulated two-way Doppler and one-way onboard distance measurement that plays the role of optical camera data have been generated, and a list of variables including the spacecraft initial conditions and the global GM have been determined by a weighted least-squares fit. The simulation results are encouraging: The spacecraft initial position accuracies for each observed arc are in average no more than 0.75km. The best global GM solution can be determined to ($4.9781\times10^{-11}\pm1.1378\times10^{-12}$) km^3/s^2 (error: 2.29%, 3σ).

1. Introduction

The geophysical parameters mass GM is the product of the gravitational constant G and the asteroid's mass. There are two different approaches to solve for GM from orbital dynamics: flybys and long-term interaction on spacecraft orbits [1].

In this work, we investigated, through a combination of forward and inverse modelling of simulated Doppler spacecraft tracking data collected from Chinese deep-space ground antenna and simulated onboard one-way measurement data which plays the role of the image data from the onboard camera, the feasibility and accuracy of HO3 GM determination in a long-term interaction way — spacecraft accompanying flight.

2. Software verification

The performance of our own software, named Asteroid Gravity Recovery and Analysis Sofware (ASGREAS), is validated by processing the real two-way Doppler tracking data recorded at ESA and DSN ground stations during Rosetta Lutetia flyby.

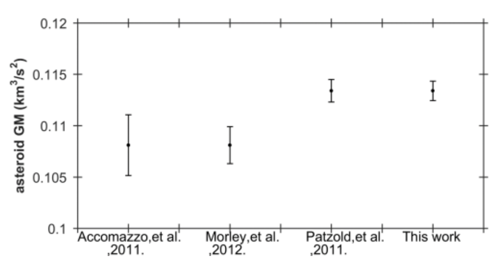

Figure 1: Comparison between GM determinations of (21) Lutetia in different papers

3. Simulation for HO3 GM estimate

The spacecraft will start accompanying together with the asteroid from February 19th, 2026 to May 19th, 2026, meanwhile the radio science experiment will be performed in this time span. The gravitational parameter of HO3 is assumed to be (5.0196 ± 3.48170) $\times10^{-11}$ $km^3.s^{-2}$ according to the current estimate of the volume [2] and the density.

The basic idea of the trajectory design is inspired from the spacecraft's home position in Hayabusa2 mission [3]. In this work, the spacecraft is set to be

10, 8, 6 and 4 kilometers above the asteroid facing the sub-Earth direction. Thus, the spacecraft hovers at the stable point and does not orbit around the asteroid.

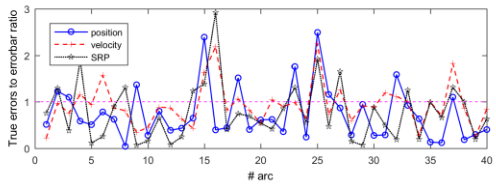

Figure 2: True errors to 1-sigma formal uncertainties ratio for spacecraft initial conditions of each arc (4-km case)

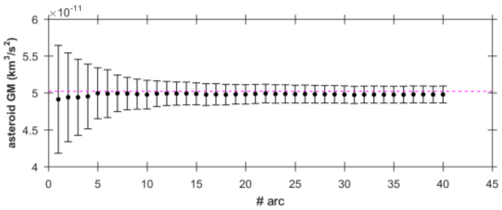

Figure 3: The GM 3-sigma error bar with the increment of arcs (4-km case)

Table 1: HO3 GM solution for different accompanying distances

Scenarios	GM relative true error(%)	GM 3-sigma error bar(%)
10km-case	2.64	6.14
8 km-case	0.84	4.10
6 km-case	1.22	3.07
4 km-case	1.00	2.29

The results can be stated in terms of spacecraft initial conditions determination and HO3 GM estimation. The formal uncertainties were compared with true errors between simulated and estimated values.

The results of the simulation are good and encouraging: The spacecraft initial position accuracies for each observed arc are in average no more than 0.75 km. The best global GM solution can be determined to ($4.9781\times10^{-11} \pm 1.1378\times10^{-12}$) km^3/s^2 (error: 2.29%, 3σ).

Acknowledgements

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