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Phobos-Grunt experiments to measure Phobos' librations

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Abstract

In the frame of the Russian Phobos-Grunt mission, Phobos librations will be measured with enough precision such that crucial constraints will be obtained on the geophysical properties of its interior, offering key information on its origin [1]. This study assess the precision that can be obtained on Phobos physical librations and discuss the knowledge on physical parameters that can be inferred.

1. Introduction

The Russian Phobos-Grunt mission should land on Phobos surface around March 2012. The lander will be tracked from the Earth during several weeks (about one Earth year) using the coherent X-band transponder onboard. The Phobos lander will also have onboard a star tracker dedicated to the investigation of proper and forced libration of Phobos [2]. We assess in this paper the precision that can be achieved on the Phobos libration angles determination using both Direct-To-Earth (DTE) Doppler measurements (as done in [3] for Mars) and star tracker (ST) measurements.

2. Phobos Rotation modeling

The Phobos rotational motion used in this paper is presented by [4]. Here, the rotational motion is expressed in right ascension α, declination δ and w, allowing to obtain the orientation of the figure axis and the prime meridian with respect to Earth mean equator of J2000. These three angles are expressed as follow:

$$\theta(t) = \theta_0 + \dot{\theta}t + \sum_T \left(\theta_T^c \cos\left(\frac{2\pi}{T}t\right) + \theta_T^s \sin\left(\frac{2\pi}{T}t\right) \right), \quad (1)$$

where $\theta \in \{\alpha, \delta, w\}$, T represents the different periods of Phobos' librations, θ_T^c and θ_T^s are the amplitudes of librations of period T, $\dot{\theta}$ characterizes a linear term (precession rate or proper rotation) and θ_0 stands for the angle value at J2000.

3. Phobos-Grunt data

In order to determine the libration angles of Phobos, we use two types of measurements that will be delivered by the Phobos-Grunt mission:

1. the Star tracker (ST) data which are quaternions that provide the line of sight direction of the star tracker camera with respect to a given reference frame.

2. the Direct-To-Earth (DTE) Doppler data which are obtained using the PRIDE-Phobos experiment including an X-band (8.4 GHz) coherent transponder and Earth-based tracking station from IKI and from ESA.

4. Results

Phobos librations are related to the motion of the nodes of the orbit (long periodic librations) and to the orbital period of the satellite (short periodic librations). Only short periods libration depend on the interior structure and on the geophysical properties of Phobos [4]. Figure 1 shows the precision that can be reached on the determination of short period libration amplitudes. We found that a precision better than 0.1% on the amplitude to be retrieved is obtained in very few weeks, providing crucial information on the relative difference in Phobos moments of inertia and interior properties. Amplitudes of librations at 0.5125 day of period, resulting from the proximity of the resonance with the proper period, are estimated at 1%

level of uncertainties (see Fig. 2).

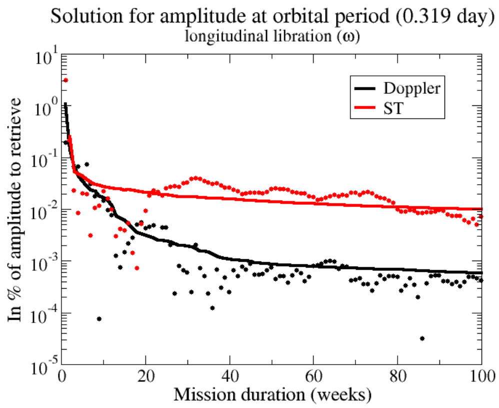

Figure 1: True errors and uncertainties in percent of the amplitude of the longitudinal libration at orbital period.

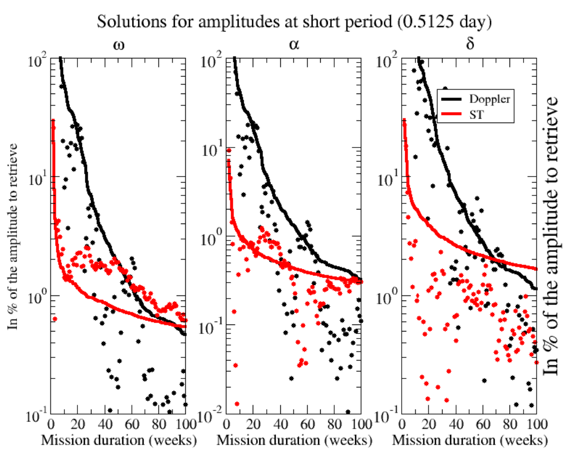

Figure 2: True errors and uncertainties in percent of the amplitudes of the libration at 0.5125 day.

5. Conclusions

This study shows that Phobos-Grunt mission will bring strong constraint on the internal structure and on the geophysical properties of Phobos through the estimation of its librations amplitudes. This will thus permit us to constrain its origin.

Acknowledgements

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