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Phobos interior structure from its gravity field

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Abstract

Phobos origin remains mysterious. It could be a captured asteroid, or an in-situ object co-accreted with Mars or formed by accretion from a disk of impact ejecta.
Although it is not straightforward to relate its interior properties to its origin, it is easy to agree that the interior properties of any body has to be accounted for to explain its life's history. What event could explain such an internal structure? Where should this object formed to present such interior characteristics and composition?
We perform here numerical simulations to assess the ability of a gravity experiment to constrain the interior structure of the martian moon Phobos, which could in turn allow distinguishing among the competing scenarios for the moon's origin.

1. Introduction

As surprising as it may seem given the numerous missions already sent to the martian system, the question of the origin of Phobos is still an open issue (e.g. Rosenblatt et al. this meeting). Where does Phobos come from? To unveil this mystery, the science community is more and more pushing the space agencies to dedicate a mission to the martian moons. The mission concepts recently proposed by different groups across the world (e.g. Pandora [1], PADME [2], MERLIN [3], PhoDEx [4]) all agree with the fact that the origin of Phobos can be revealed by combining different kinds of observation (e.g. imagerie, spectroscopy, radio, sample return, etc.).
Le Maistre et al. (2013) [5] used radio-tracking data from a lander mission to measure the libration amplitude and infer the moment of inertia of Phobos. Here we use similar data but obtained from a spacecraft in orbit around the moon long enough to accurately estimate his first degree and order gravity coefficients. Based on such data, and considering a couple of mission scenarios, predictions on the gravity harmonic coefficient uncertainties are first provided. Then, we construct models of mass repartition for a heterogeneous Phobos' interior composed of rocks, volatile (water ice) and porosity to predict the range of possible values for the gravity coefficients. We finally discuss the ability of an orbiting mission to provide constraints on the interior structure of Phobos based on radio-science data.

2. Gravity field determination

The radio-science data, sensitive to the mass distribution inside the body, are commonly used to determine the gravity field of a celestial body through precise orbit determination technics. We here show that, given the mission scenario recently proposed by different groups (see examples listed above), the degree 2 gravity field of Phobos could be estimated very precisely with a precision better than 0.1%. We also show that a determination of the gravity field up to degree 10 could be reached for a long enough mission, orbiting close enough to the surface of the moon.

3. Signature of the interior in the gravity field

In order to study the effect of the internal structure on the gravity field coefficients we build a 3 dimensional model of Phobos interior by discretizing the volume in a set of cubes of equal size [6]. Based on a random process, we first show the dependency of the low degree gravity field to the proportion and density of the assumed rocky material composing Phobos (see Fig. 1 as an example for C_{20}). Because of its small size and mass, Phobos could have very puzzling interior structure. We focus in a second part of the study on a few typical interior we found in the literature in order to see if gravity data will enable to discriminate between them.

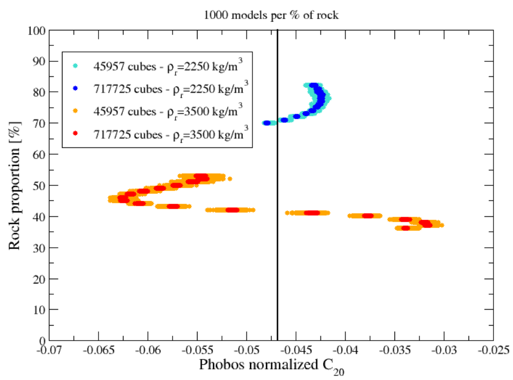

Figure 1: $C_{2,0}$ possible value as a function of the rock density, proportions of rock and cubes number. The black vertical line is the expected value for an homogeneous Phobos.

4. Conclusions

Here we study Phobos' gravity field for different plausible interior structure models. We show the signature of structural and compositional heterogeneities in the gravity field harmonics coefficients and we finally discuss the ability of a gravity experiment to discriminate between the different interior properties of Phobos proposed in the literature.

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