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Inhomegeneous mass distribution inside Phobos

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Abstract

In this study, we present models of the interior structure of Phobos. We have assumed three kinds of materials (non-porous rocks, rocks and water ice) composing the interior of Phobos. We have sought the probability density function over the possible distributions of these materials in the volume of Phobos that fit the observed libration amplitude of Phobos. Our result show that models with inhomogeneous material distribution, i.e. clusters of identical material in the interior of Phobos, are favoured by the data.

1. Introduction

Recently the Mars Express (MEX) mission has provided a new solution of the mass [4] [1] and of the volume of Phobos [5]. A precise estimate of the density of 1876 +/- 20 kg/m^3 has been derived [1] [*Rosenblatt et al., this meeting*], which is lower than the density of most of the carbonaceous chondrite material thought to compose Phobos [2]. It suggests a significant porosity and/or large fraction of water ice in the interior of Phobos [3]. However, the porosity and the water ice fraction cannot be determined from the average density alone. The forced libration amplitude of Phobos has also been estimated as -1.24 +/- 0.15 degrees [5]. Although, the error bar of this new value encompasses the value of -1.1 degrees expected from the Phobos shape with a homogeneous internal mass distribution, it may indicate a heterogeneous mass distribution inside Phobos. The forced libration depends on the principal moments of inertia of Phobos, thus on its internal mass distribution. In order to gain information about the interior structure of Phobos, we have built a model for the mass distribution inside Phobos. We have then used the average density and the libration amplitude of Phobos to infer probability density functions over the interior mass distribution for different sets of plausible constituent materials.

2. Models of the mass distribution inside Phobos

We have developed models of Phobos' interior by discretizing its volume into 2626 cubes of equal volume (1300x1300x1300 m^3). Each cube can have the density of three kinds of material: either 3100 kg/m^3 for rock material, or 1350 kg/m^3 for porous-rock material or 940 kg/m^3 for water ice. The number of cubes of each density value has been fixed, given the measured density of Phobos and assuming a bulk porosity of 10%. The corresponding water ice content is 21% of the mass of Phobos. Given this number of cubes setting, we have determined the probability density functions of Phobos' principal moments of inertia and libration amplitude from a large set of random interior material distributions. As excepted, the estimated values of the principal moments of inertia and libration amplitude are close to those of a homogeneous interior mass distribution (i.e. the cubes of different density are well mixed in the volume). However, the mean value of the estimated libration amplitude is different from the measured value, suggesting a Phobos interior mass distribution that deviates from homogeneous distribution. In order to allow for non homogeneous mass distribution inside Phobos, we have introduced in our models a smoothing parameter that, depending on its value, favours the formation of clusters of cubes of same density. Simulated sets of interior models show estimated libration values, which fit the observed value, for smoothing parameter values favouring clusters of intermediate size (Fig .1).
We have also considered sets of models with different porosity and water ice content in order to study our ability to better constrain Phobos' interior from its observed mass and libration amplitude values. We have considered smoothing parameter values favouring the formation of clusters of intermediate size and determined the probability density functions of interior mass distribution. The distribution of the estimated libration amplitude is very similar for different porosity values, showing that the observed libration amplitude alone cannot constrain the porosity content

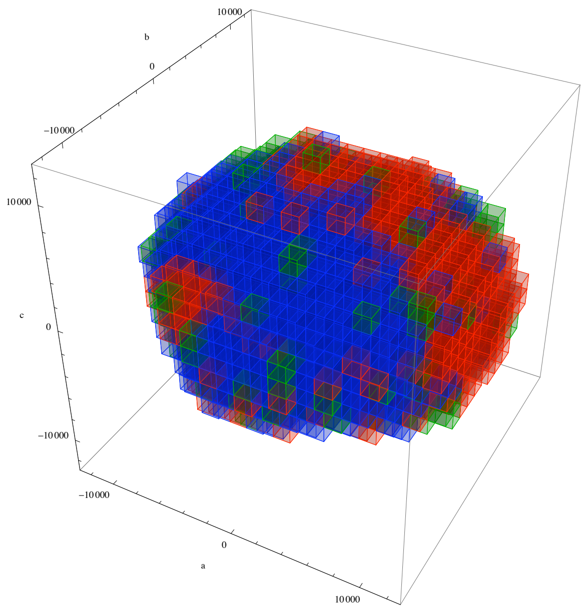

Figure 1: Model of mass distribution in the interior of Phobos, which fits the density and the libration amplitude of Phobos. The volume of the body has been discretized as cubes with assumed density of either a rock sample (red color), or porous-rock (green color) or water ice (blue color). See text for details.

inside Phobos. The mean value of the estimated moments of inertia departs from the homogeneous value for larger porosity values, showing that a precise measurement of the three moments of inertia could provide additional constraints in the interior of Phobos. These moments of inertia are related to the second-order gravity coefficients C_{20} and C_{22} of the gravity field of Phobos in addition to the libration amplitude. The C_{20} coefficient could be obtained from the Mars Express Radio-Science experiment (MaRS) at very close flybys as performed recently at a closest approach of 77 km and from the radio-tracking data of the future Fobos-Grunt mission, due to launch in 2011, when it will co-orbit Phobos at a distance as close as 45 km.

3. Summary and Conclusions

In that study, assuming three kinds of material (non-porous rocks, rocks and water ice), we have modelized the possible distributions of the mass inside Phobos. From the new values of the mass, volume and forced libration amplitude obtained by the Mars Express mission, we have shown that the mass inside Phobos can be inhomogeneously distributed as clusters of material of same density. However, constraints on the porosity and water ice content inside Phobos cannot be obtained from the density and libration amplitude of Phobos alone. Additional constraints on the internal mass distribution can be obtained from the precise measurements of the three principal moments of inertia, which could be acquired from the precise determination of the second-order coefficients of the gravity field of Phobos.

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