非一様内部構造をもつフォボスの慣性モーメント
Moments of inertia of Phobos with inhomogeneous internal structure

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The origin of Phobos is still an open issue. It may be either captured asteroid or formed from a disk of impact ejecta produced by a giant impact. Although it is not straightforward to determine the origin from internal structure alone, it will place important constraints. One of the key parameters related to the internal structure is moments of inertia (MOI). Phobos’s MOI can be determined from amplitude of short-period forced libration and degree 2 gravity coefficients. Currently, the libration amplitude is estimated to be 1.09+/-0.01 degrees by analyzing multiple image data [1]. Although the degree 2 gravity coefficients are estimated from tracking data of Mars Express on its close flyby at Phobos, they are not solved for at sufficient accuracy [2]. Axial difference of MOI can be constrained by the libration amplitude, but currently MOI of Phobos is not known. The observed libration amplitude is consistent with homogenous mass distribution of Phobos, but local mass anomalies cannot be ruled out [1, 3]. Here we consider relatively simple two-layer internal structure and assume that ice water or porosity is confined in either layer, and calculate how much MOI deviate from the value for homogeneous body if such an inhomogeneity existed.

Phobos’s bulk density of 1.86+/-0.013 g/cm^3 [4] is lower than most of the samples of carbonaceous material, which requires porosity and/or light elements like water ice. If the low bulk density was explained by water ice, its mass fraction is expected to be 10-35% depending on rocky material grain density [5]. If the mass distribution inside Phobos was inhomogeneous, e.g., water ice was concentrated near the surface or the center, we will observe a deviation of MOI from the value for homogenous interior. Here the MOI differences (dMOI) with respect to the homogenous Phobos are calculated for some cases where we assumed that (1) Phobos has a tri-axial ellipsoidal figure (a = 13.03 km, b = 11.40 km, c = 9.14 km), (2) Phobos has a two-layer structure and their boundary also has the similar ellipsoidal figure for which the libration amplitude is 1.15 degrees being consistent with the observed value of [1], and (3) water ice is confined either of the upper or lower layer and rock density is the same for both the layers. The water ice mass fraction is changed between 0 and 30% .

In the case that upper layer is composed of the rock plus water ice, when the upper layer thickness is 10% of the semi-principal axes, no more than 14 wt.% of water can be contained in the layer and the maximum dMOI is about 9%. When the layer boundary is deeper, more water can be contained, but the maximum dMOI is about 16%. In the case that the water ice is confined in the lower layer, the maximum dMOI is also about 17%.

We also tested the cases in which the porosity is responsible for the low bulk density. We calculated due to inhomogeneous distribution of the porosity using the similar two-layer structure. The results depend on the boundary depth and rock density. In the case that the lower layer is porous, the maximum dMOI is about 17% when rock density is 2400 kg/m^3, and about 9% when rock density is 2100 kg/m^3.

It is found that, for the layer configuration assumed here, dMOI is smaller than 16-17%. A 10% accuracy will not be sufficient, and it is required to achieve at least a few percent of MOI accuracy in order to detect it. To this end, the required accuracies for the libration amplitude and the degree 2 gravity coefficients are also a few percent.

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