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Revisiting Phobos' origin issue from Mars Express Radio-Science observations.

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Abstract

The origin of the Martian moons remains an open issue: asteroid capture versus *in situ* formation scenario. Recently, a precise solution of the mass of Phobos has been provided by the Mars Radio Science Experiment (MaRS) onboard Mars Express (MEX). The estimation of the bulk density of Phobos has been improved and it supports the hypothesis of a highly porous interior consistent with re-accretion early in its history. This result does not directly address the question of origin, but it provides additional support for *in situ* formation models.

1. Introduction

Several past and present space missions have provided new information regarding Phobos and Deimos, but the question about the origin of these two bodies remains open. It has been proposed that both moons are asteroid captured by Mars' gravitational attraction mainly on the basis of the similarities of their reflectance spectra with those of some low-albedo carbonaceous asteroids (e.g. [8] [12]). All capture scenarios have, however, difficulties to explain the current near-circular and near-equatorial orbit of both moons [3]. Alternative scenarios of *in situ* formation (or in circum-Mars' orbit) include the remnants of an earlier larger moon captured by Mars [15], the re-accretion of large impact debris from Mars blasted into Mars' orbit [4], and co-accretion with Mars [10]. Several models imply that both moons are composed of the same material as Mars, which is problematic [8] [12]. Early determinations of the mass and volume of the two moons were subject to systematic errors, and yielded a large range of values for the density of Phobos, from 1570 to 2200 kg/m^3. The MEX mission provided an opportunity to improve the determination of the mass of Phobos [1] [13] and of the volume of Phobos [16], yielding a precise determination of its density of 1876 +/- 20 kg/m^3 [1]. In this work, we use the improved density solution to estimate the porosity of Phobos and discussed it with regard to the origin of this moon.

2. Bulk density, porosity and origin of Phobos

The low density of Phobos is comparable to the density of many low-albedo carbonaceous asteroids. The density of these asteroids is lower than the density of their meteorite analogs, which can be explained by a large amount of porosity (or voids) in their interior [2]. We have computed the bulk porosity inside Phobos as the percentage of volume occupied by voids. We have taken into account a large range of probable material analogue to Phobos' material. Indeed, recent Phobos' spectra collected by the CRISM/MRO [9] and OMEGA/MEX [6] cameras seem to indicate a subdued signature either of carbonaceous or of silicate components. We have found a porosity range of 25% to 45% depending on the chosen analogue material (Fig. 1). This suggests a loosely consolidated or 'gravitational aggregate' structure for the interior of Phobos. Such internal structure is supported by the large impact crater Stickney. Indeed, large craters on small bodies would require a large porosity in their interior in order to absorb the energy of a large impact without destroying the body [11].

Such large porosity inside Phobos provides new constraints on the capture scenario. It has been shown that the tidal evolution of Phobos orbit is too slow to change an initial elliptical orbit in the ecliptic plane into its current near-circular orbit in Mars' equatorial plane [7]. The tidal evolution of the orbit of a highly porous body may be accelerated [5] but an unlikely tidal dissipation rate into Phobos would be required to account for its current orbit. Moreover, a highly porous body is less resistant to the tidal torques exerted

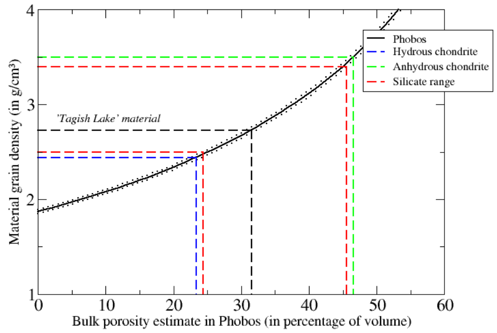

Figure 1: Estimate of bulk porosity inside Phobos needed to fit its bulk density (black solid line).

by Mars preventing it to orbit too close to Mars. Therefore, the initial elliptical orbit of such a body could not be circularized by the drag effect in the primitive Martian atmosphere as proposed by [14]. On another hand, the high porosity is in agreement with re-accretion of material blasted into Mars' orbit as proposed in [4]. As the largest debris bodies re-accrete they block smaller bodies, and form a core with large voids. The smaller debris re-accrete later, but do not fill the gaps left between the boulders [11]. This scenario depends, however, on a Phobos formed of material from Mars. An alternative scenario would imply an impact of an early moon in Mars orbit with an asteroid [10].

3. Summary and Conclusions

The low density of Phobos, derived from the MEX estimate of its mass and its volume can be explained by a high porosity content of 25%-45% in its interior. Such a high porosity may likely result from the re-accretion of material into Mars' orbit, which is in agreement with *in situ* formation scenario. The future Phobos-Grunt mission due to launch in 2011 will allow identifying the surface material of Phobos, thus will help to answer the question about its origin.

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