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Formation of the Martian Moons from a circum-Mars accretion disk

P. Rosenblatt (1,2) and S. Charnoz (3)
(1) Royal Observatory of Belgium, Brussels, Belgium, (2) Université Catholique de Louvain, ELI/TECLIM, Louvain-La-Neuve, Belgium (3) Laboratoire AIM, Univ. Paris Diderot/CEA/CNRS, France(rosenb@oma.be / Fax: +32 2 374 98 22)

Abstract

In this work, we reconsider the scenarios of formation of Phobos and Deimos from a circum-Mars accretion disk in the light of modern theories of accretion. Two regimes of accretion are studied; the high-tide regime for which accretion occur near the Roche limit and the low-tide regime for which accretion occur farther from the planet. For the former regime, irregularly shaped and porous bodies are accreted from gravity instabilities which develop at Roche limit. These accreted bodies have mass and density similar to Phobos and Deimos ones. However, all these bodies fall back on Mars in less than 1 Gy, which is incompatible with a formation of Phobos and Deimos in early Mars' history. Moreover, it is not possible to form Deimos near its current orbit (about 6 Mars' radii). On another hand, in the low-tide regime, it is possible to accrete a body with the mass and at the location of Deimos. A Phobos' mass body can also be formed but closer to Mars. It is however expected to rapidly fall back to Mars. These results are discussed with respect to parameter inputs in our modeling such as the initial mass of the accretion disk around Mars.

1. Introduction

The origin of the Martian moons, Phobos and Deimos, is still an open issue. It has been proposed they formed away from Mars and then captured by Mars gravitational attraction [1] or that they formed in-situ from a disk of debris in Mars' orbit [2]. The capture scenario has longstanding prevailed in the literature but the recent observations made by the Mars Express spacecraft have raised a renewal interest for the *in-situ* formation scenarios [3,4,5]. One of these scenarios proposes that Phobos and Deimos were formed early in Martian history from the re-accretion of debris blasted into Mars' orbit by a giant impact between Mars and a large body (1800 km in diameter) [6]. This scenario assumes that several low-mass objects (or moonlets) would have been formed beyond the Roche limit by gravity instabilities within a circum-Mars accretion disk. However, the physical processes involved in this scenario have not been studied in detail. Therefore, we explore the physics of accretion and perform numerical simulations of accretion in a circum-Mars disk of debris in order to quantitatively assess the scenario of [6].

2 Numerical simulations of a Martian gravitationally unstable accretion disk

The scenario of [6] is physically very similar to a model recently proposed to form the small irregular-shaped moons of Saturn from its rings [7]. This model has shown that when Saturn's rings spread beyond the Roche limit, they become gravitationally unstable and give birth to irregular aggregates. Through subsequent mutual accretion these aggregates grow, then they recede away from the planet due to their tidal interaction with the planet and the rings. We have modeled the evolution of a Martian gravitationally unstable accretion disk and the formation of aggregates from it by adapting the hybrid code developed for Saturn's moons [7] to Mars. We then study the evolution of both accreted objects and disk surface density and we track the amount of disk material falling back on Mars. We explore several scenarios by varying inputs of our model like the initial mass of the disk. Our results are compared with observational constraints of the Martian system such as characteristics of the Martian elongated crater population [8].

3. Summary and conclusions

Our model gives a general framework for understanding the formation of Mars' moons from a tidal disk, in which physics of moon accretion, Mars' and disk tides are explicitly taken into account and coupled in a time-dependent manner. Our model provide, for the first time, a physical basis for the accretion of moons around Mars.

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