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Direct integration of dust from Phobos and Deimos and the effect of higher degree Martian gravity on the shape of their putative dust rings

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Abstract

Dust grains ejected from the surface of the Martian moons Phobos and Deimos by impacts of the hypervelocity interplanetary particles are expected to form tenuous dust rings [1]. In this work, we perform direct numerical simulations of the equations of motion for a large number of dust particles originating from Phobos and Deimos, using the large computer cluster at the Finnish CSC – IT Center for Science.

Particles of sizes ranging from sub-micron to 100 microns are simulated: $0.5\,\mu\text{m}$, $1\,\mu\text{m}$, $2\,\mu\text{m}$, $5\,\mu\text{m}$, $10\,\mu\text{m}$, $15\,\mu\text{m}$, $20\,\mu\text{m}$, $25\,\mu\text{m}$, $30\,\mu\text{m}$, $40\,\mu\text{m}$, $60\,\mu\text{m}$, and $100\,\mu\text{m}$. The most relevant forces are considered in our simulations, including the Martian non-spherical gravity, gravitational perturbations from the Sun, Phobos, and Deimos, solar radiation pressure, as well as the P-R drag. In our model the Martian gravity field up to degree 5 and order 5 is considered. The values of the gravitational spherical harmonics are taken from the Mars gravity model MRO120D [2]. The size-dependent values of $Q_{\rm pr}$ are computed from the Mie theory [3, 4] for spherical grains, by using the optical constants for silicate grains from [5]. The well-tested numerical code [6, 7, 8] is used to integrate the evolution of dust particles.

The effect of the Martian oblateness term J_2 ($\approx 1.96 \times 10^{-3}$) was well studied for the Martian dust in previous papers [9, 10, 11]. In this work, the effect of the J_3 gravitational coefficient ($\approx 3.15 \times 10^{-5}$) is analyzed, which reflects the north-south asymmetry of the planetary mass distribution. The simulations show that the J_3 term is important for the evolution of inclination, and it disperses the distribution of the dust ring in the vertical direction relative to the Martian equatorial plane. Furthermore, the variations in inclination due to J_3 affect the location and velocity of the dust particle, and as a result change the effect of solar radiation pressure and J_2 on the orbital semi-major axis and eccentricity. Finally, the configuration of the Martian rings for various grain sizes is presented, and the simulation results is compared with the upper limits of the optical depth inferred from the Hubble observations [12].

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