SURFACE PROPERTIES OF PHOBOS/DEIMOS AND FORMATION OF SELF-SUSTAINED MARTIAN DUST TORUS, Sho Sasaki, Geological Institute, Univ. Tokyo, Bunkyo-ku, Tokyo 113, JAPAN, sho@geol.s.u-tokyo.ac.jp

Abstract: Dust ejection efficiency from Phobos/Deimos controls dust abundance of Martian dust torus. Martian oblateness effect and solar radiation pressure enhance abundance of particles with radius 20-200μm of Phobos' dust torus. This is compatible with typical size of Phobos' surface regolith. Ejecta from torus particles-satellite collision should be the most important dust source. Dust number density and optical depth are estimated for future PLANET-B mission.

Soter [1] first suggested that ejecta particles from IDPs (inteplanetary dust particles)-Phobos collision would form a dust ring along the satellite orbit. Although Viking Orbiter image data revealed no dust rings whose optical depth is greater than 3×10^{-5} [2], plasma measurements by PHOBOS-2 ASPERA detected indirect evidence of a dust ring along Phobos' orbit [3]. A number of theoretical works have been done on the dust ring or torus around Mars [4-13]. It is found that solar radiation pressure enhances dust eccentricity around Mars. Using β denoting the ratio of radiation force to the solar gravity, the maximum eccentricity of a silicate particle with radius r_d is expressed by $e_{max} \sim 30\beta = 0.20(30\mu m / r_d)$ at Phobos orbit. Then mean collision time between a dust particle and the satellite ($\sim 1/n\sigma v \sim V/\sigma v$) becomes larger under the expanded volume V, which would enhance the total particle number in the dust "torus". If e_{max} exceeds 0.63 ($\beta > 0.023$ or $r_d < 8\mu m$), the dust particle collides with Mars within a half Mars year (0.94yr). Then existence of a dust torus where particle size is around 10μm is suggested.

However, Martian oblateness should shift periapsis phase of dust orbits and e_{max} under radiation pressure becomes larger than that without the oblateness [10-13]. The oblateness effect on dust particles from Phobos are shown in terms of e_{max} - β relation in Fig. 1. The critical dust size r_{crit} colliding with Mars becomes larger (~20μm), which would decrease the total dust number density. Enhancement of e_{max} is significant when $r \leq 200\mu m$ ($\beta \geq 0.001$). Inclination variation amplitude Δi is 0.027 ($r_d = 200\mu m$) to 0.072 ($r_d = 20\mu m$). Detail orbital calculations [11-13] suggest that Deimos particles are more important in Martian dust torus.

Previously torus dust-satellite collision was taken simply as one of dust loss mechanisms. However, collisional ejecta dust may escape from the satellite if their velocity is large enough. This effect was considered for Saturn's E ring [14]. When particles from Phobos hit Phobos, collision velocity v can be as high as a few 100m/s - 1km/s, and when particles from Deimos hit Phobos, v can be a few km/s [15]. Using analytical scaling laws, we estimate dust production efficiency: the total volume of ejecta whose velocity is higher than the escape velocity to the volume of a colliding particle (Fig. 2). The dust production efficiency is still 5-10 when a particle hits Phobos at 1km/s.

Viking Thermal Infrared Data suggested typical grain size of Phobos' surface regolith is estimated to be 50-100μm [16]. At relatively low v collision onto fine grains, their size would be responsible for the ejecta size; if the surface regolith particles may reflect size of ejected particles, particles with a few 10 - 100μm would be abundant in the dust torus. This size range, which should have large e_{max} due to radiation pressure and Martian oblateness, can sustain the dust torus.

Assuming the production efficiency of the same size dust η is larger than the unity, dust-satellite collision is now dust production mechanism and the dust torus is self-sustained. Then, change of dust size by dust-dust collision is the main dust loss mechanism. Under the particle-in-a-box approximation, mean number density of dust can be expressed as $n_d \sim (\eta - 1)(r_{sat}/r_d)^2/V$. For Phobos dust torus, we have the total number and surface number density of dust particles

$$n_d V \approx 1.6\times10^{17}\left(\frac{r_d}{30\mu m}\right)^{-2} \quad \text{and} \quad \frac{n_d V}{A} \approx 2.3\times10^{2}\left(\frac{r_d}{30\mu m}\right)^{-2} [\mathrm{m}^{-2}]$$

where A is the polar projection area of the torus. For Deimos torus where smaller dust can survive, we have

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$$n_d V \approx 4.9\times10^{17}\left(\frac{r_d}{10\mu\mathrm{m}}\right)^{-2} \quad \text{and} \quad \frac{n_d V}{A} \approx 8.3\times10\left(\frac{r_d}{10\mu\mathrm{m}}\right)^{-2}[\mathrm{m}^{-2}]$$

Optical thickness of the dust torus is also estimated. Along the direction perpendicular to the torus and along the direction parallel to the torus, we have

$$\tau_\perp \approx \frac{n_d V}{A}\pi r_d^{\,2} \approx 6\times10^{-7} \quad \text{and} \quad \tau_{//} \approx \tau_\perp\frac{2R}{H} \approx \frac{\tau_\perp}{i} \approx 3\times10^{-5}\left(\frac{i}{0.02}\right)^{-1}$$

respectively. Dependence on dust particle size is canceled out. The above estimate is compatible with the upper limit 3×10^{-5} by Viking Orbiter data. Dust detector and optical camera of PLANET-B are expected to clarify the existence of the Martian dust torus.

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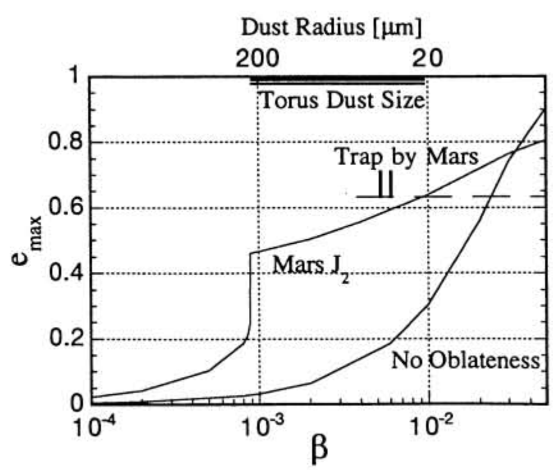

Fig. 1 Eccentricity amplitude e_{max} of Phobos dust particle under solar radiation pressure. When Martian oblateness (higher order of gravity potential J_2) is taken into account, e_{max} abruptly increases at $\beta = 0.00886$. When e_{max} is larger than 0.63, a dust particle is quickly lost by collision with Mars.

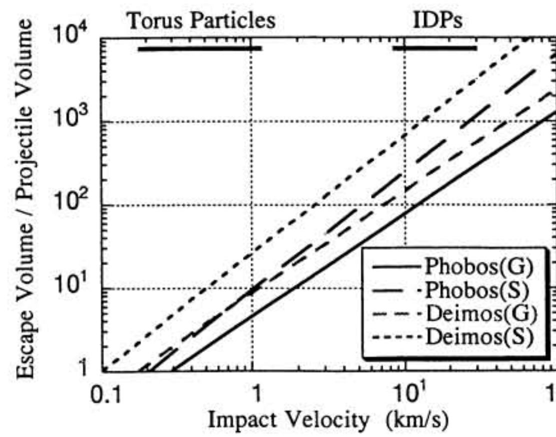

Fig. 2 Dust ejection and escape efficiency is described against impact velocity. Four cases are shown: "G-gravity regime" and "S-strength regime" collisions on Phobos and Deimos. Gravity regime denotes the case when satellite surface is regolith and gravity is dominant resistant force against dust ejection. Strength regime denotes the case when surface is rocky and fracture strength is resistant force [17].