Dust levitation about Itokawa's equator

C. Hartzell[1], M. Zimmerman[2], and Y. Takahashi[3]

[1]University of Maryland, College Park
[2]Applied Physics Laboratory
[3]Jet Propulsion Laboratory

Introduction: Electrostatic dust motion has been hypothesized to occur on the asteroids, due to the observations of the Eros dust ponds [1] and the potential presence of such a phenomenon on the Moon [2]. There are two phases of electrostatic dust motion: lofting and the subsequent trajectories. The feasibility of electrostatic dust lofting can be assessed by comparing the strength of the electrostatic force to the gravity and cohesion which hold the grain on to the surface [3–5]. The motion of the dust grains after they detach from the surface can be described as either ballistic, escaping, or levitating. We are interested in dust levitation because it could potentially redistribute grains on the surface of an asteroid (for instance, producing the Eros dust ponds) and it could also be hazardous to spacecraft. Specifically, levitating dust could obscure the observations of surface-based spacecraft or possibly trigger obstacle avoidance routines during landing.

Dust Levitation: Dust levitation is defined as the altitude oscillation of grains prior to their redeposition on the surface of an asteroid. Levitation occurs about equilibria where the electrostatic and gravity forces on the grain are equal and opposite. An equilibrium state is defined as a position and charge for a specific grain size. We have previously identified equilibria using a 1D plasma model and a simple gravity model for Itokawa [6]. In this simple model, the largest grain that was capable of stable levitation above Itokawa was 3 microns (in radius) [6]. Additionally, we have shown that levitating dust grains follow the variation in the equilibria for a rotating asteroid (i.e., the grain continues to oscillate about an equilibrium state that approaches the surface) [7]. Due to the nonspherical shape of Itokawa, both the gravity and plasma environments are much more complicated than the 1D approximations made in our previous work. Thus, in order to accurately assess the feasibility of dust levitation about Itokawa, we must include accurate plasma and gravity models. We use a 2D PIC code (described in [8]) to model the plasma environment about Itokawa's equator. The plasma model includes photoemission and shadowing. Thus, we model the plasma environment for various solar incidence angles. The plasma model gives us the 2D electric field components and the plasma potential. We model the gravity field around the equatorial cross-section using an Interior Gravity model [9]. The gravity model is based on the shape model acquired by the Hayabusa mission team and, unlike other models, is quick and accurate close to the surface of the body. Due to the nonspherical shape of Itokawa, the electrostatic force and the gravity may not be collinear.

Given our accurate plasma and gravity environments, we are able to simulate the trajectories of dust grains about the equator of Itokawa. When modeling the trajectories of the grains, the current to the grains is calculated using Nitter et al.'s formulation [10] with the plasma sheath parameters provided by our PIC model (i.e., the potential minimum, the potential at the surface, and the sheath type). Additionally, we are able to numerically locate the equilibria about which dust grains may levitate. Interestingly, we observe that equilibria exist for grains up to 20 microns in radius about Itokawa's equator when the Sun is illuminating Itokawa's 'otter tail'. This grain size is significantly larger than the stably levitating grains we observed using our 1D plasma and gravity models.

Conclusions and Future Work: The possibility of dust levitation above asteroids has implications both for our understanding of their evolution and for the design of future missions to these bodies. Using detailed gravity and plasma models, we are above to propagate the trajectories of dust particles about Itokawa's equator and identify the equilibria about which these grains will levitate. Using these simulations, we see that grains up to 20 microns in radius may be able to levitate about Itokawa's equator, which is significantly larger than had previously been considered. In the future, we plan to improve the fidelity of our grain-charging model by using plasma species densities rather than Nitter et al.'s model. Additionally, we will explore the stability of the numerically identified equilibria for a range of dust grain sizes.

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