THE FEASIBILITY OF ELECTROSTATIC DUST LEVITATION IN SMALL BODY PLASMA WAKES.

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Introduction: Electrostatic dust levitation has been hypothesized to occur at the Moon and other small airless bodies, such as asteroids [1,2]. We define electrostatic dust levitation to be the suspension and dynamics of dust grains above the surfaee of the host body. In order for levitation to occur, the electrostatic force on the dust grain must oppose gravity. The electrostatic force is produced by the interaction of the charged dust grain with the plasma sheath of the celestial body. While limited observational evidence for electrostatic levitation exists, this phenomenon could provide a means to relatively rapidly redistribute regolith about a small body, possibly producing features such as the Eros dust ponds [2]. Additionally, levitating dust, released from the surface due to either natural causes or spacecraft activities, could be hazardous to future surface exploration vehicles.

In prior studies, we have investigated the dynamics of dust grains about a spherical asteroid using a semi-analytical plasma sheath described by Nitter *et al.* [3, 4]. We have shown that stable dust levitation is possible for small grains (<10microns) close to the surface (<10m) of hypothetical spherical asteroids with masses ranging from the Moon to Itokawa [4]. The major simplification of our prior work, however, is the assumption of a spherical asteroid shape. The asteroid shape influences the gravity environment as well as the plasma environment. The semi-analytical plasma sheath model developed by Nitter *et al.* [3] was not designed to consider aspherical shapes nor to describe the complex environment near the terminator (dawn/dusk) region. Using a numerical plasma model (see [5]), we have been able to accurately model the plasma environment about the asteroid Itokawa, using the asteroid's shape model. Coupling the Itokawa's equatorial gravity and plasma environments, we have produced a highly accurate near-surface environment model. For a single orientation of Itokawa with respect to the sun, we have identified locations above the asteroid's surface where dust levitation may occur. In order to assess the significance of dust levitation, however, we must understand the dynamical stability of the levitating grains. We have shown [6] that dust levitation in the sunlit region of Itokawa is similar to our predictions using the spherical asteroid approximation. However, the possibility of dust levitation in the shadowed, wake region of the asteroid is unexpected and will be explored here.

Methods: Three forces are considered in our investigation of the near-surface asteroid environment: gravity, solar radiation pressure, and the electrostatic force. The gravity environment is modeled using the Interior Brillouin model from Takahashi *et al.* [7]. The gravitational acceleration is calculated about the equator of Itokawa using the shape model created by the Hayabusa mission and available in the PDS. A uniform density of 1.9 g/cc is assumed. Any gravitational accelerations out of the equatorial plane are ignored.

The solar radiation pressure is calculated following the development in [8]. Solar radiation pressure is only active if the grain is in sunlight. Complex shadowing is not considered – the radius of the shadowed region is assumed to remain constant with distance from the sun. We assume that Itokawa is oriented with its long axis along the x axis and that the sun is located on the –x axis. The analysis described here can be completed for any arbitrary orientation of the asteroid with respect to the Sun.

The plasma environment is modeled using a treecode numerical simulation (see [5] and [9]). Photoemission is considered. The model is capable of describing the plasma environment about the entire 2D asteroid cross-section, including the shadowed, wake region. As the dust grain charge is time- and space-varying, the current to the dust grain is calculated using the plasma species densities from the numerical simulation.

We identify where dust grains may levitate by identifying the equilibria of the system: for a specific grain size with a specific charge, at what altitude above the surface do the electrostatic and gravitational forces balance? Although this is a 2D model, we define the equilibria to occur when the acceleration normal to the surface is zero – i.e. the grains may be accelerated 'horizontally' above the surface, but not towards or away from the surface. Note that the state of the grain is described by it's position, velocity and charge. Thus, at the equilibrium state, both the normal acceleration of the grain and the current to the grain are zero. Additionally, we calculate the equilibria above the center of each facet of the shape model. From our prior work using the simplified plasma and gravity models, we have seen that, for a given grain size, grains may 'slide' between equilibria as the body rotates (and the associated plasma conditions change) [4,10], thus creating the possibility for long duration dust levitation.

It is necessary to evaluate the stability of the equilibria in order to assess the practical feasibility of levitation. Given the numerical nature of the plasma model used here, we numerically calculate the stability of the equilibria by taking the partial derivatives of the force and current equations with respect to variations in grain altitude and charge.

Results: We have identified the equilibria for a range of grain sizes about the asteroid Itokawa (see Figure 1).

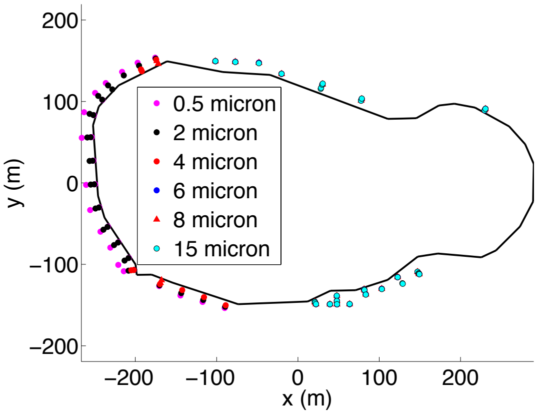

Figure 1. Locations where dust grains of varying sizes may levitate about Itokawa's equator. The sun is located along the –x axis, with the solar wind flowing from left to right. The large grains only appear to have equilibria in the wake (shadowed) region.

The equilibria heights and grain sizes in the sunlight region (the solar wind flows in the +x direction) agree quite well with predictions from our simplified plasma and gravity model investigations. However, our prior plasma models were unable to characterize the plasma wake region. In this region, we observe the possible levitation of dust grains as large as 15 microns.

When evaluating the stability of the equilibria in the wake region, we find that they are saddle points over the full range of grain sizes and altitudes. Since none of the equilibria appear to be strictly stable, it is unlikely that long term levitation in the wake region is possible. Interestingly, we also see variation in the *sign* of the charge of the equilibrium states above a given facet in the wake region. For a given electric field, grains of opposite signs are accelerated in opposite directions. Thus, variation in the sign of the equilibrium charges indicates a variation in the direction of the gravitational acceleration that must be opposed by the electrostatic force. The charge variation could also be due to resolution issues in our calculation of the electric field.

Conclusions and Future Work: Using the shape model of the asteroid Itokawa, we have combined realistic gravity, plasma and solar radiation pressure models to understand the dynamics of small dust grains above the surface. For the first time, we are able to study the dynamics of these grains in the plasma wake region. Although equilibria exist in the wake region, our preliminary stability analysis indicates that long-term dust levitation in the wake is not possible. We are currently improving our interface with the plasma model to eliminate resolution issues that may appear when we query the electric field. The new interface between these two models will allow us to conclusively assess the feasibility of dust levitation in the wake region.

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