On the Edgeworth-Kuiper Belt Dust Flux to Saturn

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Introduction

The Edgeworth-Kuiper Belt (EKB) produces approximately 3×10^7 tons/year of dust grains with radii between 0.1 and 10.0 μm through a combination of mutual collisions and bombardment by interstellar dust grains [1]. These grains migrate inward through the outer solar system under the combination of gravity, solar radiation pressure, solar wind drag, and the electromagnetic Lorentz force, forming a tenuous dust halo extending from the orbit of Jupiter out past the classical EKB, and in turn, EKB-generated grains are believed to be the dominant species of dust from Saturn outward [2].

The influx of EKB dust grains into the saturnian system drives or influences several physical phenomena, depending on if the grain impacts the planet, one of Saturn's satellites, or the main saturnian ring system. Grains that strike either the planet or Titan directly will ablate in the saturnian or titanian atmosphere, depositing neutral and ionospheric layers [3], which in turn alter the atmospheric chemistry of both Titan and Saturn in distinct ways [4]. If the grain strikes one of Saturn's airless satellites, the impact will typically eject surface material with mass yields greater than unity. The ejected grains will form dusty exospheres or tenuous dust rings, including, for example, the recently-discovered ring originating from Phoebe [5], and the arcs associated with the small saturnian moons Methone, Anthe, and Pallene [6]. Finally, grains that strike the main saturnian ring system can induce spatial and compositional changes, including erosion of the C ring, mass and angular momentum transport between the various rings, and shaping of the A and B ring edges [7, 8, 9]. Compositional and color changes in the rings are induced by the introduction of "polluted", non-icy material from impacting micrometeorites and such changes can be used to estimate the age of the main ring system [9].

Model Description and Results

In order to calculate the influx of micron-sized, EKB-generated dust grains into the saturnian system, we have employed the results from a dynamical dust grain tracing model, described in detail in [1]. The model consists of a series of equilibrium density and velocity distributions with $1 \times 1 \times 1$ AU resolution for each of eleven grain sizes, $a_d = [0.5, 1.0, 2.0, ..., 9.0, 10.0]$ μm. The absolute density for each grain size is established by using an overall mass production rate of 8.9×10^5 g/s and a differential mass production distribution, $d\dot{M}/dm = \dot{M}_o(m/m_o)^{-\alpha/3}$, where $\dot{M}_o$ is a constant, $m_o = 10^{-11}$ g, and $\alpha = 3.02$ [1]. Figure 1 shows the relative density of 10 μm grains in the Neptune-rotated frame in the ecliptic x-y and x-z planes with the trajectory of Saturn (in the same frame) over plotted for comparison, showing that Saturn resides well within the EKB dust halo.

We follow Saturn's trajectory in the Neptune-rotated frame and interpolate the dust grain density and velocity distribution from the nearest $1 \times 1 \times 1$ AU grid points for each grain size and type. The dust grain velocities are vectorially added to the saturnian velocity at each point in order to establish the impact velocity distribu-

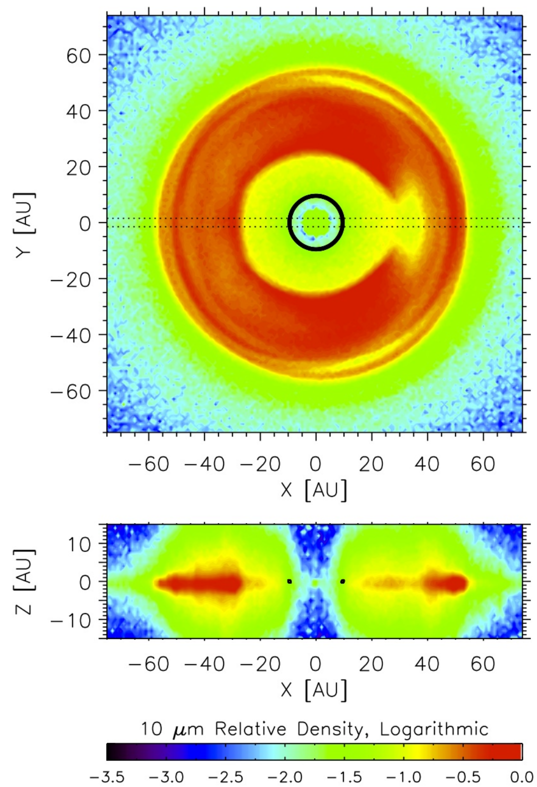

Figure 1: Relative, logarithmic model densities of 10 μm EKB grains seen from above the ecliptic and the side view for the cut denoted by the dashed lines. Saturn's orbit is over plotted in black.

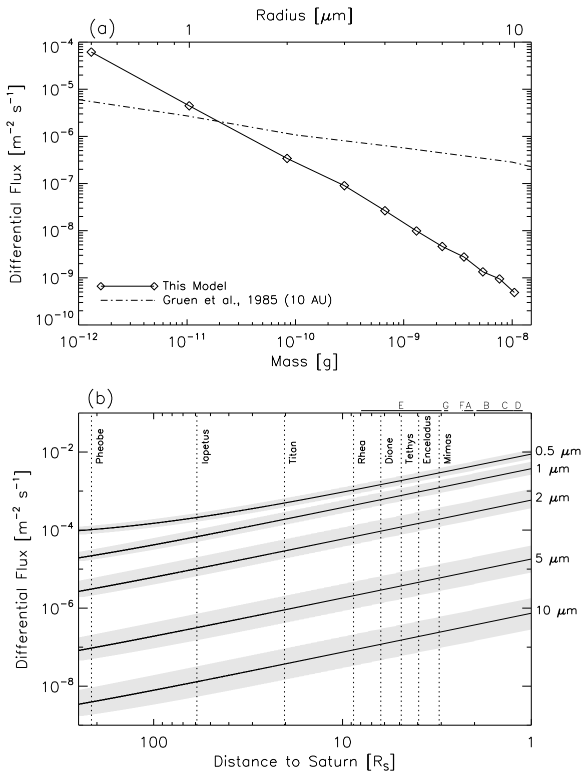

Figure 2: (a) Differential EKB dust flux to Saturn as a function of grain radius. (b) Gravitationally-focused EKB dust grain flux as a function of distance from Saturn for a selection of grain sizes.

tion into Saturn at infinity. The differential influx at each grain size is determined by the product of the EKB grain density and the impact velocity. Figure 2(a) shows the differential flux of EKB-generated grains into Saturn as a function of grain radius before any local gravitational acceleration or focusing. For comparison, we also show the differential flux from the *Grün et al.* [10] model at 1 AU, appropriately scaled to 10 AU. The discrepancies between the two models is not necessarily surprising, given that the *Grün et al.* model is based on measurements at 1 AU and knowingly does not include any information about dust grain sources and dynamics in the outer solar system.

To calculate the EKB dust grain flux at any point *within* the saturnian system, we must account for the increase in cross section for each grain size that results from the acceleration of dust grains into Saturn's gravity well, $G^a(r) = 1 + (v_{esc}(r)/v^a_\infty)^2$, where $v_{esc}(r)$ is the escape velocity as a function of distance from Saturn, r, and v^a_∞ is the grain impact velocity at infinity [11, 3]. Figure 2(b) shows the differential flux for a selection of EKB dust grain sizes as a function of distance from Saturn, taking into account the cross sectional increase. The flux at each grain size increases at least by two orders of magnitude from infinity to Saturn's cloud tops, and in turn, each of Saturn's moons and rings will experience different fluxes and velocity distributions given their differing orbital distance from Saturn.

While this model is based off of in-situ observations of dust grain density in the outer solar system, we also aim to compare our model with measurements by the Cassini Cosmic Dust Analyzer (CDA), currently making measurements of endogenous and exogenous dust grains in the saturnian system [12].

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