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A new model of the lunar ejecta cloud: implications for *in situ* dust measurements

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Abstract

We apply a recent model of the cloud of ballistic impact ejecta surrounding an airless body [1] to the lunar case. For power-law-distributed ejection speeds [2, 3, 4], we identify regimes where the height and the speed distribution of ejecta are approximately power-law functions that directly depend on the exponent of the ejection law. Likewise, key features of the distribution of a particle's speed with respect to an orbiting spacecraft depend sensitively on the ejection zenith angle. Measurements at those regimes can therefore constrain the ejection physics.

Introduction

Every airless body in the solar system is surrounded by a cloud of ejecta produced by the impact of interplanetary meteoroids on its surface [5]. Such "dust exospheres" have been observed around the Galilean satellites of Jupiter [6, 7]. The prospect of long-term robotic and human operations on the Moon by the US and other countries has rekindled interest on the subject [8]. This interest has culminated with the recent investigation of the Moon's dust exosphere by NASA's *LADEE* spacecraft [9].

The most detailed models to-date [3, 4] have focused on measurements at relatively high altitudes ($\geq$ a few tenths of a satellite radius $- R_S$). Exploiting new datasets requires models that focus on the low-altitude ($\lesssim 0.1 R_S$) regime.

Model Predictions

A new model of a ballistic, collisionless, steady state population of impact ejecta was presented in [1]. For grains launched vertically with speed v_L distributed according to the law

$$p(>\mathrm{v}_L) = (\mathrm{v}_L/\mathrm{v}_0)^{-\gamma}, \mathrm{v}_L > \mathrm{v}_0 \quad (1)$$

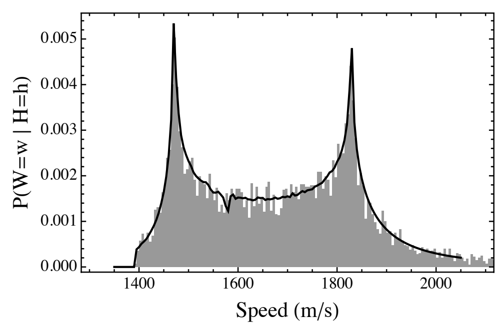

Figure 1: Probability density function of grain impact speed on a low-altitude lunar orbiter. See text for details.

where v_0 & γ are model parameters [2, 3, 4], the model furnishes closed-form expressions for the probability density functions (pdfs) of grain altitude $p(h)$ and grain speed at a given altitude $p(\mathrm{v}|h)$. The functional forms of these pdfs show that both (a) the *altitude* distribution of grains, and (b) the grain *speed* distribution near the surface, follow a power-law with an exponent that depends on γ. The result holds even if non-vertical ejection is imposed.

The model also treats the statistics of grain motion relative to a moving platform such as an orbiting spacecraft. Fig. 1 shows the pdf (bold curve) of the grain impact speed w on a platform moving horizontally at a speed and altitude typical of a low-altitude lunar orbiter: $u = 1650$ m sec^{-1} and $h = 30$ km. The ejection zenith angle z has been set to 30 degrees. The grey bars represent a snapshot of the w-statistics of 10^7 particles ejected with randomly-distributed speeds following the pdf in Eq. 1. The two-pronged shape is due to the non-vertical ejection (i.e. $z \neq 0$) with the two peaks merging into one as $z \to 0$.

Implications and Future Work

The raison d'être of any model is to interpret measurements and understand the physical processes at work. The model presented here is probabilistic (i.e. normalised to integrate to unity) therefore verifying its predictions does not require absolute measurements.

If a power-law ejection speed distribution is physically realistic, the model predicts that the steady state distribution of grain altitudes in the first instance, and that for the speeds of near-surface grains in the second, are related to each other and to the exponent of this power law. Future measurements from landers combined with data from *LADEE* would therefore form a strong observational test of Eq. 1. Moreover, accurate orbital measurements of grain speed within the ejecta cloud combined with models such as that in Fig. 1 can constrain the ejection zenith angle of grains.

Future improvements to the model will include a dependency of the ejection speed on grain size and a probabilistic distribution of ejection angles. This will increase its predictive power and allow to place additional constraints on the dust population.

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