Small Lunar Crater Ray Geometry and Target Topography. K. S. Martin-Wells[1] and J. Partee[1], [1]Ursinus College (Pfahler Hall, 601 E. Main Street, Collegeville, PA 19426, kmartinwells@ursinus.edu).

Introduction: Investigations of lunar crater rays have revealed key insights not only into the formation and preservation of rays themselves, but also the role that rays play in distributing and mixing primary ejecta with local material [e.g., 1-6]. As such, an understanding of lunar rays is essential to understanding the evolution of the surface not only of the Moon, but other airless bodies. Sabuwala et al. [2018] determined a relationship between topographic undulations of pre-impact target surfaces in granular cratering experiments and the number of rays of the resulting craters [7]. In this work, we aim to investigate the extent to which this trend is measurable in actual lunar impact craters.

Background: Combining low-velocity granular cratering experiments and simulations of hyper-velocity impacts into granular targets, Sabuwala et al. [2018] addressed a long-standing puzzle in granular cratering experiments—what could account for the lack of prominent rays produced, and what could their absence tell us about the origin of rays in the impact cratering process? They observed a linear relationship between the wavelength of undulation of the pre-impact surface, λ, the size of the impactor, D, and the number of prominent rays observed, N [7].

Previous to Sabuwala et al. [2018], granular cratering experiments had not reproduced the prominent rays of impact craters on planetary surfaces. Such experiments resulted instead, in axisymmetric distributions of the granular ejecta. By observing impacts into pre-impact surfaces with regular, hexagonal depressions of wavelength, λ, their experiments produced N prominent rays [7]. Using simulations of hyper-velocity impacts into granular targets, Sabuwala et al. [2018] found that N did not depend on whether impacts were low-velocity or hyper-velocity. As with the laboratory experiments, impacts into smooth surfaces at hyper-velocity did not produce prominent rays; hyper-velocity impacts into targets with regular undulations did [7].

Sabuwala et al. [2018] proposed a simple geometric model to explain the dependence of N on the dimensionless ratio, D/ λ. Specifically, they proposed that the number of low-points ("valleys") within the target undulations that intersected with the edge of the impacting ball explained the number of resulting prominent rays. In short, an axisymmetric flow field at the smooth target surface produces an axisymmetric distribution of granular ejecta. On an undulating target surface, a non-axisymmetric flow field arising from the side-walls of these valleys focuses granular ejecta into rays [7]. They explained the variations in slopes between N and D/λ observed in their experiments and simulations by the fact that the number of these intersections can vary slightly, depending on the exact placement of the impactor within the pattern of undulations.

By tracing the paths of granules in their simulations, Sabuwala et al. [2018] found that the ray particles originated from a narrow annulus straddling the edge of the impacting ball during the early-time interaction of the impactor with the target. Distal ejecta has long been understood to reflect early-time interactions between impactor and target, thus reflecting asymmetries in impact conditions [8]. Similarly, the degeneracy between projectile velocity and size on energy-scaling properties is a well-known problem. To this end, Sabuwala et al. [2018] applied their observed linear relationship between N and D/λ to estimate the diameter of the impactor associated with the lunar crater, Kepler. They estimated a projectile diameter of D = 3.4 km, within a factor of two of the D = 2.5 km quoted from scaling laws [7]. In this work, we hope to extend these results to investigate the relationship between N, D, and λ for small lunar primary craters with well-preserved ray systems.

To do so, we aim to identify a statistically significant sample of lunar craters with ray systems in preservation states that likely reflect the initial distribution of rays. That is, we aim to avoid craters with partially preserved ray-systems, as the erasure of some but not all rays might affect any conclusions drawn about target topography and the distribution of rays. In order to best satisfy these aims, we have focused our search to date on small (D < 5 km), fresh lunar craters. We have limited our investigation to small craters in order to increase the number of candidates and to fresh craters to increase the likelihood that their ray systems have not been erased due to space weathering.

Data Collection: We have been using LRO Diviner Rock Abundance maps in the LROC Quickmaps utility to identify these craters. Specifically, we've been looking for craters with elevated rock abundances that extend inside and outside of the crater rim, to avoid signatures resulting from mass wasting down the steep slopes of interior rims, rather than the presence of blocky continuous ejecta blankets, which we are using as a proxy for crater freshness. Small craters with bright rays in LROC NAC mosaics available on the Quickmaps tools have also been included in the list of potential candidates for evaluation. To date, we have identified over a hundred potential craters for study. The candidate selection and data gathering process for this study is ongoing. Because of the nature of impact crater ray retention, different datasets will reveal different structures of the rays [e.g. 6, 9]. For this reason, we also plan to map the ray systems of our small craters in LRO Mini-RF mosaic data.

Sabuwala et al. [2018] estimated the undulations of the pre-impact target surface for lunar craters by extracting concentric topographic profiles from annular regions within 1.5 and 2 crater diameters from the crater centers in SLDEM 2015 elevation data [10]. We intend to employ the same procedure, but also drawing from LROC DTMs, where available [11].

Future work: We aim to expand this survey to include lunar Copernican craters in both the simple and complex regimes; in mare and highlands targets; and in the strength and gravity regime, in order to assess whether these factors play any role in the number and orientation of the rays associated with these craters, or if the simple N vs. D/λ relationship from the experimental and simulation investigations holds across these regimes [7]. For larger craters with longer ray preservation ages, we intend to avoid the use of craters with mainly compositional rays, since the loss of immaturity rays due to space weathering may not preserve the initial distribution of the rays, as controlled by pre-impact conditions, but would, instead, reflect long-term effects of erosion.

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