

Size - Distance - Velocity Analysis of Occator Secondary Craters. N. Schmedemann¹, A. Nathues¹, G. Thangjam¹, ¹MPI for Solar System Research, Justus-von-Liebig-Weg 3, 37077, Göttingen, Germany (schmedemann@mps.mpg.de).

Introduction: The Dawn spacecraft [1] is in orbit about Ceres since March 6, 2015. The spacecraft transmitted data from the dwarf planet until the end of October 2018. Ceres is the only dwarf planet in the Main Asteroid Belt and orbits the Sun at a semi-major axis distance of ~ 2.8 AU. During the Low Altitude Mapping Orbit (LAMO) the cerean surface has been globally mapped several times by the Dawn Framing Camera (FC) [2] in order to deliver enough imaging data (~ 35 m/pxl) for the generation of digital elevation models (DEM), derived from stereo-photogrammetric computations [3]. Previous analysis of the FC imaging data [4,5] indicated that the cerean surface is peppered with secondary craters more densely than expected. This observation may point to unique material properties of the cerean regolith. In this work we apply impact ejecta modelling [4,5], crater morphology and crater size - frequency distribution (CSFD) analysis in order to understand relationships between projectile flight distance, impact velocities and resulting crater size.

Methodology: The methodology of our ejecta model is detailed in [4,5]. Our model provides the distance of ejecta particle flight paths in space and the impact velocities of ejected particles at a given location. In order to discriminate between secondary and primary craters, we measure the crater depth-diameter ratios which are expected to be shallower for secondary craters if compared with primary craters. The respective DEM is computed from LAMO imaging data by using the Ames Stereo Pipeline [6]. The CSFD analysis follows the standard techniques described in [7,8].

Preliminary Results: Fig. 1 shows three areas each covered by one LAMO clear filter image and the modelled trajectories of particles which were ejected from Occator crater and impacted in the mentioned areas. An ejection angle of 30° with respect to the local surface plane was chosen such that the resulting trajectories align as well as possible with the observed secondary crater chains pointing to Occator. According to our model most of the particles flew directly from Occator to their points of impact. A small number of particles that were ejected at significantly higher velocities were deflected relative to the cerean surface by Coriolis effects caused by the relatively fast rotation of Ceres. The average impact velocities in areas 1 – 3 amount to $206 (+/- 27)$ m/s, $232 (+/- 19)$ m/s and $284 (+/- 78)$ m/s respectively. The length of the ground path

of direct trajectories are approximately 210 km, 280 km and 350 km for areas 1 – 3, respectively.

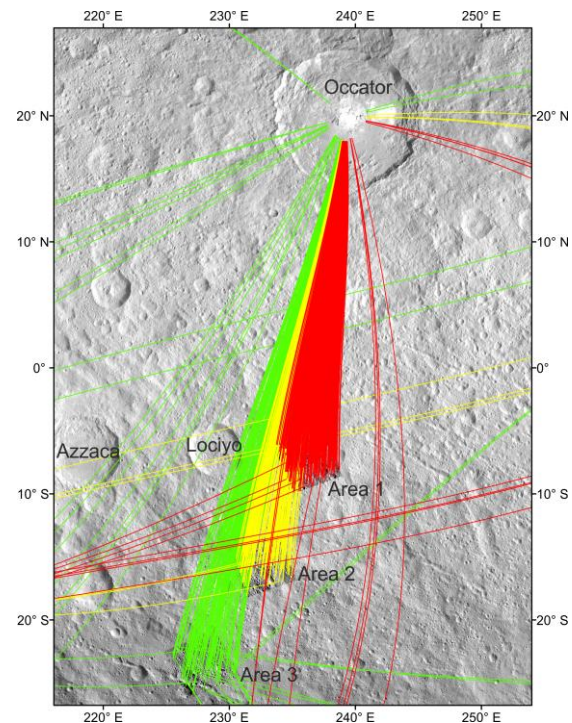


Fig. 1: Clear filter basemap of Ceres superimposed by individual LAMO images in areas 1 – 3 and trajectories for particles that impacted in area 1 (red), area 2 (yellow) and area 3 (green).

Fig.2 shows the measured CSFD of areas 1 – 3 in a differential crater plot. Interestingly craters ≥ 1.2 km follow the lunar derived isochron [10] for a surface model age of 1.5 Ga. Smaller craters are observed less frequently than expected from the frequencies of the large craters (≥ 1.2 km). This could be a result of resurfacing of the areas due to ejecta blanketing from two large relatively pristine craters Azzaca and Lociyo, located west of the measured areas. Indeed the resurfacing effect is strongest in area 1 which is located closest to Lociyo crater. In addition, all areas are located in the range of the 150 km diameter Urvara crater ejecta blanket. Since all these craters are younger than 1.5 Ga, the shallow CSFD for craters ≤ 1.2 km is not necessarily in contradiction to usually steep distributions of secondary craters.

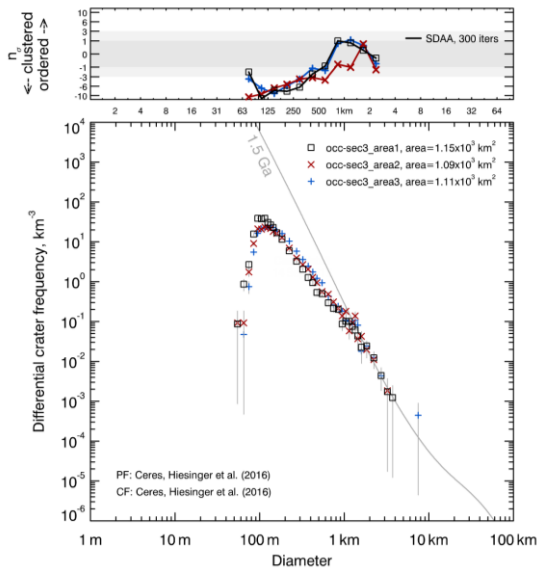


Fig.2: Upper Panel: SDA Randomness analysis [8]. Craters smaller than ~ 300 m diameter show clear clustering, typical for proximal secondary craters. Lower Panel: Differential crater distributions for areas 1 – 3.

The comparison of the three CSFDs, in the size range $\lesssim 0.5$ km further shows that crater frequencies in area 3 are consistently higher than in the other two areas. Similarly, frequencies in area 2 plot slightly higher than in area 1 but below that of area 3. This could be an effect of increasing impact velocities with increasing distance to the source crater, which would result in larger craters assuming the same projectile size. Together with steep crater distributions, typical for secondary craters this effect would translate to higher frequencies at a given crater diameter. Basically this is the result of shifting the secondary crater distribution towards larger crater diameters due to higher impact velocities. At the same time it is expected that projectiles that are ejected at higher velocities are also smaller than lower velocity projectiles [9]. Hence, more distant craters are expected to be smaller, because the respective projectiles were ejected at higher velocities. In addition, it is expected that many more ejecta particles are deposited close to the source crater than further away, as can be seen in the exponential outward thinning of ejecta blankets. In fact our ejecta model predicts a ejecta particle density ratio between area 1 and area 2 of 2.5 and between area 1 and area 3 of 3. Both effects counteract the increased crater sizes due to higher impact velocities at larger distances. Judging from the measured CSFDs the velocity effect appears to outweigh both, smaller secondary projectiles at

higher ejection velocities and more secondary impacts closer to the primary crater.

This Analysis does not yet discriminate between primary and secondary craters. Thus, the results stem from all craters mapped in the study areas.

References: [1] C. T. Russell, et al., *Science*, 353, 1008 (2016). [2] H. Sierks et al. (2011) *Space Science Reviews*, 163, Issue 1-4, pp. 263-327. [3] Preusker F. et al. (2016) *LPSC*, 47, Abstract 1954. [4] N. Schmedemann N. et al. (2018) *LPSC*, 49, Abstract 2083. [5] N. Schmedemann et al. (2018) *EPSC*, 12, Abstract EPSC2018-998. [6] Ross A. Beyer, Oleg Alexandrov, and Scott McMichael. 2018. *Earth and Space Science*, 5. <https://doi.org/10.1029/2018EA000409>. [7] R. E. Arvidson, et al., *Icarus*, 37 (2), pp. 467-474. [8] G. G. Michael, et al., *Icarus*, 218 (1), pp. 169-177. [9] H. J. Melosh, *Book, Impact cratering : a geologic process*, New York : Oxford University Press ; Oxford : Clarendon Press, 1989. [10] H. Hiesinger, et al., *Science*, 353, 1003 (2016).