SHOCK MELTING, CRATER FORMATION, AND EJECTA DISTRIBUTION IN THE 17TH MARCH 2013 LUNAR IMPACT EVENT.

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Introduction: The flux of small bodies in the size range of 10-50 m in the Earth-Moon System is suggested to be higher by one order of magnitude than predicted by current estimates based e.g. on the lunar crater record [1]. Thus, further observations are necessary for constraining the small body population. The method of ground based lunar impact flash observation covers a large detection area on the Moon with only one instrument. The size of an impactor is estimated by the intensity of the flash, which is related to its kinetic energy. However, the correlation of flash energy and duration with the impact process and impact energy is poorly understood. We use the unique case of the only detected impact crater that is assumed to correspond to an impact flash (March 17, 2013) [2] to study the vapour and melt production and to constrain the impactor energy based on the crater, including target properties.

Methods: We compare different recent LRO-NAC images and measured the rim diameter of the crater and derive digital elevation models (DEM). From the DEMs and photoclinometry, we determined a crater profile and estimated the crater depth from the rim height. Based on these observational constraints, we modeled the crater formation with the iSALE 2D code [3,4,5] for an impact velocity of 8.5 km/s and various projectile masses to constrain the kinetic energy of the impact. We assumed a smaller velocity to minimize the CPU time required to run the models until a late stage of crater formation. The projectile material as well as the target are simulated with an ANEOS for basalt [6]. A Drucker-Prager strength model describes the behavior of granular materials with and without cohesive strengths with the strength $Y = \min(Y_0 + \mu\, p;\, Y_m)$, where Y_0 is the cohesion at zero pressure, μ is the coefficient of internal friction, p is the pressure and Y_m is the limiting strength at high pressure. We choose a coefficient of friction (~1.0) according to literature values for lunar soil [7]. The cohesion is set to zero, a typical estimate for sand-like material. We assumed a target porosity of ~40%. Due to the high crater efficiency (i.e. final crater diameter much bigger than the projectile size), a resolution of 10 cells per projectile radius (CPPR) was selected. In a first series, the models were stopped when the transient crater was reached. Those runs that reproduced the observed depth and diameter best, we re-ran at higher resolution of 40 CPPR to study the peak shock pressure distribution. The shock pressure required for melting of porous and solid basalt are estimated to be 65 GPa and 115.5 GPa and larger, respectively [6,8]. We analysed the mass of molten material, its distribution, and determined the fraction of highly shocked material that is expelled from the crater. Radiation originating from shreds of molten ejecta may also contribute to the observed bright impact flash [9] that is usually associated with vaporized projectile and target material.

Results: The rim diameter of the crater is on average of 18.6 ± 0.2 m (1σ). From photoclinometry, we get a maximum rim-to-floor crater depth of 4.6 ± 0.6 m. The radial crater profile determined by 6 points between crater center and crater rim suggest a parabolic shape. A parabola fit gives: $d(r) = 4.7r^2 - 4.4$ with depth d and radius r (R^2=0.94). We find a good agreement with our models in terms of rim diameter (18.4 m) and depth (4.4 m) for a projectile with a mass of 285.9 kg and a kinetic energy of 1.03×10^{10} J. For impact velocities of 12 km/s, 17 km/s and 25 km/s we find a mass of shock molten material of ~277 kg, ~543 kg and ~408 kg, respectively, that is partly ejected.

Discussion: Measuring the crater dimensions is limited by the resolution of the LROC-NAC images (~1.2 m). However, measuring the diameter on several images by best fit circles improve our observational results even at sub-pixel resolution and we report the results with standard deviations for our measurements. The diameter measurement agrees within this standard deviation with the results from [3]. Our value of depth does deviate from previous estimates by 1.6-2.6 m, possibly due to limited data resolution. The projectile characteristics we determined in the impact simulations agree with the previous mass and energy interval. The amount of molten material first increases with impact velocity from 12 km/s to 17 km/s. However, for 25 km/s the amount of molten material decreases again due to the smaller projectile size. Further studies including different target cohesions and a vapour plume are ongoing. We aim at further specifying characterisitcs of the impact plume (as e.g. amount of melt, or temperature of vapour) for several impact scenarios.

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