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How the Distribution of Impact Ejecta may explain Surface Features on Ceres and Saturnian Satellites

N. Schmedemann(1), A. Neesemann(1), F. Schulzeck(2), K. Krohn(2), I. von der Gathen(2), K. A. Otto(2), R. Jaumann(1,2), R.Wagner(2), G. Michael(1), C. A. Raymond(3), C. T. Russell(4)
(1)Institute of Geological Sciences, Freie Universität Berlin, Berlin, Germany; (2)German Aerospace Center, Institute of Planetary Research, Berlin, Germany; (3)JPL, Caltech, Pasadena, CA, USA, (4)University of California, Los Angeles, CA, USA. (nico.schmedemann@fu-berlin.de)

Abstract

The numerical simulation of impact ejecta on Ceres shows deposition patterns in very good agreement with observed anomalies in color ratio data as well as the location and orientation of secondary crater chains. Secondary craters are also observed on the Saturnian satellites Rhea and Tethys where the same approach could help to improve the analysis of the cratering records.

1. Introduction

Since March 6 2015 the Dawn spacecraft [1] has been in orbit around the dwarf planet Ceres. High resolution global mapping with its Framing Camera (FC) [2] revealed a much more densely cratered surface than expected [3]. At small (< 10 km) crater diameters Ceres appears to be peppered with secondary craters that often align in chains or form clusters. Some of such possible crater chains follow curved geometries and are not in a radial orientation with respect to possible source craters [4]. Ceres is a fast rotating body (~9 h per revolution) with comparatively low surface gravity (~0.27 m/s²). Thus, the distribution pattern of the back-falling ejected material is heavily affected by Coriolis forces that results in a highly asymmetrical and curved pattern of secondary crater chains.

2. The Model

In order to simulate flight trajectories and the distribution of impact ejected material for individual craters on Ceres we used the scaling laws by [5] adjusted to the Cerean impact conditions, the impact ejecta model by [6] and for more sophisticated simulations regarding the ejection angles the modified Maxwell Z-model by [7]. These models provide the starting conditions for tracer particles in the simulation. The trajectories of the particles are computed as n-body simulation. The simulation calculates the positions and impact velocities of each impacting tracer particle with respect to the rotating surface of Ceres, which is approximated by a two-axis ellipsoid. Since high and far flying particles reach significant fractions of the escape velocity, disturbing gravitational forces by the Sun and the major planets are also taken into account. In the model we assume an impact with an angle of 45 degrees and a symmetric geometry for the ejected particles. The scaling parameters for the projectile-crater size conversion are given in [8] (LDM model). The more simplistic model further assumes that all particles are ejected at a fixed angle with the local surface (in general 45°). All particles that are ejected at lower velocities than 150 m/s are neglected, because they are deposited fairly symmetrical around the source crater (continuous ejecta) but due to the high number of particles take most of the computing time. The value of 150 m/s is chosen because this might be the lower limit for forming secondary craters [9].

3. Results

Initial results of the more simplistic model show a number of interesting features in the deposition geometries of specific craters that are roughly in agreement with features that can be observed in FC imaging data of the Cerean surface. Fast jets that leave the source crater at low ejection angles appear to form systems of rays around fresh impact craters. In the case of Occator one of such rays can be mapped half way around the circumference of Ceres in color ratio data. Our ejecta model is able to reproduce this feature if a narrow beam of particles is assumed to leave Occator crater at a shallow angle of 10° w.r.t. the local surface at an azimuth of 256° (Figure 1, top and middle panel). Areas of high tracer particle density of the Urvara impact coincide with observed crater chains that are not in a radial orientation to any nearby crater (Figure 1, bottom panel). Particles that are ejected faster than a certain velocity into the rotation direction of Ceres are overtaken by the rotation of Ceres during their flight. This effect is causing a slowing down of the eastward propagation speed of the back-falling ejecta curtain and eventually the direction is reversed, such that eastward-ejected particles are falling back into and west of the source crater. For the case of the Urvara impact the curved geometry of the border line where the ejecta curtain changed its propagation direction can be identified in color ratio data (Figure 1, top and bottom panel). The higher color ratio closer to Urvara further indicates a relatively young age for the ejecta deposition time [10]. For the Saturnian satellite Tethys we find good agreement with Telemachus' secondary crater chains south-west of the Odysseus basin, which cross-cut Odysseus secondary crater chains.

4. Conclusions

Our ejecta simulation is able to give reasonably good indication of how specific features in color ratio data and certain crater chains might have formed. The simulations are primarily visualizing the probability for secondary cratering and ejecta accumulations by the spatial density distribution of tracer particles pictured by kernel density maps (Figure 1, bottom panel). The ejected volume of specific craters is limited. Thus, individual tracer particles are not representative for individual secondary projectiles or craters. In this study, we model symmetric ejection geometries at fixed ejection angles in order to understand the basic effects of high Coriolis forces. The more sophisticated modified Maxwell Z-model can be used in future work for simulating oblique impacts causing asymmetric ejection geometries.

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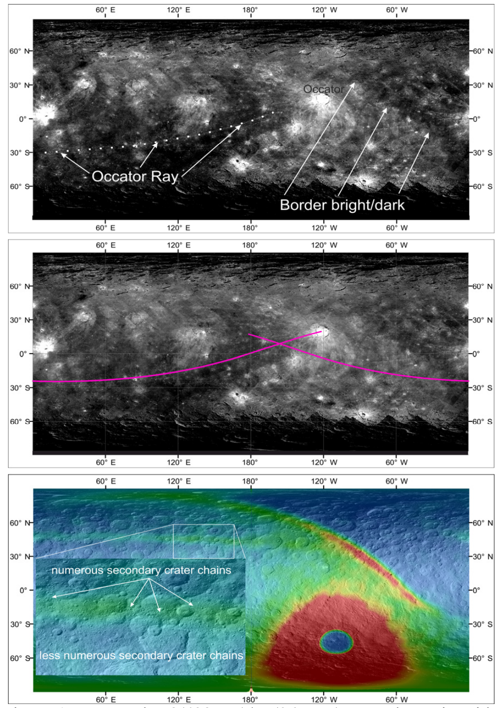

Figure 1, top panel: F8(438 nm)/F5(965 nm) FC color ratio with marked ray of Occator crater and a border between high/low color ratio. Middle panel: Trajectory of tracer particles that are ejected from Occator at 10° angle with the local surface and 256° azimuth with velocities of ≤ 510 m/s. Bottom panel: Kernel density map of the positions where tracer particles reimpacted on the surface after they were ejected during the Urvara impact. Colors indicate the relative particle density from low (blue) to high (red). The inlay shows a magnified clear filter version of the boxed area. The inlay confirms several E-W oriented crater chains where the kernel density map also indicates an E-W oriented narrow band of increased tracer particle density. The dark/bright boundary from top panel is coinciding with high densities of eastward-ejected particles.

References

[1] Russell C. T. et al.: *Science*, 353, 1008 (2016). [2] Sierks H. et al.: *Space Science Reviews*, 163, 263 (2011). [3] Bland M. T. et al.: *Nature Geoscience*, 9, 538 (2016). [4] Scully J. E. C. et al.: *American Astronomical Society, DPS meeting #48*, id.321.02 (2016), Pasadena, USA. [5]. Ivanov B. A.: *Space Science Reviews*, 96, 87 (2001). [6] Housen K. R. and Holsapple K. A.: *Icarus*, 211, 856 (2011). [7] Anderson J. L. B. et al.: *Meteoritics and Planetary Science*, 39, 303 (2004). [8] Hiesinger H. et al.: *Science*, 353, 1003 (2016). [9] Bierhaus E. B. et al.: *Icarus*, 218, 602 (2012). [10] Schmedemann N. et al.: *GRL*, 43, 11987 (2016).