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The issue of secondary craters on Ceres for the example of the Ahuna Mons region

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Abstract

Ceres shows an unusual high fraction of crater clusters and crater chains, unprecedented among other asteroidal bodies. It appears that even relatively small craters on the order of 16 km diameter are able to produce a formidable amount of secondary craters stretching out over at least 300 km or 1/10 the Cerean circumference around the crater. Due to Ceres' relatively fast rotation and related Coriolis effects as well as the body's low surface gravity, a significant amount of ejecta is falling back to the surface far from its source crater in a highly asymmetrical distribution. The modelled ejecta distribution pattern predicts certain areas of increased secondary crater density consistent with observations.

1. Introduction

Since March 2015 the Dawn spacecraft is in orbit around dwarf planet Ceres [1]. High resolution imaging data of the Framing Camera (FC) [2] from the low altitude mapping orbit (LAMO) revealed a densely cratered surface [3]. Large basins that likely formed early in the Cerean history are absent or at least muted to a degree of quasi-circular depressions [3], [4]. Crater morphologies very similar to those of the icy satellites in the outer Solar system [3], geophysical investigations [5] as well as spectral observation of volatiles [6] indicate relatively high amounts of water ice that likely governs the rheological behavior of the crustal material [7]. Its properties in conjunction with the Cerean surface gravity in the same range as those of Vesta and the mid-sized Saturnian icy satellites may also support the formation of wide-spread secondary craters. The cratering record of planetary bodies is often used in order to determine their geologic histories. Secondary cratering and other geologic processes can affect the cratering record such that a reasonable age determination becomes challenging. Due to ambiguous reasons Ceres appears to be densely peppered by secondary craters that make surface age determination by the classic approach of analyzing the crater size - frequency distributions of geologic units very difficult. Here we will investigate secondary craters in the region of Ahuna Mons on Ceres.

2. Ejecta Modelling

In order to better understand the spatial distribution of potential secondary craters we model the flight trajectories, impact locations and impact speed of ejecta tracer particles that were ejected from a primary impact crater on Ceres [8]. Previous work demonstrated that the used ejecta model is capable to explain certain features of global scale in color ratio imaging data [8]. The model incorporates crater – projectile scaling [9] and crater ejecta scaling [10]. It takes the rotation of Ceres into account and propagates the particle trajectories as n-body simulation under the influence of the Cerean' gravity as well as the gravitational disturbances of the Sun and the major planets.

3. Results

Figure 1 shows a region north-west of Ahuna Mons with indications of secondary crater chains and crater clusters. In this region, at least two prominent directions (NW – SE; SW – NE) of secondary crater chains can be identified which likely belong to two independent sources. While the source of the chain system in NW-SE direction is unknown, the perpendicular oriented system appears to be consistent with modelled ejecta trajectories of an unnamed crater at 279°E longitude and 23°S latitude.

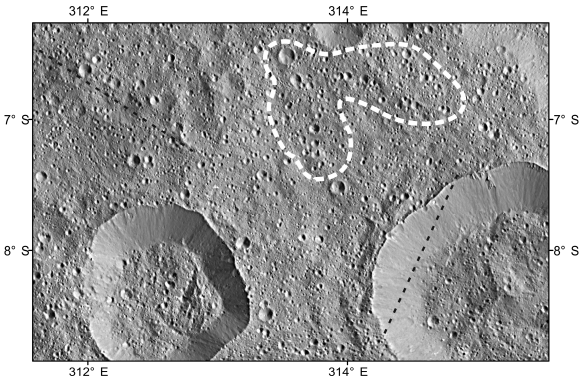

Figure 1: Dawn FC clear filter mosaic. The large crater at the lower left has a diameter of 11 km. The black dashed lines indicate predominant directions of secondary crater chains. The white dashed line outlines an area of unusual high density of similar sized craters, which is characteristic of a secondary crater cluster.

The outlined crater cluster (Figure 1) contains significantly larger craters than the crater chains and requires a larger primary source crater. In fact the presented region is located exactly where the eastward ejected material from Urvara crater is reaching its maximum distance to the east of Urvara. Material that would fly further is overtaken by the rotation of Ceres during its flight time and is impacts closer to its source crater. Figure 2 presents a kernel density map of Urvara tracer particles that indicates regions of higher secondary crater density in warmer colors. In addition, it shows the modelled particle trajectories from an unnamed crater at 279°E / 23°S with about 16 km diameter.

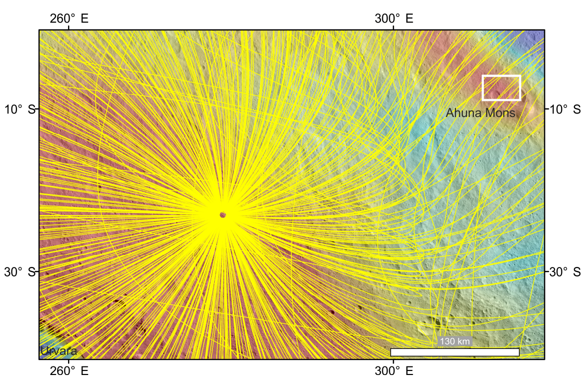

Figure 2: Kernel density map of Urvara (lower left corner) ejecta with warm colors indicating higher probability for secondary cratering and modelled ejecta trajectories (yellow) of a 16 km diameter crater at 279°E /23°S. The position and size of Figure 1 is indicated by a white rectangle close to Ahuna Mons.

4. Conclusions

The modelling of impact crater ejecta can help to identify the source crater of specific populations of secondary crater chains and even secondary crater clusters. In the presented example a set of SW – NE trending secondary crater chains is consistent in its orientation with ejecta trajectories originating from a 16 km diameter crater at 279°E / 23°S. It is surprising that such a small crater at roughly 300 km distance is able to produce so many well visible secondary crater chains. Furthermore, the outlined cluster of relatively large craters near Ahuna Mons is located in a region that is heavily affected by secondary cratering from the 160 km diameter Urvara crater that is located about 560 km to the south – west. Linking the distance of secondary craters with their impact velocity may help to identify a scaling law for secondary projectiles/ craters and to better understand the material properties.

Acknowledgements

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