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Ceres and Rhea: Comparison of the Cratering Records of Two Icy Bodies

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Abstract

Early imaging data of Ceres that was acquired during Dawn's approach at Ceres allows for preliminary measurements of the Cerean crater size-frequency distribution (CSFD). In the Saturnian system, the Cassini mission already provided high resolution imaging data of the icy satellites of which Rhea shows significant physical similarities with Ceres. The direct comparison between the cratering records shows high similarities in the CSFDs of both bodies. This finding has significant implications for the understanding of the projectile populations in the outer Solar System, but requires further evaluation by upcoming high resolution imaging data of Ceres (by Dawn) and Pluto (by New Horizons).

1. Introduction

The Dawn mission [1] recently arrived at Ceres after it completed its mission at its first target Vesta in 2012. Since March 6, 2015 the Dawn spacecraft is gravitationally bound to the dwarf planet Ceres that circles the Sun in the middle asteroid Main Belt at ~2.77 AU. Initial imaging data with ground resolutions of up to ~2 km/pixels allow for reliable measurements of the cratering record down to crater diameters of ~7 km. Previous investigations of Ceres revealed significant amounts of water, thus an icy crust of substantial thickness is expected for Ceres [e.g. 2]. In the Saturnian system the Cassini spacecraft is taking high resolution imaging data since 2004 [3]. Especially the mid-sized Saturnian satellites Tethys, Dione, Rhea and Iapetus are of particular interest for the Dawn mission because all of these bodies feature an icy crust and surface gravities similar to Ceres. This does not only allow for predictions of crater morphologies, e.g. simple to complex transition, on Ceres [4] (as long as Dawn imaging data is still at comparatively low resolution), but in turn Ceres can help understanding the cratering records of the Saturnian satellites as well. It is widely believed that the main impactor source in the Saturnian system are projectiles on comet-like orbits [e.g. 5]. However, that view has been challenged by others [e.g. 6] who argue for collisionally evolved projectiles on planetocentric orbits as the main impactor source in the satellite systems of Jupiter and Saturn. Thanks to the Dawn and Cassini missions, a detailed direct comparison of the cratering records between icy bodies in the asteroid Main Belt and in the Saturnian system with very similar surface gravities becomes possible. Among the mentioned Saturnian satellites, Rhea (g~0.26 m/s²) shows the highest similarity in surface gravity with Ceres (g~0.28 m/s²).

2. Methodology

We measure crater diameters on projected imaging data in ArcGIS using the CraterTools add-in [7]. The measured data is presented in cumulative crater plots created by the craterstats software [8], following [9]. Since the absolute crater frequencies differ between Ceres and Rhea, we normalize the vertical position of the measurements as described by [10]. That improves the comparability of the data, but does not change the shape of the crater distribution. A vertical shift only accounts for different absolute projectile flux and exposure ages.

3. Measurements

For Ceres and Rhea we use one global measurement that covers the distribution of the large craters. This approach has the disadvantage to count across numerous different geologic units and various image resolutions, which usually results in shallower crater distributions. However, as long as such obstacles do not affect the crater sizes that we use for the comparison, this approach is sound. For smaller craters, we use smaller areas that show continuously good image resolution and which are located within a single geologic unit. In Figure 1, we compare the measured crater distributions with a preliminary crater production function that has been derived for Ceres by [4]. In order to show the difference in crater scaling between basaltic and icy targets, we also show a measurement from Vesta and its respective crater production function [11]. Surface gravities as well as impact velocities on Vesta and Ceres are also similar [4].

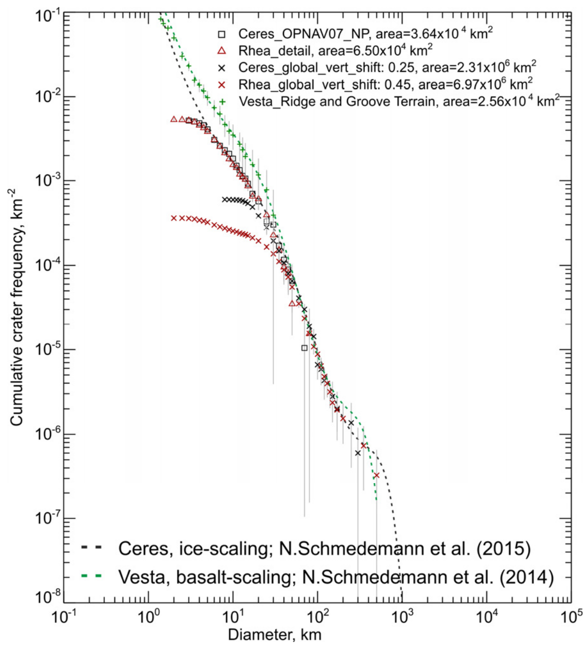

Figure 1: Measured crater distributions from Ceres and Rhea follow closely the crater production function (PF) for Ceres [4]. If vertically aligned around 100 km Vesta's crater PF is clearly different from Ceres's PF around 10 km.

4. Discussion

The different shapes of the crater size distributions on Vesta and Ceres/Rhea as well as the high similarity between Ceres and Rhea is likely caused by the fact that the impact craters on Ceres and Rhea are formed in water ice, while craters on Vesta formed in basaltic regolith with different scaling properties [4]. The very high similarity of the cratering records of Ceres and Rhea suggests a very similar projectile population that impacts both bodies even with similar velocities. According to [4] for Ceres an average impact velocity of ~4.6 km/s is expected. [6] proposes an impact velocity of 3.99 km/s for Rhea which is based on the assumption that it is impacted by planetocentric, asteroid-like projectiles with an eccentricity of 0.6. Thus, for now it appears that both, Ceres and Rhea are predominantly impacted by asteroid-like projectiles and comet-like projectiles play only a minor role. This may also be true for the other Saturnian satellites. However, although our preliminary results show a very good correlation of the cratering records of Ceres and Rhea, it cannot be ruled out, that Kuiper Belt objects show a similar collisionally evolved body size-distribution like the Main Belt asteroids. In that case it might be hard to discriminate between both projectile populations. With the fly-by of the New Horizons spacecraft at Pluto in July 2015, the Kuiper-Belt object size-frequency distribution may finally be revealed.

References

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