Craters on comets

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This paper reviews the observations of crater-like features on cometary nuclei. ”Pits” have been observed on almost all cometary nuclei but their origin is not fully understood [1,2,3,4]. It is currently assumed that they are created mainly by the cometary activity with a pocket of volatiles erupting under a dust crust, leaving a hole behind. There are, however, other features which cannot be explained in this way and are interpreted alternatively as remnants of impact craters.

This work focusses on the second type of pit features: impact craters. We present an in-depth review of what has been observed previously and conclude that two main types of crater morphologies can be observed: ”pit-halo” and ”sharp pit”. We extend this review by a series of analysis of impact craters on cometary nuclei through different approaches [5]:

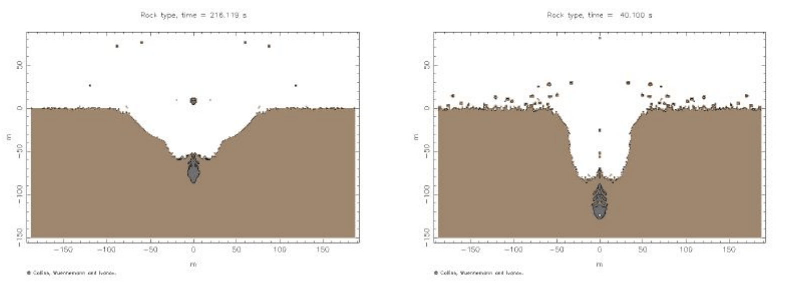
(1) Probability of impact: We discuss the chances that a Jupiter Family Comet like 9P/Tempel 1 or the target of Rosetta 67P/Churyumov-Gerasimenko can experience an impact, taking into account the most recent work on the size distribution of small objects in the asteroid Main Belt [6].

(2) Crater morphology from scaling laws: We present the status of scaling laws for impact craters on cometary nuclei [7] and discuss their strengths and limitations when modeling what happens when a rocky projectile hits a very porous material.

(3) Numerical experiments: We extend the work on scaling laws by a series of hydrocode impact simulations, using the iSALE shock physics code [8,9,10] for varying surface porosity and impactor velocity (see Figure).

(4) Surface processes and evolution: We discuss finally the fate of the projectile and the effects of the impact-induced surface compaction on the activity of the nucleus.

To summarize, we find that comets do undergo impacts although the rapid evolution of the surface erases most of the features and make craters difficult to detect. In the case of a collision between a rocky body and a highly porous cometary nucleus, two specific crater morphologies can be formed: a central pit surrounded by a shallow depression, or a pit, deeper than typical craters observed on rocky surfaces. After the impact, it is likely that a significant fraction of the projectile will remain in the crater. During its two years long escort of comet 67P/Churyumov-Gerasimenko, ESA’s Rosetta mission should be able to detect specific silicate signatures on the bottom of craters or crater-like features, as evidence of this contamination. For large craters, structural changes in the impacted region, in particular, compaction of material, will affect the local activity. The increase of tensile strength can stop the activity by preventing the gas from lifting up dust grains. On the other hand, material compaction can help the heat flux to travel deeper in the nucleus, potentially reaching unexposed pockets of volatiles, and therefore increasing the activity [11]. Ground truth data from Rosetta will help us infer the relative importance of those two effects.



(a) $v = 4.2\ km.s^{-1}, \phi = 60\%, Y = 20\ MPa$ (b) $v = 4.2\ km.s^{-1}, \phi = 85\%, Y = 20\ MPa$

Figure: Comparison of crater profiles on highly porous surfaces (60 % and 85 %).

References: [1] Soderblom et al, Science, 2002. [2] Brownlee et al, Science, 2004. [3] Belton et al, Icarus, 2013. [4] Bruck Syal et al, Icarus, 2013. [5] Vincent et al, PSS, submitted 2014. [6] Marchi et al, Science, 2012. [7] Holsappple et al, Icarus, 2007. [8] Amsden et al, 1980. [9] Collins et al, 2004. [10] Wünnemann et al, 2006. [11] Höfner et al, ACM, 2014.