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Constraints on cometary surface evolution from a statistical analysis of 67P's topography

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Abstract

We present a statistical analysis of the distribution of large scale topographic features on comet 67P/Churyumov-Gerasimenko. We observe that the cumulative cliff height distribution across the surface follows a power law with a slope equal to -1.69 $\pm$ 0.02. When this distribution is studied independently for each region, we find a good correlation between the slope of the power law and the orbital erosion rate of the surface.

Our study suggest that the current size of a cliff or other topographic feature on the comet is not controlled only by material cohesion but by the dominant erosional process in each region. Therefore, a measure of the topography can provide a quantitative assessment of a comet erosional history. We argue that our observations of 67P lead to a general model which can be applied to all other comets. We propose that primordial nuclei are characterized by the presence of large cliffs with a cumulative height power index equal or above -1.5, while eroded cometary surfaces are broken in smaller blocks with a power index equal or beyond -2.3 [1].

The primordial topographic power law distribution is particularly important as it may bring some insights on the stratification of the nucleus [2] but also on early erosional processes such has low speed impacts in the early Kuiper Belt, a poorly constrained epoch particularly fundamental to understand comet formation [3].

Ultimately, our work allows to define an age for the surface of a comet or at least characterize its degree of erosion since it entered the Inner Solar System [1]. We propose that this technique can be applied in a similar way as crater statistics coupled with dynamical models are used to date rocky surfaces on asteroids and planets. This brings a whole new sets of constraints to refine dynamical models of cometary orbits, often limited to the last few orbits. Indeed, any backward integration beyond the last encounter with Jupiter will often lead to a wide range of solutions, due to the chaotic nature of such orbits [4]. Our results, for instance, lead to the exclusion of orbital solution which would have brought 67P as close the Sun as in the current orbit (since 1959), and favor ancient orbits more similar to that of comet 81P/Wild 2, another dynamically young comet.

References

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