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The layered structure of the nucleus of the comet 67P: implications on missing volumes and lobes orientations

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Abstract

The OSIRIS cameras onboard Rosetta revealed that each lobe of comet 67P/Churyumov-Gerasimenko (67P) is characterized by a deep layering that can be modelled as sets of concentric ellipsoidal shells. We present several implications of this geological model that can be useful to shed light on the evolution of the planetesimal. The model allows to estimate that more than the 50% of the original material forming the comet is now missing. Furthermore the geological models of the two lobes appear to have their axes consistently aligned, possibly helping to better understand the dynamics of the low velocity impact that merged two independent planetesimals into a single bilobate body.

Introduction

The OSIRIS cameras onboard the Rosetta orbiter allowed to observe the bilobate comet 67P/Churyumov-Gerasimenko with unprecedented resolution, revealing the presence of geomorphological features that are unequivocally related to layered materials.

From these observations the first geological cross sections of the northern hemisphere were produced [1], while by fitting the observed terraces using concentric shells shaped like ellipsoids the first three dimensional model of the inner layering was provided [2]. These investigations well demonstrated that the comet bilobate shape results from the merging of two independent onion-like objects, but it can also provide additional constraints on the evolution of the body. The 3D model allows to quantify a lower bound for the volumes that have been lost since its formation, and possibly providing some indication about its evolution.

We will thus review some of the major results that have been obtained from the three dimensional modelling of the layered structure of 67P in terms of the lost volumes.

Geometry of the layers

Figure 1 helps visualizing the models of the layering based on ellipsoids, their centres and orientations. Each lobe is characterized by a different model (here only one of the skins of the onion-like model is shown) which is not aligned with the average topography of the lobes.

The two red arrows extending from the ellipsoids centres represents the orientation of the semi-major axes of the ellipsoids. Both the major axes resulted to be roughly aligned, and lay in a plane orthogonal to the actual axis of rotation of the body (z-axis). Furthermore the junction of the two lobes is aligned with the direction of the minor axis of the Big Lobe ellipsoidal model.

Missing Volumes

The presence of terraced terrains on 67P has been considered as the main evidence of a layered structure of global extension. Terraces are morphological features that have been observed on the whole cometary body and are usually related to layered terrains. Indeed each terrace is a flat patch of terrain bounded on one or multiple sides by cliffs. Sets of terraces are organized in a staircase pattern representing superimposed layers of cometary material.

Each terrace is the morphological expression of an inner surface. The geometrical concept is illustrated in Figure 2 which shows a geological section of the comet cutting the latest shape model [3] through Imhotep, Bes and Anhur regions. Each terrace has been highlighted with a blue segment, while the cliffs are shown as red segments. The geometry of terraces can be explained as the results of discontinuity surfaces running within the nucleus, here represented by the dotted lines.

Each layer is bounded by two 3D surfaces. Some of

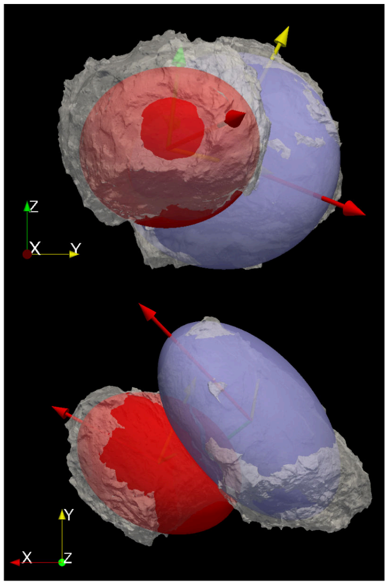

Figure 1: Overview of two *skins* of the onion-like model as resolved from terraces orientations. The two major axes are practically aligned and coplanar, and roughly perpendicular to the rotation axis of 67P.

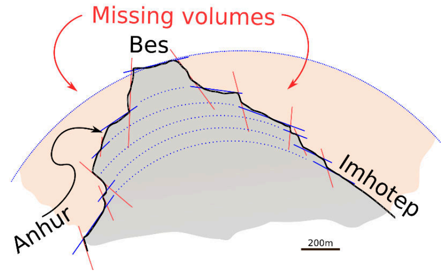

Figure 2: The ellipsoidal models can be used to reconstruct the latest preserved layer on the surface and derive the missing volumes.

these surfaces (e.g. on beneath the Imhotep surface) are completely enclosed within the nucleus, while others (e.g. at the top of Bes) are preserved only in restricted portions on the surface. The geological model permits to reconstruct a surface passing through that locations, allowing to compute the amount of lost material. Applying this technique to both the lobes we obtained a total volume loss of $\sim 60\%$ of the initial volume for the Big Lobe and $\sim 70\%$ for the Small Lobe. These losses correspond to an evolution from an initial volume of the Big Lobe of $33km^3$ to the observed $12km^3$ and from $20km^3$ to $6km^3$ for the Small Lobe. Therefore, the overall missing volume is about 35 km^3. Notice that these values provide an order of magnitude and only a lower limit for the estimated volumes: indeed the "primordial" external layer might not be preserved at all on the cometary surface.

Conclusions

The peculiar alignment of the two lobes ellipsoidal model axes suggests that the two lobes are joined along their minor axis. These observations could help in developing better models to describe the impact that created the peculiar bilobate shape of 67P, and possibly to resolve the primordial rotational axes of the two cometesimals.

Results show that a volume of at least $35km^3$ is missing, and that it is highly localized on the cometary body, with locations that have experienced enhanced material removal and others that still preserve some of the shallower layers that were once present on the body. Furthermore the missing volumes cannot be easily justified as mass loss by sublimation, as measured by the RSI (Radio Science Investigation) onboard Rosetta [4], meaning that some other processes of material removal must be considered. The mass loss from the lobes may have occurred either during the gentle collision that lead to the merging of the two cometesimal or during the subsequent cycles of split and merging of the cometary body [5].

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