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Geomorphology and spectrophotometric properties of the highly active Anhur-Bes regions on the 67P/Churyumov-Gerasimenko comet

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Abstract

In this work we present the spectrophotometric and geomorphological analysis of the Anhur and Bes regions located in the Southern hemisphere of the 67P/Churyumov-Gerasimenko nucleus (see Fig. 1). These regions are more fragmented than other areas on the nucleus and show local compositional heterogeneities with fresh exposure of several ice-rich patches. They are also highly active regions and sources of several jets, including the strongest outburst observed by Rosetta, which took place at the comet's perihelion passage.

1. Introduction

Comet 67P/Churyumov-Gerasimenko has been observed with the OSIRIS cameras on board Rosetta with unprecedented spatial and temporal resolutions. The OSIRIS images revealed a comet having a peculiar bilobated shape with a surface characterised by a variety of astounding morphological regions including both fragile and consolidated terrains, dusty areas, depressions, pits, boulders, taluses, fractures and extensive layering (1, 2, 3, 4). The Southern hemisphere became visible from Rosetta only since March 2015, two months before the Southern vernal equinox. This side of the comet was illuminated during its perihelion passage and therefore it contains the regions that experienced the strongest heating and erosion, thus exposing the subsurface most pristine material. The Southern hemisphere shows a clear morphological dichotomy compared to the Northern one, with much less variety associated with the absence of wide-scale smooth terrains.

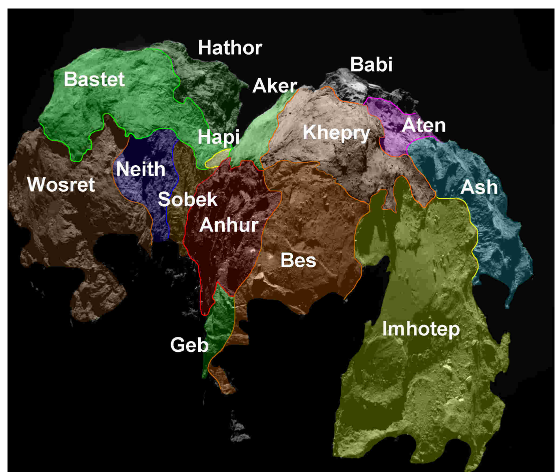

Figure 1: Image from 2 May 2015 UT 07:53 showing the morphological regions visible at that time and in particular the location of the Anhur and Bes regions.

2. Results and discussion

Bes region is dominated by outcropping consolidated terrain covered with fine particle deposits, while Anhur appears strongly eroded with elongated canyon-like structures, scarp retreats, different kinds of deposits, and degraded sequences of strata indicating a pervasive layering. The Anhur/Bes regions are sculpted by staircase terraces that support the nucleus stratification hypothesis formulated by (4). Anhur shows the presence of several scarps dissecting the different strata. Interestingly, at the feet of scarps and cliffs, we observed both taluses and gravitational accumulation deposits. These deposits often have a relatively bluer spectral behaviour than the surround-

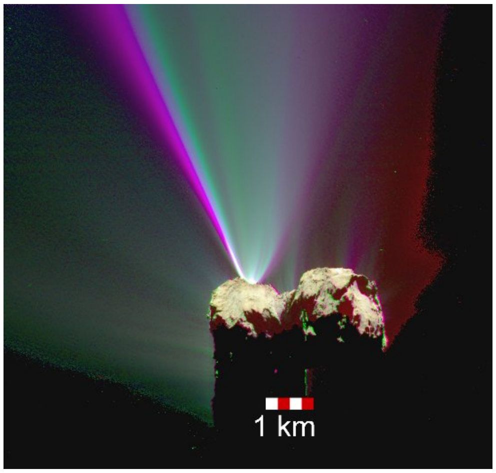

Figure 2: RGB map showing the 12 August 2015 outburst originating from the Anhur region.

ings, pointing to an enrichment in the surface water ice content, and in some cases a higher reflectance and a flat spectrophotometric behaviour, consistent with the presence of exposed water ice. These deposits are sometimes also sources of activity. These observations thus reinforce the hypothesis that the fresh material falling from cliffs/scarps is volatile rich and may become active (5).

In the boundary between Anhur and Bes, two water-ice-rich patches were visible for about 10 days, and they were observed one month after the unique detection of exposed CO_2 ice on the 67P's nucleus (6). These ice-rich patches formed in a smooth terrace covered by a layer of fine deposits on the consolidated material. The fact that first the CO_2 ice and then the H_2O ice was exposed, indicates a progressive stratification of different volatiles resulting from recondensation and sintering of the subsurface material during previous perihelion passages, and clearly points to local compositional heterogeneities on scales of several tens of meters.

In this peculiar Anhur/Bes boundary, we also noticed a new scarp formed sometime between the perihelion passage and December 2015. The scarp is about 140 m long and 10 m high, bounding a depressed area of about 4000-5000 m^2, and generated a collapse of the material with the formation of new boulders. The strong activity throughout the perihelion passage, together with the observed local surface and subsurface enhancement in volatiles in these areas presumably triggered the formation of this new scarp. The freshly exposed material collapsed from the scarp shows a relatively bluer colour and a lower spectral slope indicating the presence of some water ice, reaching abundance of about 17% in the shadows of some boulders located in the new depression.

Several jets have been observed originating from these regions, including the strong perihelion outburst (Fig. 2), as well as an active pit. We detected fainter jets up to 2.2 AU outbound, including an optically thick plume with an estimated optical depth of 0.43.

The spectral slope evolution from April 2015 to June 2016 indicates that the Anhur/Bes regions, as observed for other regions of the comet, became spectrally redder post-perihelion at heliocentric distances > 2.0 AU compared to the pre-perihelion data. This indicates continuous changes of the physical properties of the uppermost layers. Close to perihelion the strong cometary activity thinned out the nucleus dust, partially exposing the underlying ice-rich layer, resulting in lower spectral slope values seen all over the nucleus as shown by (7). This implies that water ice is abundant just beneath the surface on the whole nucleus.

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