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Seasonal Changes of the Icy Dust Cover on Comet 67P/Churyumov-Gerasimenko

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Abstract

The morphology of comet 67P/Churyumov-Gerasimenko (67P) is distinctly dichotomous. Notably, the northern hemi-nucleus of the comet is covered by expansive dust deposits [1]. Over the two-(and-plus-)year rendezvous of Rosetta with 67P, the OSIRIS cameras onboard the spacecraft observed in detail the evolution of the dust cover around the 2015 perihelion passage of the comet. We catalog the observed surface changes before and after perihelion. We will elaborate on the global distribution as well as timeline of the changes and illustrate how the dust cover is cyclically eroded and renewed around each perihelion. We will discuss how the expansive changes were likely driven by sublimation of small amount of water ice preserved in the dust cover.

1. Introduction

The prevalent dust cover over the northern hemi-nucleus of 67P had formed by the deposition of ejecta from the south that was briefly but intensely illuminated during the previous perihelion passage of the comet (before 2015) [2]. The dust cover had undergone wide and continuous transformations from early 2015 when 67P reached the heliocentric distance of about 2.5 au inbound [3, 4, 5]. Many changes were manifested in an increase of surface roughness, for example, the formation of "honeycombed" textures over formerly smooth surfaces, that had probably resulted from uneven erosions of dust deposits [3]. Other forms of changes, such as emergence of consolidated substrates, retreating of scarps, and etc., had also been noted, that were likewise invigorated by the intensifying solar illumination as 67P approached perihelion (Figure 1). The aftermath of the pre-perihelion surface changes was buried with the renewal of the dust deposits during the northern polar night by dust ejected from southern hemi-nucleus around perihelion (Figure 1).

2. Results

Potential surface changes are detected via comparison of images of common locations and indicated by visual differences between observed surface morphologies. The shape-from-shading technique is applied to reconstruct the topography of surface roughness from observations. The comparison of the resulting topographic models enables a quantification of the (minimum) thickness of surface erosion and restoration. At most locations of detected changes, the surface had been excavated by at least several decimeters before perihelion and replenished by at least a comparable amount during perihelion.

The distribution of the surface changes exhibits a clear latitudinal dependence and a concentration between about 20°N and 40°N. In particular, the changes occurred in open surface areas amply illuminated and, thus, susceptible to strong surface erosion before perihelion. They occurred in phase with the movement of the sub-solar point toward the south across the latitudes of their distribution. The surface erosion was ostensibly driven by water sublimation. The roles of other, more volatile species are unclear, but were most likely secondary.

We apply thermal models to estimate the accumulated erosion of water ice in response to the increasing insolation over the visibly eroded surface areas. The comparison of model estimates with the minimum amount of surface changes quantified from OSIRIS observations provides a constraint on the abundance of water ice in the dust cover.

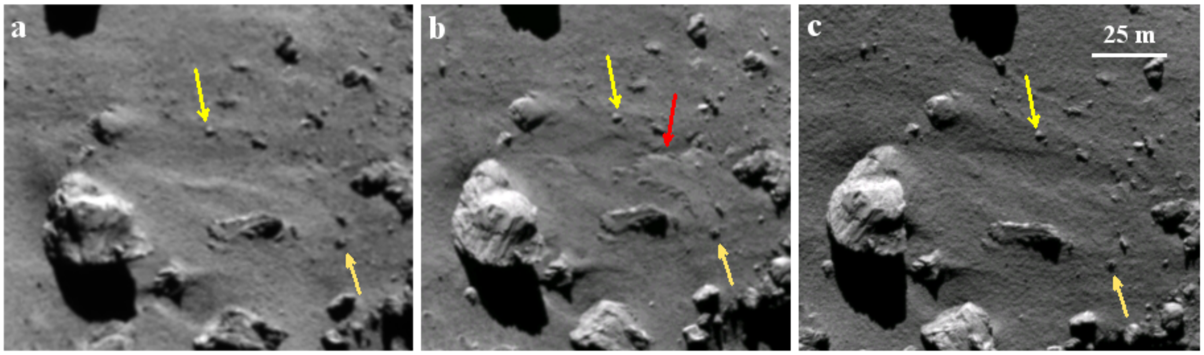

Figure 1: Erosion and restoration of dust deposits in the Ma'at region on comet 67P observed by OSIRIS. The dust deposits had been visibly eroded between December 2, 2014 (**a**) and March 28, 2015 (**b**), forming a V-shaped scarp and exposing the sharp edges of several consolidated boulders or outcrops. Observation on June 6, 2016 shows the disappearance of the scarp after perihelion, probably veiled by the renewed deposits (**c**). Red arrow in **b** indicates the newly formed scarp. Yellow arrows point to a common boulder in three panels as a landmark. This figure is adapted from [5].

3. Conclusions

The erosion and restoration of dust deposits over the northern hemi-nucleus of 67P are seasonal and cyclic phenomena as a result of cometary activity. The dust deposits were icy: it is found that they contained a few percent of water ice in mass, which corresponds to an average dust-to-ice ratio in excess of ten and, thus, greater than the dust-to-gas ratio of six as measured in the coma of 67P [6, 7]. This is a necessary consequence of the observed redistribution of an appreciable amount of non-escaping dust ejecta over the nucleus surface, which most notably shaped the surface morphology of the northern hemi-nucleus.

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