Evolution of cometary surfaces.

J.-B. Vincent[1] and the OSIRIS team, [1]DLR Institute of Planetary Research, Berlin, Germany, jean-baptiste.vincent@dlr.de

Introduction: Cometary surfaces evolve on a different time scale than most Solar System objects. Because changes are principally driven by the sublimation of volatiles in the subsurface, most changes take place when the comet orbit brings the nucleus within the inner Solar System, for a time period that typically lasts a few 10^4 years before the nucleus becomes extinct or disintegrates.

Recent work based on the analysis of several comets visited by space missions, especially Rosetta, has shown that the large scale topography of cometary nuclei is mostly controlled by events which took place in the Outer Solar System [1, 2]. Tall cliffs and deep pits are more likely to be the outcome of impacts in the primitive Kuiper Belt or large scale outbursts when the comet was in its Centaur phase, rather than being due to the current sublimation.

Indeed, water driven activity (<3AU) tends to not carve large features in the surface, but instead breaks apart the topography in smaller features, until the surface is dominated by a sooth layer of pebbles and dust (e.g. comet 103P/Hartley 2). Therefore, the large scale roughness of cometary nuclei provides a measure of how evolved the surface is, and can be used as a crude datation tool to assess how long the comet has been in the inner Solar System [2, 3].

Surface changes: In order to model the physical processes involved in this evolution and constrain the various time scales, it is necessary to first describe thoroughly the type of changes observed.

So far, this has been done for large changes (~100 m) for 2 different bodies: 9P/Tempel 1 [4] and 67P/Churyumov-Gerasimenko [5]. Both objects showed surprisingly little amount of large scale changes, with most modifications being very localized: cliff retreat, deflation of smooth terrains, transport of a few decameter-size blocks, expansion of a few fractures.

Using a mapping tool specifically developed for the study of small bodies [6, 7], and a new algorithm designed for automating the detection of surface changes [8], we are now able to extend our coverage of surface changes to the whole nucleus, with resolution of a few meters. Figure 1 shows an example of such change detection for the Agilkia region before and after perihelion. Our technique reveals that while most of the large scale morphological features have remained unchanged, the small scale topography is completely different.

Focusing primarily on the high resolution OSIRIS-NAC [9] images obtained by the Rosetta mission, we have been able to detect several thousands changes, ranging from the redistribution of dust in local ponds, to the possibly thermally induced breaking of blocks, or the opening of small pits (10 m diameter) in conjunction with fracture expansion and/or outbursts.

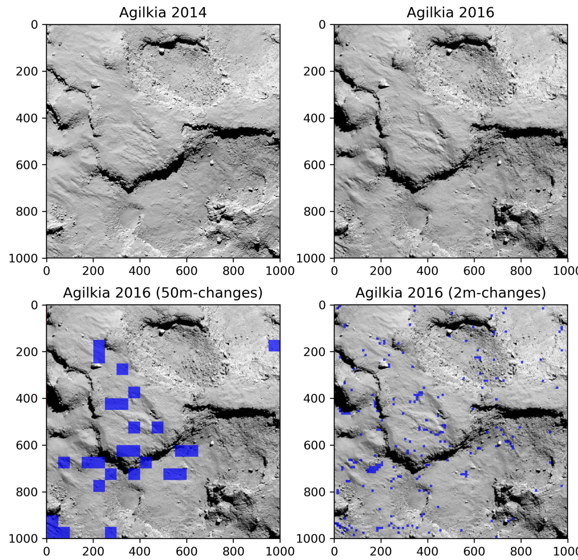

Figure 1: Automatic change detection on nucleus-referenced images of the Agilkia region (comet 67P), at two different scales

The aim of this study is to provide an exhaustive coverage of surface changes on 67P at all scales over the course of one perihelion passage, thus putting strong constraints on the physical processes at work. The analysis of each type of change gives a measure of physical properties of the material, such as thermal inertia, tensile strength, cohesion, and thickness of the dust cover, lifting force. We will report on these first results, as well as on the new techniques developed to enhance our mapping and change detection capabilities, and how they could be applied to other datasets.

References:

[1] Vincent et al, Nature (2015)
[2] Vincent et al, *MNRAS* (2017)
[3] Birch et al, *MNRAS* (2017)
[4] Thomas et al, *Icarus 222* (2013)
[5] El Maarry et al, *Science* (2017)
[6] Vincent et al, *LPSC* (2018)
[7] http://www.comet-toolbox.com/shapeViewer.html
[8] Vincent et al, *EPSC* (2017)

[9] Keller et al, *SSR 128* (2007)

Acknowledgements:

Optical, Spectroscopic, and Infrared Remote Imaging System (OSIRIS) was built by a consortium led by the Max Planck Institut für Sonnensystemforschung, Göttingen, Germany, in collaboration with CISAS, University of Padova, Italy, the Laboratoire d'Astrophysique de Marseille, France, the Instituto de Astrofisica de Andalucia, CSIC, Granada, Spain, the Scientific Support Office of the European Space Agency, Noordwijk, the Netherlands, the Instituto Nacional de Tecnica Aeroespacial,Madrid, Spain, theUniversidad Politecnica de Madrid, Spain, the Department of Physics and Astronomy of Uppsala University, Sweden and the Institut fir Datentechnik und Kommunikationsnetze der Technischen Universität Braunschweig, Germany.

The support of the national funding agencies of Germany (DLR), France (CNES), Italy (ASI), Spain (MINECO), Sweden (SNSB), and the ESA Technical Directorate is gratefully acknowledged.

We thank the Rosetta Science Ground Segment at ESAC, the Rosetta Mission Operations Centre at ESOC and the Rosetta Project at ESTEC for their outstanding work enabling the science return of the Rosetta mission.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 686709.