Thermal wave and geomorphologic features on cometary nuclei

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Activity of cometary nuclei is closely linked to thermophysical processes. The main catalyst to activity is the temperature wave induced by solar heating. So far, remote sensing of the nucleus surface temperature has been the single method of direct measurement. However, while remote sensing is of undisputed relevance, it only reveals surface properties and their thermal signatures. Additionally, these are quite dependent on the geometric setup of the observation (angles of solar incidence, azimuth, and emission): Thermal models of cometary nuclei still show a deviation between predicted temperatures and measurements, especially at higher irradiance angles [1,2].

Understanding the heat flux towards the comet interior is crucial to predict activity not only on global but also local level. A thermal model has been set up to derive the temperature gradient from the top layer down to depths of 10 m; one of the findings was that no temperature fluctuations were found in deeper layers. The model takes into account radiative heat transfer for surface facets and conductive fluxes in depth direction. Among the parametric variations were surface topological features (such as smooth terrain compared to crater-like structures), and differences in the bulk material, e.g., building blocks, porosity, and grain size. We apply a great variety of illuminating conditions to account for shadowing effects and solar exposure time deviations.

In a previous work, we discussed the influence of micro-roughness [3]. We present here the effects of macro-roughness, taking into account topographic features likely to be found on a cometary surface. One of the first examples are pits/impact craters. They are found in all comets but their origin is not fully understood [4]. It is assumed that most of them are a consequence of the activity; but some of these features can definitely be related to impact craters. We analyzed such features described by Vincent et al. [5,6] and looked at the effect of impact craters on the thermal wave. In this work, we compare temperatures of a flat porous terrain analog to a nucleus surface to the temperatures found under the floor of an impact crater formed in the same terrain. We show that both crater morphology and compaction of material affect the thermal properties of the surface.

The figure outlines the temperature wave at several depths for comet 67P/Churyumov-Gerasimenko, the target of the Rosetta mission. The plot covers one orbital revolution, starting at perihelion. The line width, especially at depths lower than 5 cm, is related to the diurnal heat wave; both its amplitude and the average temperature declines with the growing distance to the Sun. The graphs exhibit a rising thermal lag in depth as well. We noted that both thermal lag time and extremum position are dependent on the effective thermal conductivity of the assumed material. Another contributing effect (in the figure, right side) is the shadowing and the heat transfer to the crater walls — the crater might act as a heat trap.

The goal of this study is to develop a tool that can be used to derive local thermal behavior depending on shape and roughness (macro and micro). The results of this analysis will be used to better constrain the onset and decay of activity in various terrains of comet 67P, allowing us to better understand and quantify the thermophysical effects that trigger cometary activity.

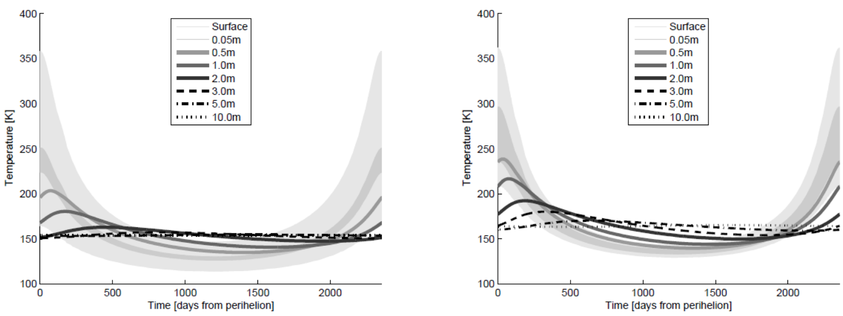

Figure: Temperature wave for two scenarios (left: porous terrain, right: compacted material below a crater)

References: [1] Groussin et al, Icarus 2012. [2] Davidsson et al, Icarus 2012. [3] Höfner et al, EPSC 2013. [4] Belton et al, Icarus, 2013. [5] Vincent et al, EPSC 2012. [6] Vincent et al, PSS, submitted 2014.