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A Numerical Modeling Approach to Cometary Nucleus Surface Roughness Determination

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Abstract

Activity of cometary nuclei is closely linked with thermophysical processes. Main catalyst to activity is the diurnal temperature wave induced by solar heating. Highly resolved comet nucleus geometric models are used to model temperatures with flat surfacial facets taken from shape modeling approaches [1, 3].

Recent analyses of Groussin et al. [4] and Davidsson et al. [2] compared thermal inertia and surface temperatures of Tempel 1 and Hartley 2 synthetic models to those derived from spectral images. They outlined that applying beaming factors and radiative self-heating is not sufficient to understand the thermal behaviour of the nucleus surface. Regions with large incidence angles (e.g. at the morning terminator) distinctively deviate from predicted temperatures.

One of the main contributions to this deviation is the effect of surface roughness with scales that are considerably smaller than the model facets. Combined with a relatively low thermal inertia, temperatures cover a wide range of values even at closest neighbourhood to each other. The radiative measurement for a distant observer unveils a smearing effect that indicates higher temperatures compared to average.

The authors follow two numerical approaches to model small-scale surface roughness: (A) by using randomly generated fractal surfaces and (B) by downscaling groups of facets originating from larger shape models of Tempel 1. We apply a model that accounts for both radiative heat exchange for all facets and shadowing effects due to incoming solar radiation. These values are calculated in a thermal model. The revealed temperatures are analyzed with respect to average large-scale surface temperatures. Hence, they are compared to deviating temperatures that are measured by a distant observer that is unable to resolve sub-structure surface patterns.

A parametric study varying thermal inertia and the degree of surface roughness then outlines a bandwidth of feasible surface structures and relates them to derived temperature by remote sensing. A surface roughness parameter is introduced that takes into account these effects while keeping numerical nucleus models simple.

The results outline that a surface roughness parameter can be a way to model small, unresolved morphological nucleus features in order to better understand the thermal behaviour and to predict related effects, e.g. the onset of activity. It has to be noted, however, that other effects might have a considerable influence on thermal surface diurnal waves, as well as seasonal effects and orbital changes.

References

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[4] Groussin, O., et al., 2012. The temperature, thermal inertia, roughness and color of the nuclei of comets 103P/Hartley 2 and 9P/Tempel 1, Icarus 222, 580-594.