Physical Properties of Morphological Units on Comet 9P/Tempel 1.

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Introduction

Deep Impact NIR nucleus spectra of Comet 9P/Tempel 1 have been analyzed, focusing on the photometric and thermophysical effects caused by surface roughness. Nucleus maps of spectral reddening, surface temperature T, beaming function Λ times directional emissivity ε_d ($\Lambda\varepsilon_d = X'$), self heating parameter ξ, thermal inertia $\mathcal{I}$, and volume emissivity factor γ^2 of constituent particles have been produced. The parameters $\{X', \xi, \mathcal{I}, \gamma^2\}$ vary significantly across the nucleus surface and correlate strongly with morphological units defined by [1]. Allowance for surface roughness in thermophysical modeling is indispensable for reproducing the observed temperatures. Relaxing the $\xi = 0$ assumption of [2] we find that the thermal inertia is high for certain regions, $\mathcal{I} = 1000$–$3000\,\mathrm{W\,K^{-1}\,m^{-2}\,s^{1/2}}$.

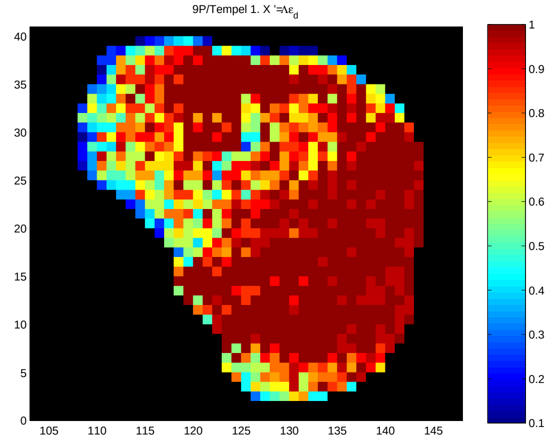

Figure 1: Product of beaming function and directional emissivity $X' = \Lambda\varepsilon_\mathrm{d}$ at wavelengths $3.0 \leq \lambda \leq 3.6\,\mu\mathrm{m}$.

Methods

Absolute calibrated HRI–IR spectra from the Planetary Data System (PDS) website[1] are cleaned from hot pixels, scattered solar light is removed and the remaining thermal spectrum yields X' and T across the surface. Figure 1 shows that X' deviates substantially from unity for the scarped/pitted terrain on the nucleus. Temperatures are reproduced by a thermophysical model taking thermal emission (corrected for subpixel surface roughness) and thermal inertia into account, avoiding areas known to be icy. Global self heating (i.e., between pixels) and shadowing due to nucleus topography are calculated and found to be negligible except in a few regions that are avoided. This yields ξ, and $\mathcal{I}$ within $\sim 3\,\mathrm{m}$ of the surface.

A beaming function $\Lambda = \Lambda(f,\ S,\ e, \gamma^2)$ is calculated based on a fraction f of the surface at emission angle e being covered by circular paraboloid craters with depth–to–diameter ratio S, consisting of particles characterized by γ^2. The directional emissivity $\varepsilon_\mathrm{d} = \varepsilon_\mathrm{d}(e, \gamma^2)$ is obtained from Hapke theory. Using ξ to constrain S and f, and using e from the PDS geometrical nucleus model, yields the γ^2 map by requiring that X' is reproduced.

Mie theory for various materials and particle sizes is used to interpret the γ^2 map. For pyroxenes, olivines (of any iron abundance), troilite, and carbon, the measured Bond albedo limits the particle radius to $0.1 \leq a \leq 0.5\,\mu\mathrm{m}$.

[1]http://pds.jpl.nasa.gov/

Results

Scarped/pitted and thick layers terrains are rough with $\xi \approx 0.7$ (e.g., $\sim 90\%$ area coverage of $S = 1$ pits), and the thermal inertia $\mathcal{I} = 2000 \pm 1000\,\mathrm{W\,K^{-1}\,m^{-2}\,s^{1/2}}$ is consistent with 20%–60% porosity for granular silicate surface material. Scarped/pitted terrain has a low γ^2 consistent with $0.5\,\mu\mathrm{m}$–sized particles of any considered composition, or with $0.1\,\mu\mathrm{m}$–size but only for iron–poor silicates. Thick layers have $\gamma^2 \approx 1$, only consistent with small ($0.1\,\mu\mathrm{m}$) carbon–rich grains.

Thin layers terrain is smoother with $\xi \approx 0.2$ (e.g., $\sim 60\%$ cover of $S = 0.5$ pits) and the comparably low thermal inertia ($\mathcal{I} \leq 200\,\mathrm{W\,K^{-1}\,m^{-2}\,s^{1/2}}$) is consistent with 80% porosity. With $\gamma^2 \approx 1$, the surface composition and particle size is similar to those of thick layers terrain.

Morphological units on Comet 9P/Tempel 1 differ in terms of surface roughness, thermal inertia, composition and/or grain size. These differences may be primordial or caused by evolutionary processes.

References

[1] P. C. Thomas and 14 colleagues. The shape, topography, and geology of Tempel 1 from Deep Impact observations. *Icarus*, 187:4–15, 2007.

[2] O. Groussin and 9 colleagues. Surface temperature of the nucleus of Comet 9P/Tempel 1. *Icarus*, 187:16–25, 2007.