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Surface temperatures of Steins and Lutetia : Thermal modeling and Rosetta flyby configurations

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Abstract

During its long interplanetray journey toward the comet 67P/Churyumov-Gerasimenko, the ESA/NASA Rosetta spacecraft has already flew by the small E-type asteroid (2687) Steins in September 5^{th} 2008, and will fly by (21) Lutetia in July 10^{th}, 2010.

The infrared spectrum of these bodies dominates the reflected light beyond 4μm. Thermal emission of asteroids depends of physical properties of the regolith such as the bond albedo, the thermal inertia and the porosity. Thus, infrared data interpretation should provide physical constrains of the first layers of the surface itself. We have developped a quasi-3D thermal model that computes the surface temperature depending on local conditions of illuminations and assuming a 3D shape model of Steins and Lutetia. A comparison of this model with remote sensing Rosetta data will certainly provide new insights on Steins and Lutetia thermal properties.

1. Introduction

During Steins' flyby in September 2008, remote sensing instruments onboard the Rosetta spacecraft have acquired precious informations about the asteroid. Its surface was mapped at different wavelenghts from visible to infrared with OSIRIS, VIRTIS and MIRO instruments, and at different local times and illuminations conditions as Steins was spinning.

Similar strategy will be applied for the Lutetia flyby in July 2010. The surface temperatures can be estimated from the near-infrared spectra between 4 and 5 μm by using basics photometric models that allows to derive both reflectance and emissivity of the surface.

2. Thermal model

Our thermal model is based on recents ThermoPhysical models (TPM) used when the three dimensional shape of the body is known. The shape of the asteroid is decribed by vertices and facets. As the size of facets are often larger than the thermal skin depth (few millimeters), we assume heat conduction only in the radial direction. The amount of flux absorbed by each facet depends on its bond albedo, on the incidence angle (i.e. the local time), and on the mutual shadowing (concavities or eclipse due to binary asteroids). Heat conduction is computed using a Crank-Nicholson algorithm, and mutual heating that may play a role for convexe local shapes (e.g. inside craters) is taken into account. The thermal inertia controls the rate of heating and cooling, and is described by $\Gamma = (1-p)(\rho K C_p)^{1/2}$, where p is the porosity, ρ and K are the bulk density and the thermal conduction, and C_P is the heat capacity. The local conditions of illumination, associated to the topography and the spin axis, are computed using the most recents SPICE PCK kernels of both Steins and Lutetia, that provides the accurate spin axis orientation relative to the Sun and to the observer.

3. Steins thermal modeling

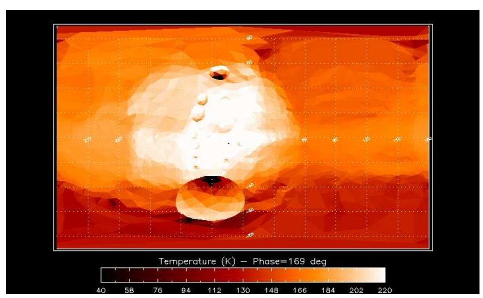

Figure 1: Simulated thermal map of Steins.

The shape of Steins is described by the shape model provided by the OSIRIS/Rosetta Team [1]. To decrease the time of computation we reduced the number of facets to 3000. We use the following thermal parameters : $A_v = 0.21$, $\epsilon = 0.8$, $\Gamma = 150 \text{Jm}^{-2}\text{K}^{-1}\text{s}^{-1/2}$

[2]. The Fig. 1 shows cartographic projection of the computed surface temperature during the Rosetta closest approach at 18:38:00 UT. At least two regions located inside craters are usually unilliminated and thus cold. The modeled temperature distribution ranges from 180 to 230 K on the illuminated side of Steins. A larger thermal inertia should imply a wider temperature distribution as the thermal contrast above the surface would be smaller. Temperature histogram analysis is a powerful test to retrieve thermal properties of the surface at the first order.

4. Lutetia thermal modeling

Rosetta will flyby (21) Lutetia in July 2010. The closest approach will occur at a relative distance of 3000 km. The shape model of Lutetia has been recently updated using adaptative optic images and visible light curves [3]. Due to limited geometries of observations, the polar axis is still few constrained. However, the pole axis appears to be tilted with respect to the orbital plane such that the southern hemisphere (latitudes lower than -50 deg) will be in the constant shadow during the Rosetta approach. Fig. 2 provides the geometry of the flyby. Rosetta instruments will be able to measure the surface temperature of the constantly illuminated North pole, and the daily periodic temperatures variations at mid-latitudes. Measurements of the daily heating and cooling rates at mid latitudes will be usefull to retrieved thermal properties of Lutetia.

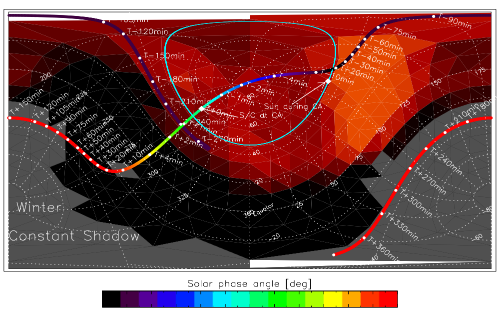

Figure 2: Oblique Mercator projection of the sub-Rosetta and sub-solar path during the Lutetia encouter, color-coded in phase angle.

Fig. 3 shows the expected temperatures of Lutetia during the Rosetta flyby, assuming a lower thermal inertia ($\Gamma = 50 J m^{-2} K^{-1} s^{-1/2}$). Large asteroids are indeed assumed to be covered by a thin regolith layer, implying a low thermal inertia. Moreover, the important size of this body (almost 100 km diameter) will probably generate variations of thermal properties at the surface, that Rosetta instruments will be able to detect.

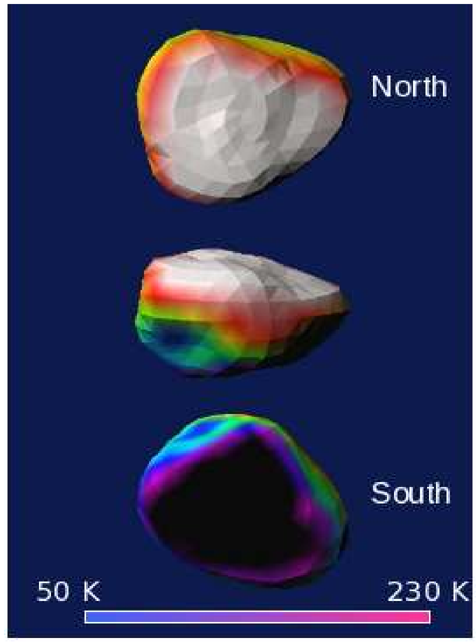

Figure 3: Three views of the thermal modeling of Lutetia during the flyby configuration. Images are color coded in surface temperature.

References

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[3] Carry, B., et al. : Physical properties of ESA/NASA rosetta target asteroid (21) Lutetia : Shape and flyby geometry, A&A submitted