Thermophysical modeling with a particle size distribution: application to Ryugu and Bennu

E. Rognini[1,2], M. T. Capria[3], A. Zinzi[1,4], E. Palomba[3], S. Ivanovski[5]

[1]ASI Space Science Data Center (SSDC), Rome, Italy (edoardo.rognini@ssdc.asi.it);
[2]INAF-OAR Osservatorio Astronomico di Roma, Monte Porzio Catone (RM), Italy;
[3]INAF-IAPS Istituto di Astrofisica e Planetologia Spaziali, Rome, Italy;
[4]ASI, Rome, Italy
[5]INAF-OATS Osservatorio Astronomico di Trieste, Via Tiepolo 11 I-34143 Trieste, Italy

Introduction

- Physical status of the surface material of airless bodies → evolution, geology, and selection of landing/sample site
- Thermal inertia TI = $(k \rho c)^{1/2}$ controls the maximum daytime temperature, and the time at wich the maximum occurs
- Standard thermophysical models assume that the thermal skin depth is greater than particle size. But for rubble pile asteroids (es. Bennu and Ryugu) the boulders size maybe **greater** than the thermal skin depth
- Bennu shows a low value of thermal inertia, not compatible with boulder size

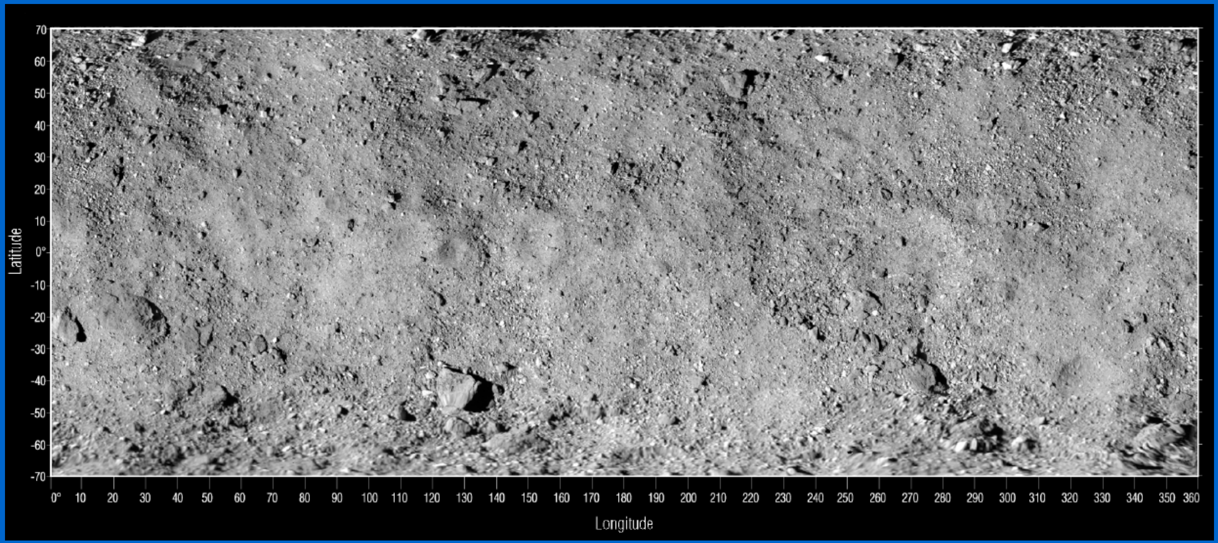


Figure 1. Surface of Bennu from Osiris-Rex. Image adapted from DellaGiustina et al. (2019)

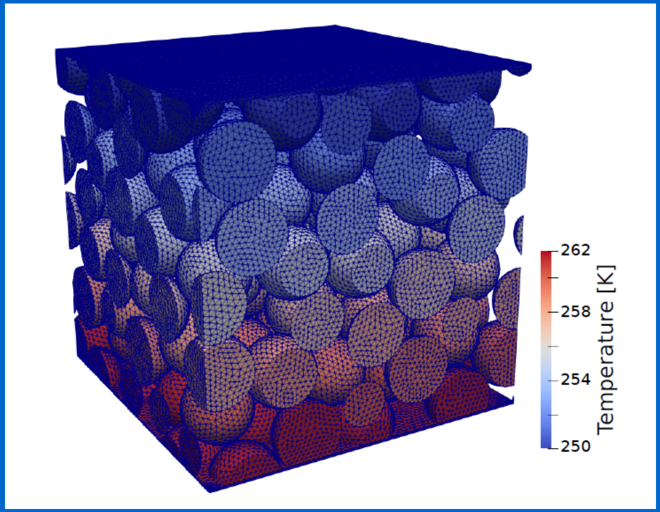
Edoardo Rognini (edoardo.rognini@ssdc.asi.it)

Methods

We calculate the surface temperature with a thermophysical code (Rognini et al. 2019, Capria et al. 2014) that solve the 1D heat equation:

$$\rho c \frac{\partial T}{\partial t} = \frac{\partial}{\partial x} k \frac{\partial T}{\partial x}$$

Thermal conductivity *k* is calculated for a polydisperse soil by taking an effective particle diameter D_{32} given by the volume-to-area ratio (Ryan et al. 2020)



$$D_{32} = \frac{\sum_{i=1}^{N} D_i^3}{\sum_{i=1}^{N} D_i^2}$$

Figure 2. Simulation of thermal flux applied to a monodisperse soil. Image from Ryan et al. 2020

Results: Ryugu

Observation and simulation date for the asteroid Ryugu: 2018 August 01, 14:26:08 (Okada et al., 2020)

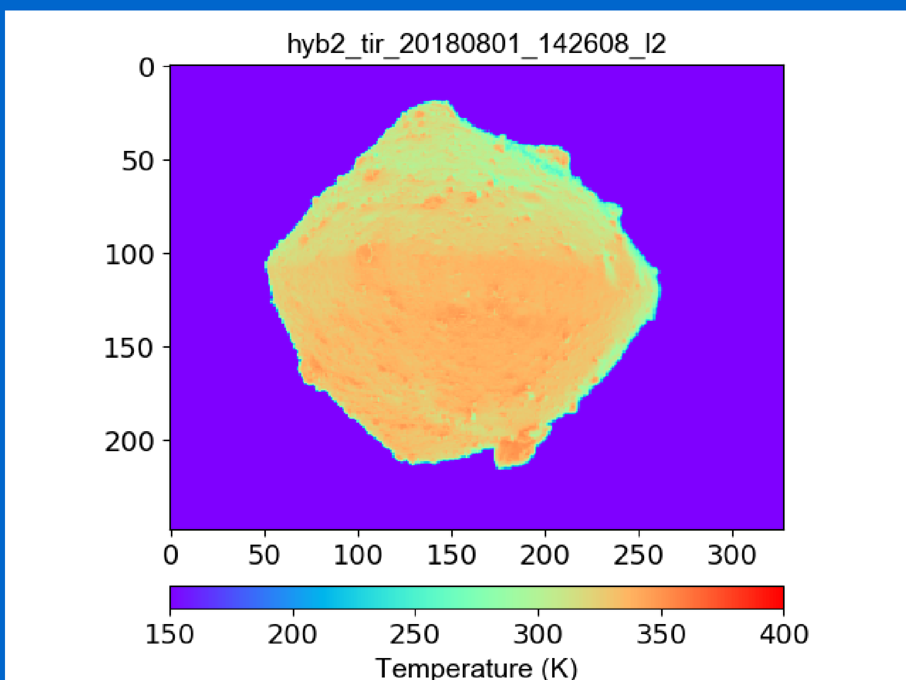


Figure 3. Thermal image of Ryugu. Image from https://data.darts.isas.jaxa.jp/

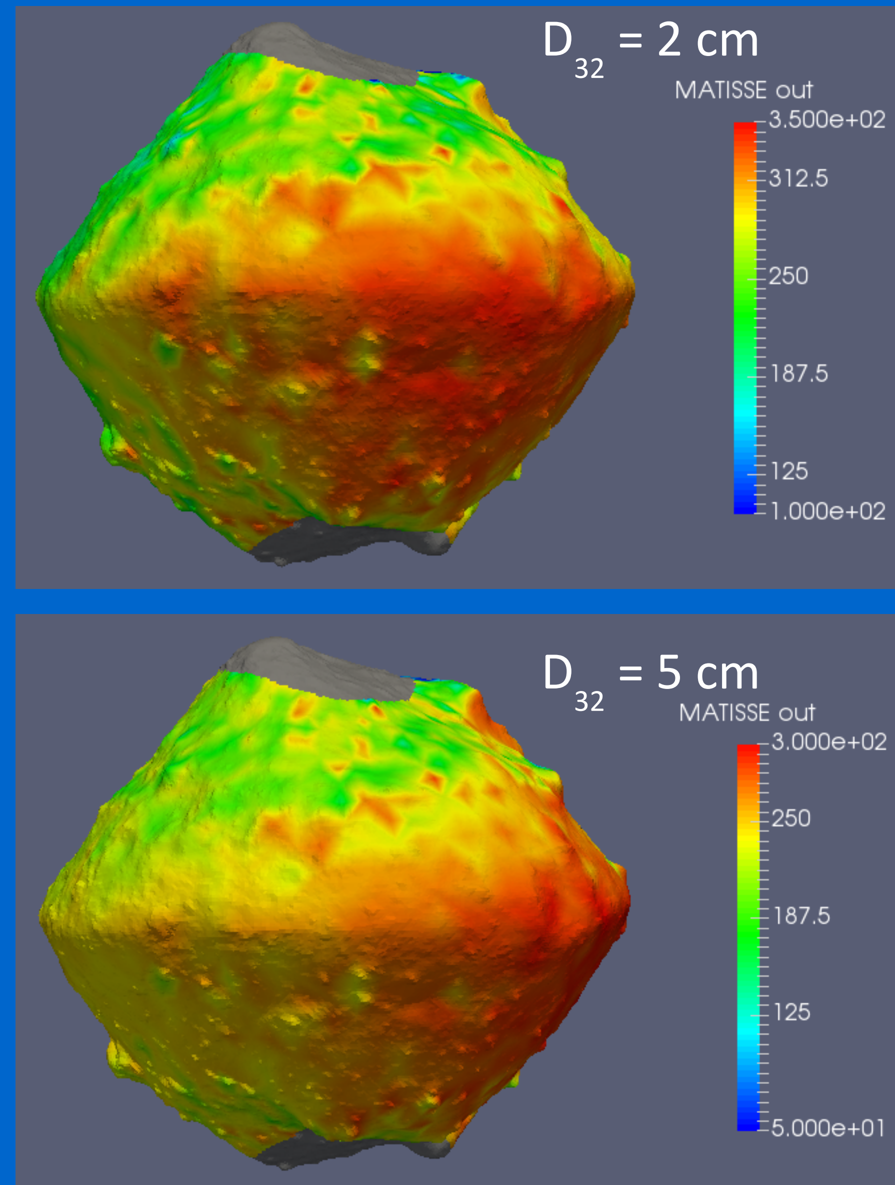


Figure 4. Simulated temperature on Ryugu

Edoardo Rognini (edoardo.rognini@ssdc.asi.it)

Results

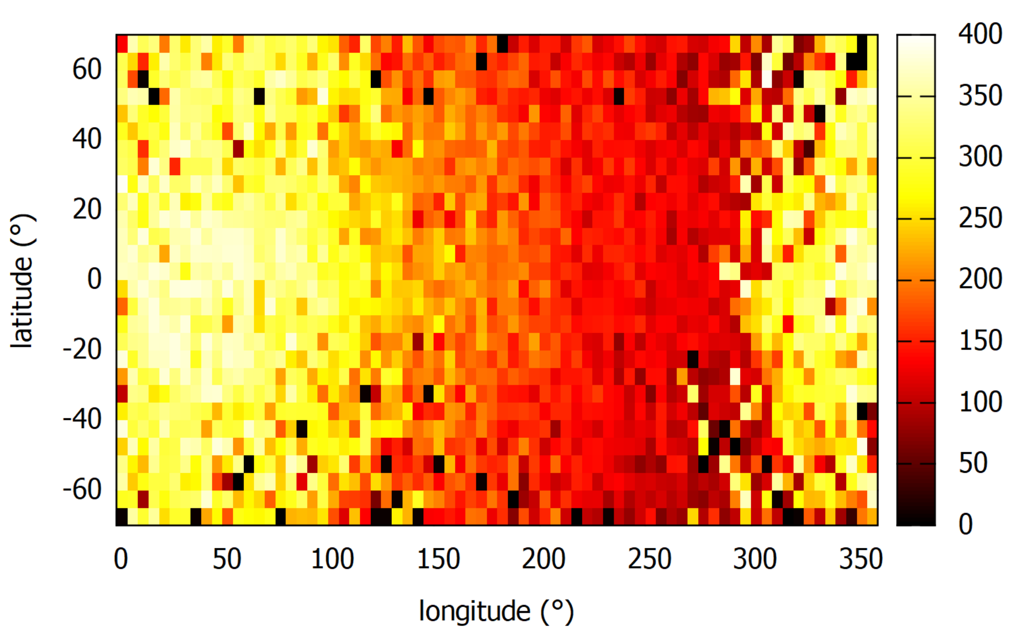


Figure 5. Thermal map of Bennu, with D_{32} = 5 cm, heliocentric distance = 1 A.U.

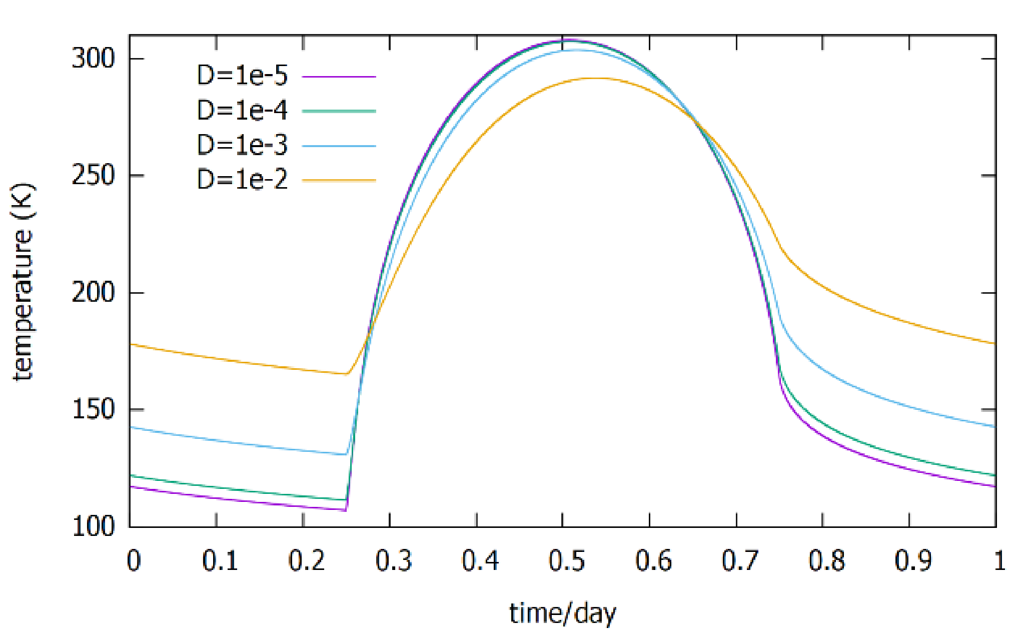


Figure 6. Examples of temperature curves calculated with different average particle sizes $D=D_{32}$ (meters), for a point located on the equator of an asteroid with emissivity 0.9, heliocentric distance 1.6 A.U., albedo 0.1, density 2146 kg/m^3, specific heat 600 J/kg K, rotation period 11.92 h.

Edoardo Rognini (edoardo.rognini@ssdc.asi.it)

Further applications

- Temperature provided by the thermophysical model can be used as input for non-spherical dust dynamics models (Ivanovski et al. 2017) for near asteroids environments;
- dust distribution constrain;
- prevision of dust environment encountered by the ESA mission HERA at the encounter with the Didymos binary system.

The code will be available to the interested communities in MATISSE (Zinzi et al. 2016), the tool developed at ASI-SSDC and which will be used also for LICIACube mission (talk of Elisabetta Dotto).

References.
Capria, et al. (2014), Geophysical Research Letter, https://doi.org/10.1002/2013GL059026
Della Giustina, et al. (2019), Nature, https://doi.org/10.1038/s41550-019-0731-1
Ivanovski, et al. (2017), Icarus, https://doi.org/10.1016/j.icarus.2016.09.024
Okada, et al. (2020), Nature, https://doi.org/10.1038/s41586-020-2102-6
Rognini, et al. (2019), Journal of Geophysical Research, https://doi.org/10.1029/2018JE005733
Ryan, et al. (2020), Journal of Geophysical Research, https://doi.org/10.1029/2019JE006100
Zinzi, et al. (2016), Astronomy and Computing, https://doi.org/10.1016/j.ascom.2016.02.006