Brightness temperature modelling of icy and dusty materials applied to comet 67P/Churyumov-Gerasimenko.

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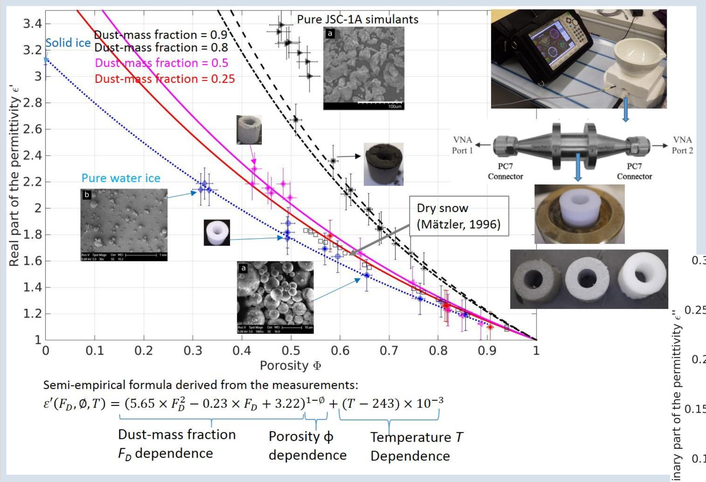
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Introduction

Comets, mainly composed of **organic compounds, silicate minerals and water ice** [1], enclose clues about processes and chemical and physical conditions of the **early phases of the Solar System**. The European Space Agency's **Rosetta spacecraft was in orbit around comet 67P/Churyumov-Gerasimenko** (hereafter 67P) from August 2014 to November 2016. From June 2014, the **Microwave Instrument on the Rosetta Orbiter (MIRO) acquired maps of the subsurface brightness temperatures (hereafter BT) of comet 67P, at 1.6 mm and 0.5 mm wavelengths [2][3].** These data can provide clues about the heat transport and ice sublimation processes experienced by the comet 67P. The dusty nature of the nucleus has been inferred by different instruments with a lower limit of the dust-to-ice mass ratio possibly greater than 4 [4][5]. In order to **interpret the BT measured by the MIRO radiometer**, we are currently developing a **general model** composed of a 1D thermal model, taking into account the 3D shape model of the nucleus, associated with a radiative transfer model. This work is developed in the context of the **Multi-instrumental Analysis of Rosetta Data (MiARD)** project funded by the European Union's Horizon 2020 research and innovation programme.



Electrical properties [8][9]



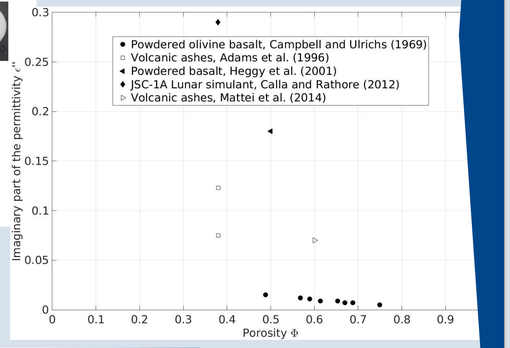
Semi-empirical formula derived from the measurements:

$$\varepsilon'(F_D, \emptyset, T) = (5.65 \times F_D^2 - 0.23 \times F_D + 3.22)^{1-\emptyset} + (T - 243) \times 10^{-3}$$

Dust-mass fraction F_D dependence | Porosity ϕ dependence | Temperature T Dependence

Lab. measurements at 243 K:
*Pure ice samples
*Pure JSC-1A Lunar simulants
*Ice/JSC-1A mixtures with controlled porosity and dust-mass fraction

*Frequency range: 50 MHz - 2 GHz

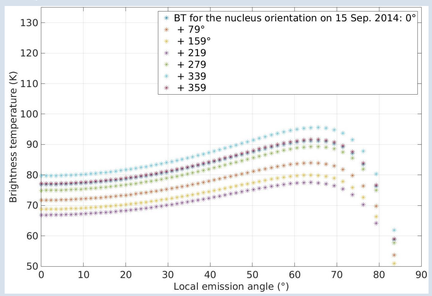


Radiative transfer model [7]

*Stratified scatter-free medium
*Takes into account the temperature profiles associated with each facet
*Homogeneous electrical properties
*BT as a function of local emission angle, thermal and electrical properties

$$\mathrm{BT}(\theta) = \frac{\int_0^{+\infty} T(z) e^{-\sec\theta_t z/\delta_{el}} dz}{\int_0^{+\infty} e^{-\sec\theta_t z/\delta_{el}} dz} = \frac{\sec(\theta_t)}{\delta_{el}} \int_0^{+\infty} T(z) e^{-\sec\theta_t z/\delta_{el}} dz$$

*Fresnel reflectivity coeff. (specular emissivity model)



BT as a function of the emission angle for facet #1

Thermal model [6]

* Incidence angle of solar radiance is computed for every facet of the selected shape model (here 124938 facets) of the comet for a given date + 359° of rotation (/1°)

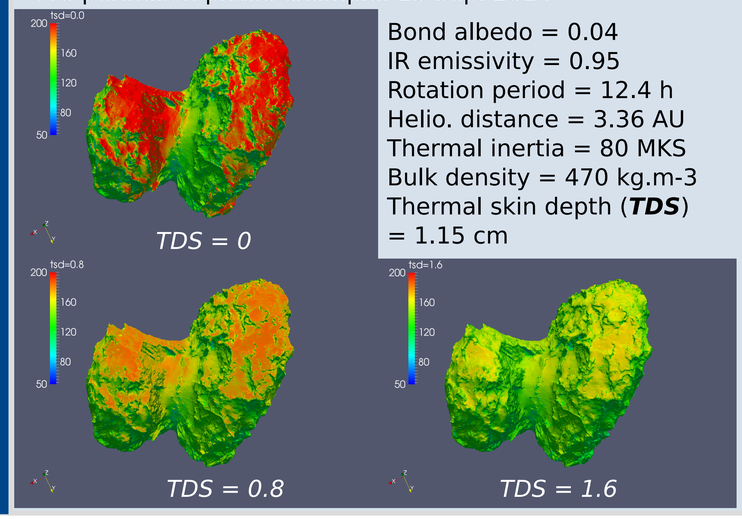
* Shadowing is taken into account

* A homogeneous layer of material is considered for each facet (depth expressed in thermal skin depth)

* A 1D thermal conduction model is applied for each facet, taking into account the diurnal variations of the illumination

* A steady state temperature profile at a given rotation step is reached for each facet after 6-7 rotations of the comet.

Pre-perihelion phase exemple: 15 Sep. 2014



Bond albedo = 0.04
IR emissivity = 0.95
Rotation period = 12.4 h
Helio. distance = 3.36 AU
Thermal inertia = 80 MKS
Bulk density = 470 kg.m-3
Thermal skin depth (***TDS***) = 1.15 cm

Simulated brightness temperatures

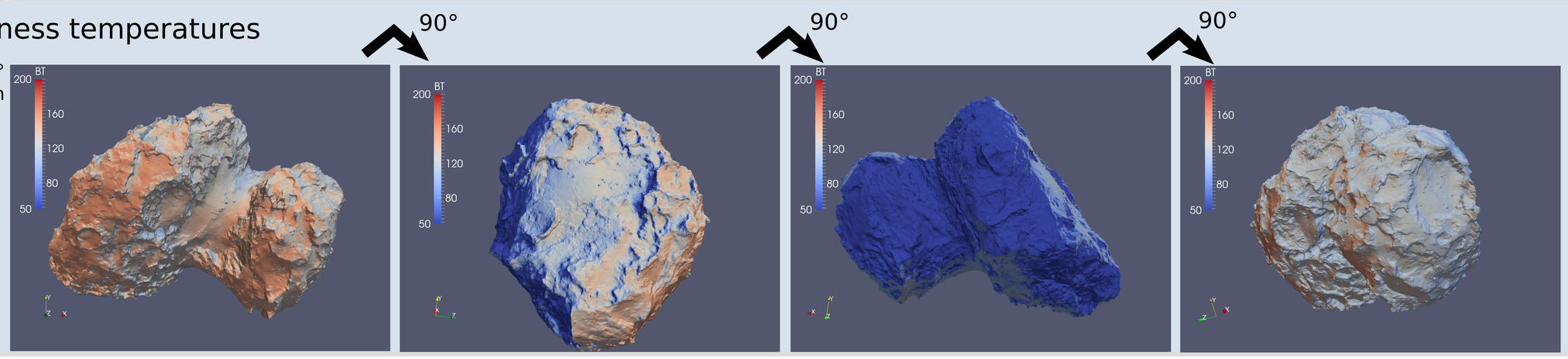
Emission angle = 0°
Wavelength = 1.6 mm

Physical and thermal constraints of the material layer:
*Thermal inertia = 80 MKS
*Bulk density = 470 kg.m^{-3}

***Porosity = 80%**
***Dust-mass fraction = 0.9**
***Mean temperature = 125 K**

$\varepsilon' = 1.37$
$\varepsilon'' = 0.005$

Electrical skin depth = 6 cm



Conclusions and next steps

- BT simulated as a function of of internal structure properties (porosity, ice-mass fraction);
- Different emissivity models will be tested (roughness);
- Comparison with MIRO data should constrain the structural properties of the top centimeters of the nucleus 67P;
- Physical processes experienced by the subsurface will be investigated.

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