Fragmentation processes on the 67P/Churyumov-Gerasimenko surface from the OSIRIS images

PhD Research Proposal

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67P/Churyumov-Gerasimenko comet

Objectives:

- physical and chemical properties of the nucleus;
- evolution of the nucleus and the coma during the comet's approach to the Sun;
- analysis of the interaction between interstellar medium and comet;

OSIRIS

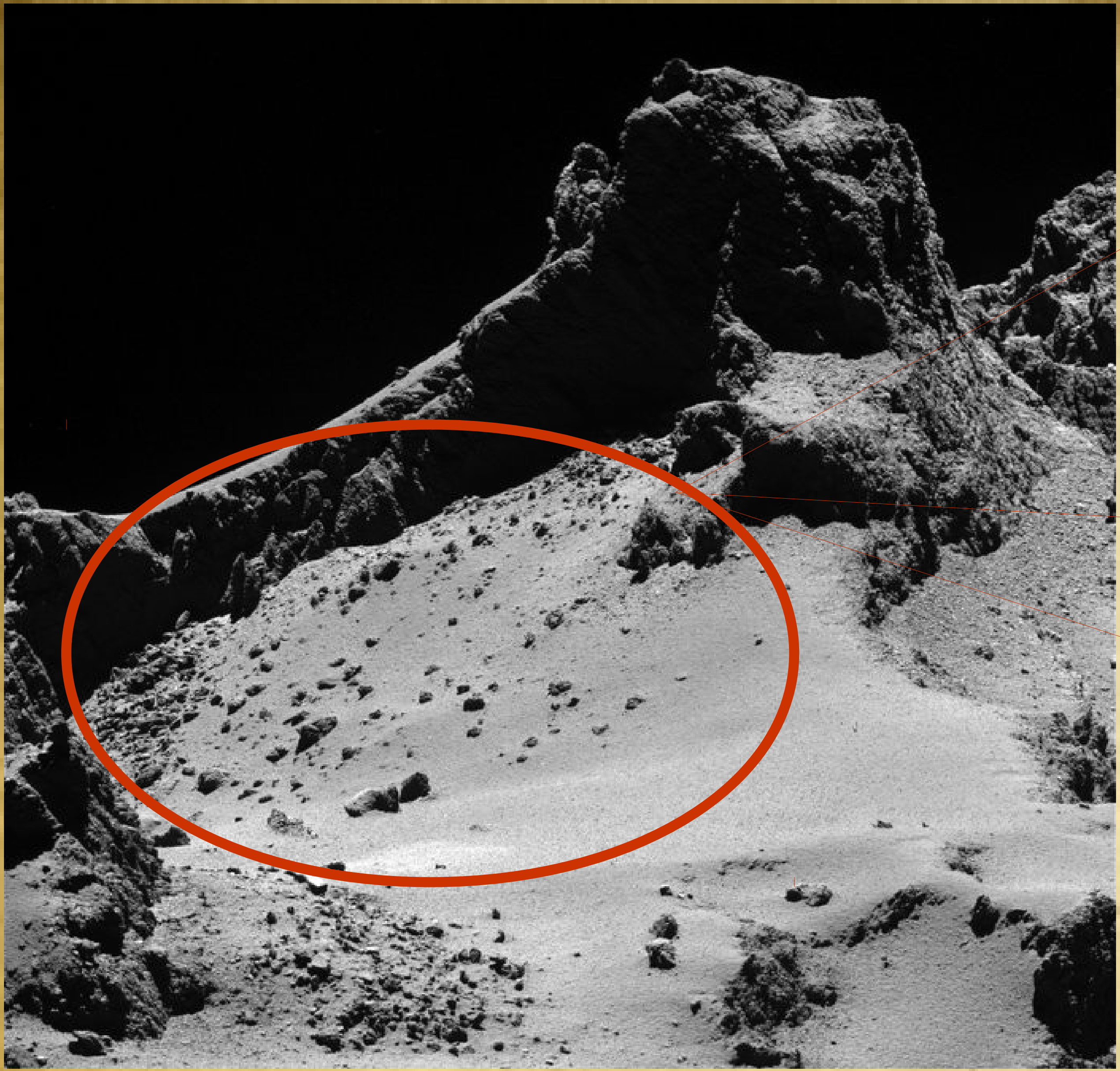
Optical Spectroscopic and Infrared Remote Imaging System

cometary nucleus, activity and surface morphology

Results:

the surface is a collection of contrasts

- smooth plains;
- scattering of boulders;
- imposing craggy cliffs;
- fractures from hundreds meter scale to decimeters scale;



Boulders scattered all over the surface

isolated

cluster

No evident impact craters

How these boulders were formed?

FRAGMENTATION

Breaking of a contiguous body into several pieces and it occurs in very distinct contexts at any scale

Application of fragmentation theory on boulders distribution

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OSIRIS images

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Understand the processes underlying their formation and thus the evolution and structure of comet itself

Boulders formation

- **Thermal stress and sublimation**: diurnal and seasonal changing insolation conditions. Dichotomy between northern hemisphere (weakly illuminated, spin-axis obliquity 52°) and southern hemisphere (strongly insolated during perihelion passage, 1.24AU).
- **Surficial material composition**: analysis of the abundance of H_2O and CO_2 ices.
- **Gravitational phenomena**: because of sublimation and comet activity, higher layers are fragmented and the fragments fall down.

(1) Correlation between thermal stress, sublimation and boulder formation

- Boulder size-frequency distribution for all comet regions $\longrightarrow$ number of boulders VS diameter $\longrightarrow$ power-law index
- Database containing all the boulder physical features
- Calculation of capacitive heat storage $Q_{cap,i}$

$$Q_{cap,i} = \boxed{Q_{abs,i}} + \boxed{\sum_j Q_{radi,j}} + \boxed{Q_{con,im} + Q_{con,in}} + \boxed{Q_{sub,i}}$$

absorbed

self-heating

conductive heat flux between nodes

heat-sublimation process

$\Rightarrow$ **Thermal and sublimation model**

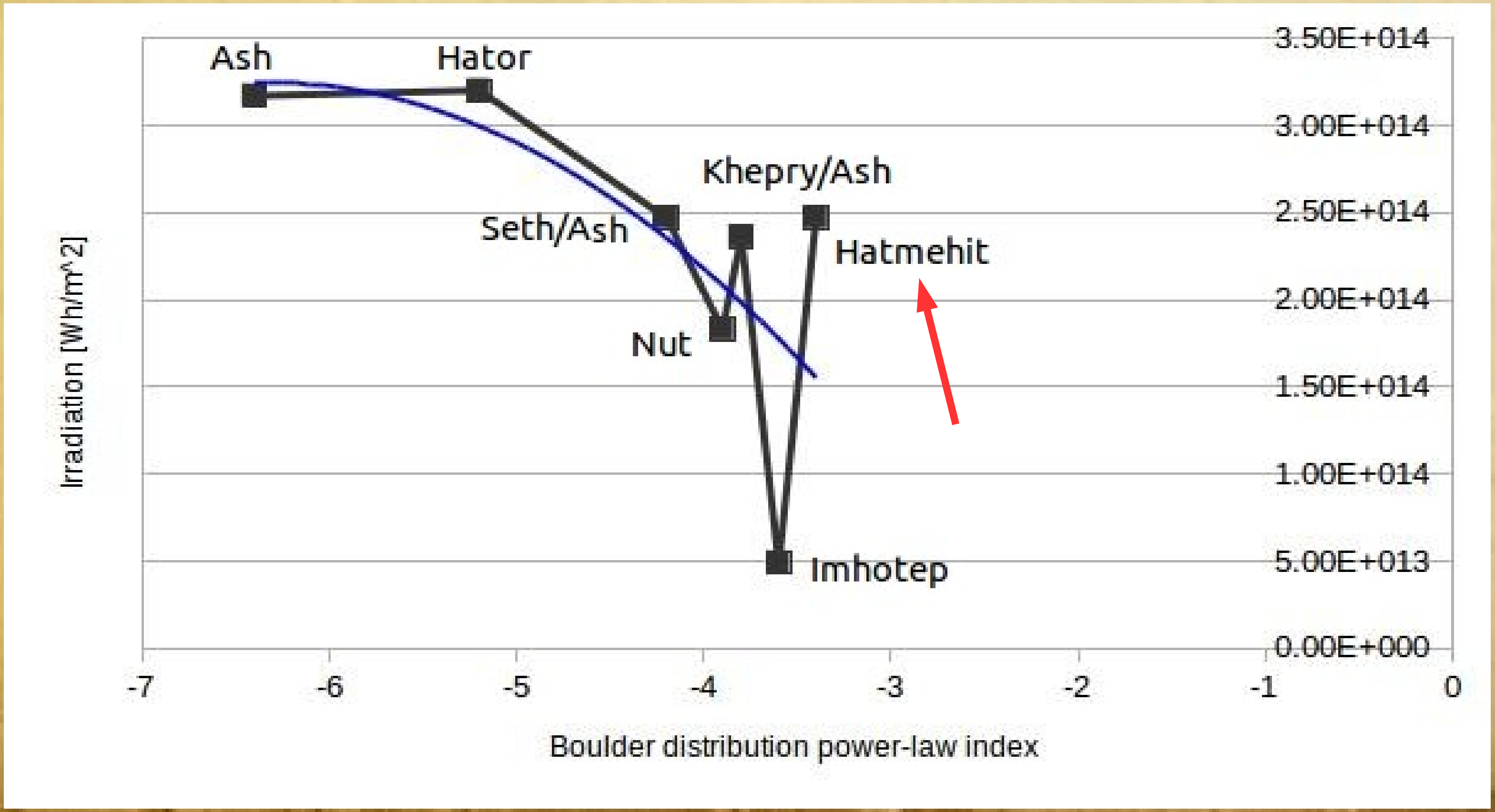
Preliminary results from my master degree thesis

Absorbed heat flux, irradiation W/m^2

$Q_{abs,i}=(1-\alpha)(S/r_h^2)A_i\cos\theta_i(t)$ if $\cos\theta_i > 0$

$Q_{abs,i}=0$ if $\cos\theta_i \leq 0$

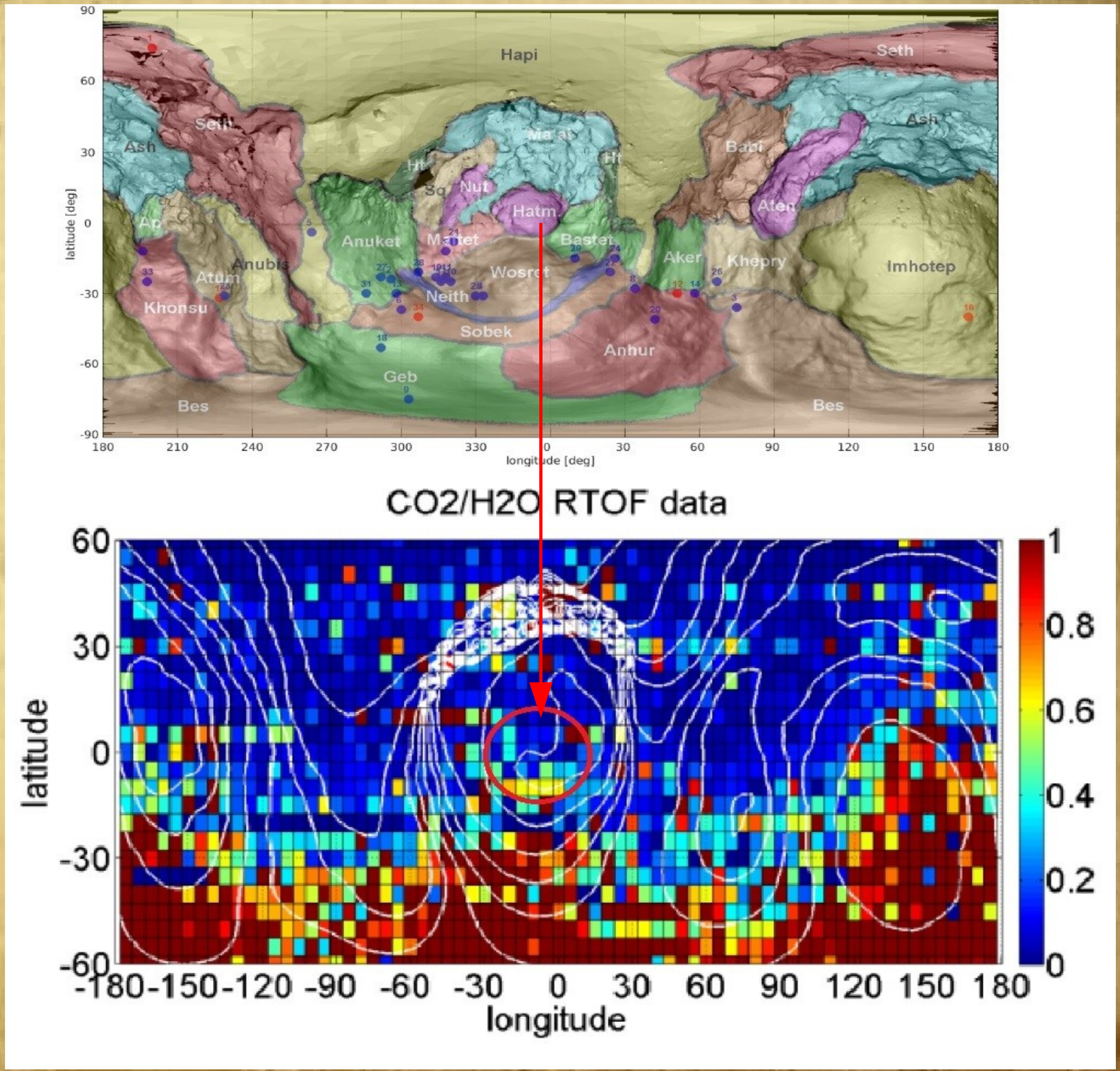
α=0,059 albedo
S=1306,656 W/m^2 solar constant
r_h=heliocentric distance [AU]
i=region
θ=solar incidence angle



(2) Study the surface composition linked to the coma molecules

ROSINA
Rosetta Orbiter Spectrometer for Ion and Neutral Analysis

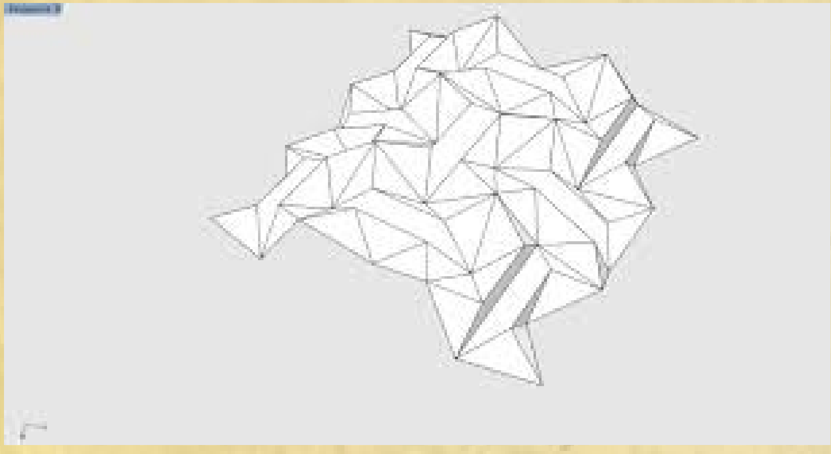
Fragmentation model



COMPUTATIONAL METHOD

Tessellated plate model

The surface of the object is represented as a collection of triangular plates



Finite Element Method

Subdivision of a whole domain into simpler parts

Accurate representation of complex geometry

Inclusion of dissimilar material properties

Easy representation of the total solution

(3) Gravitational phenomena

The erosion caused by sublimation affects strata with different content of material and the results are scarp evolution and gravitational falls

- To analyze all OSIRIS images containing both geological features, such as scarps, deposits and fractures, and products of nucleus activity.
- To compare all data considering that the origin of terrains and morphological features are linked with the gravitational slopes, the nature of the cometary material and its mechanical properties, in particular tensile, shear and compressive strength.
  - Low-slope terrains = 0-20°, covered by unresolved material made of particles smaller than 20 cm. Some isolated boulders (>10 m).
  - Intermediate-slope terrains = 20-45°, fallen consolidated material, debris fields and dust, with numerous boulders from 1 m to 10 m.

(3) Gravitational phenomena

- High-slope terrains = 45-90°, cliffs that expose consolidated material, no boulders or fine material. Probably bare nucleus.

The link between the different types of terrains (smooth,hummocky, consolidated material, dust covered, with or without boulders) and their gravitational slope is important to better constrain the processes in play and the nature of the cometary material.

- Include in the comparison the tensile, shear and compressive strength

Tensile strength	**Shear strength**	**Compressive strength**
σ_T~3-15 Pa small overhangs (10m) σ_T~3-15 Pa collapsed structures(100m)	σ_S~4-30 Pa with boulders on surface	σ_c<15.6 Pa from Philae footprints

Collaborations and data analysis

- New size-frequency distribution for all 67P regions from OSIRIS images. Power-law index and surficial features database.
- Calculation of heat capacitive storage $Q_{capi,i}$ along the 67P orbit.

→ Collaboration with Stefano Mottola, Berlin DLR. Complete thermal and sublimation model including self-heating. Calculation of $Q_{capi,i}$ for the same regions of my master degree thesis in order to collect data and to compare with my results. Extention to all other 67P regions.

Thermal and sublimation model

- Link the surface composition with the abundance of H_2O and CO_2 ices in the coma to better understand the correlation between power-law index and insolation.

→ Collaboration with Kathrin Altwegg, PI ROSINA, University of Berna. Distribution map of H_2O and CO_2 ices molecules.

Fragmentation model

- Compare all data with gravitational slopes and mechanical properties of the surface material.

Thanks for your attention