Characterization of the Subsurface of 67P/Churyumov-Gerasimenko's Abydos Site

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Introduction

On November 12, 2014, *Rosetta*'s descent module *Philae* landed on the Abydos site of comet 67P/Churyumov-Gerasimenko (67P). Among the instruments onboard *Philae*, the *Ptolemy* mass spectrometer performed the analysis of several samples collected from the surface and atmosphere of the comet. Here we investigate the structure of the subsurface of the Abydos site. To do so, we employ a one dimensional cometary nucleus model [1] with an updated set of thermodynamic parameters relevant for 67P. The comparison of the production rates derived from our model with those measured by *Ptolemy* allows us to place constraints on the structure of the subsurface of *Philae*'s landing site.

Model and Parameters

We consider a mixture of crystalline ices (H_2O, CO and CO_2) and dust, with parameters updated from the recent *Rosetta* measurements (see **Table 1**). Based on the *ROSINA* observations [2], we assume $CO/H_2O = 0.13\pm0.07$ and $CO_2/H_2O = 0.08\pm0.05$ as a starting composition in the matrix. Two key parameters, the dust/ice mass ratio and the porosity, initially set at 4±2 [3] and 65±20% [4] respectively, are allowed to vary in the model (see **Figure 1**).

Table 1. List of physical and orbital parameters of 67P's nucleus used in this work.

Semi major axis	3.463 UA	Effective latitude of the Abydos site	- 21 °
Eccentricity	0.641	Bolometric Bond's albedo	$6.5 \cdot 10^{-2}$
Initial radius of the nucleus	2.43 km	Obliquity of the comet	52.25 °
Rotational period of the comet	12.4 h	Argument of sub-solar meridian at perihelion	- 111 °

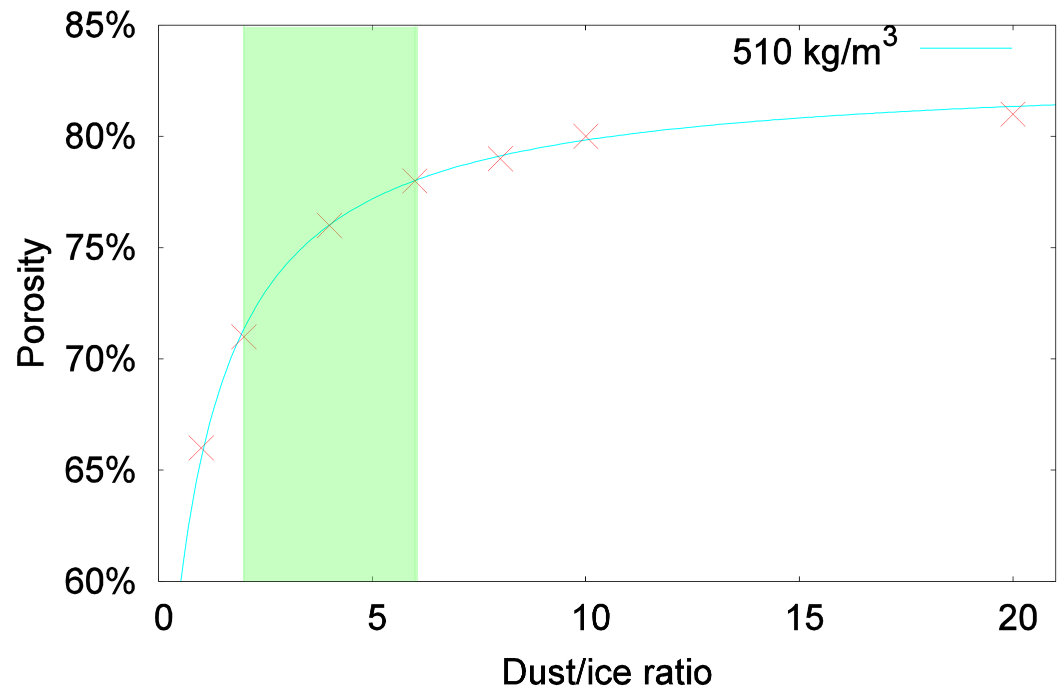

Figure 1. Nucleus porosity as a function of the dust/ice mass ratio, as to match a density of 510 kg/m³ in the nucleus.

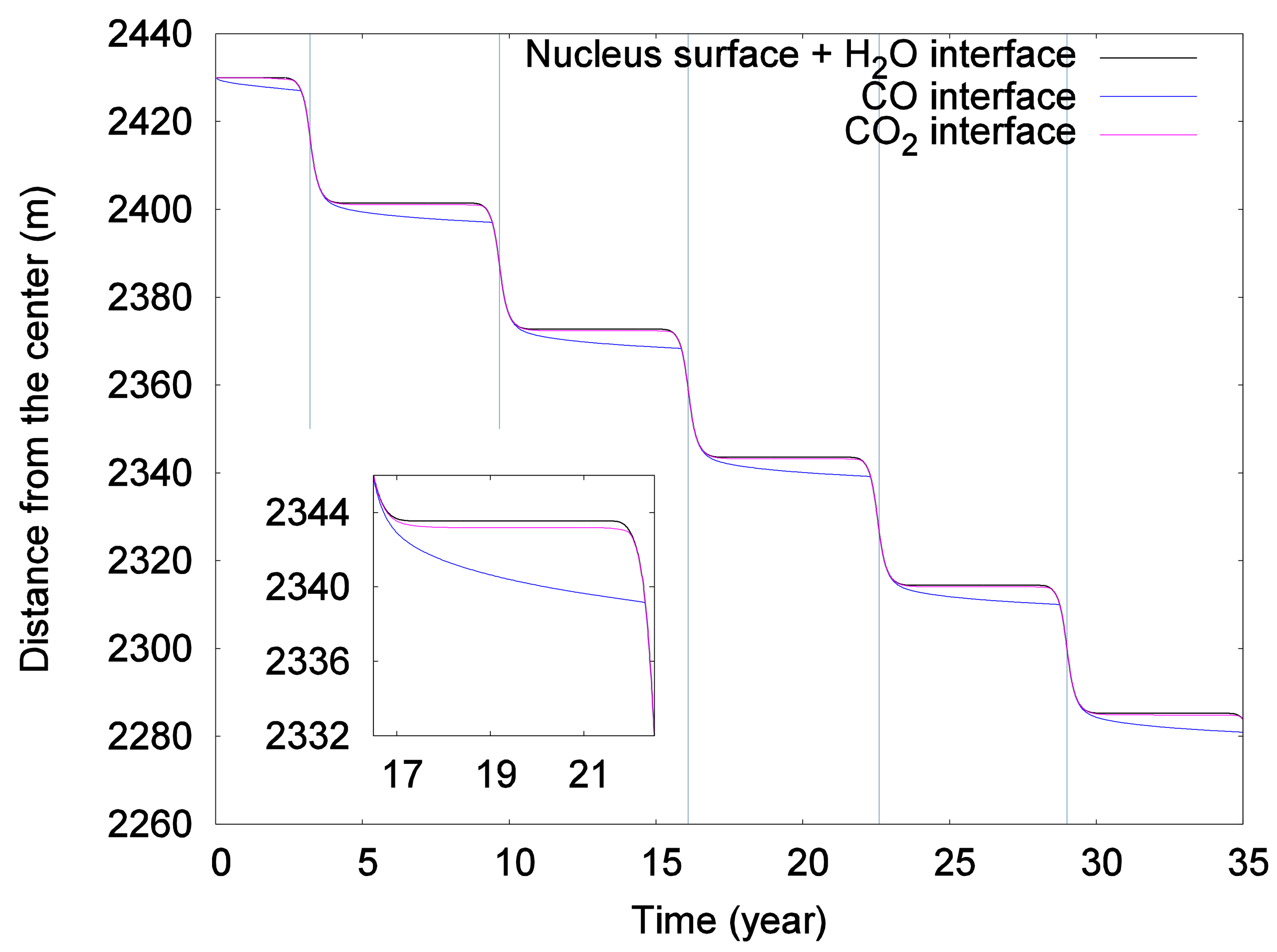

Figure 2. Stratigraphy of the nucleus, showing the interfaces of sublimation of all species. An ablation of the surface occurs at each perihelion, reaching all interfaces. Detail of one revolution: the nucleus' physical differentiation has a limited depth because of the low thermal conductivity of 67P.

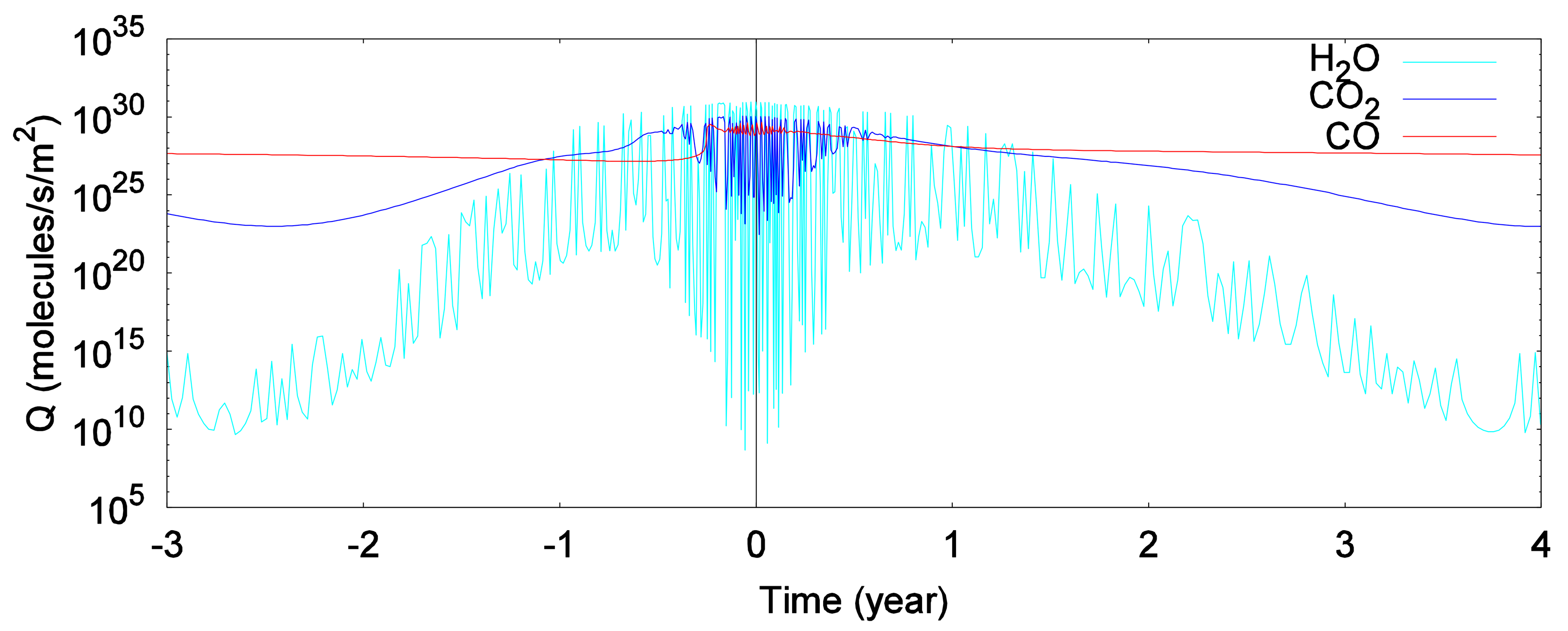

Figure 3. Outgassing profiles of all species at Abydos during one orbital evolution (perihelion occurs at 0 years). Peaks noticed for $Q(H_2O)$, Q(CO) and $Q(CO_2)$ correspond to the diurnal effects. The outgassing profile of each species varies as a function of the heliocentric distance, with an amplitude depending on the abundance and depth at which the species is buried in solid form (see **Figure 2**).

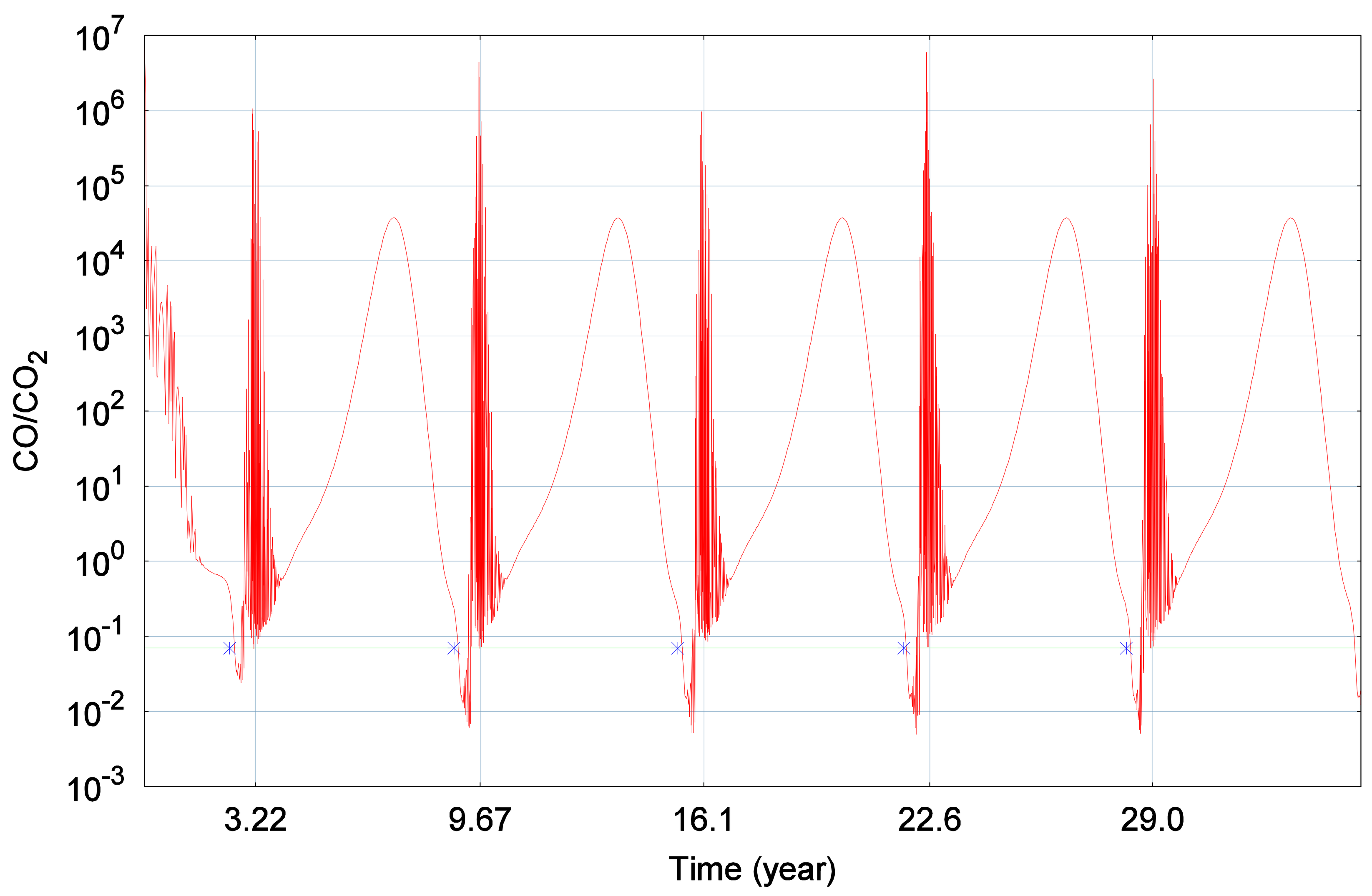

Figure 4. Evolution of the CO/CO_2 outgassing ratio at Abydos. The green line represents the *Ptolemy* value and the blue dots correspond to the measurement epoch (November 12, 2014). The *Ptolemy* value is matched with a 51 days difference (< 2% of error on 67P's year).

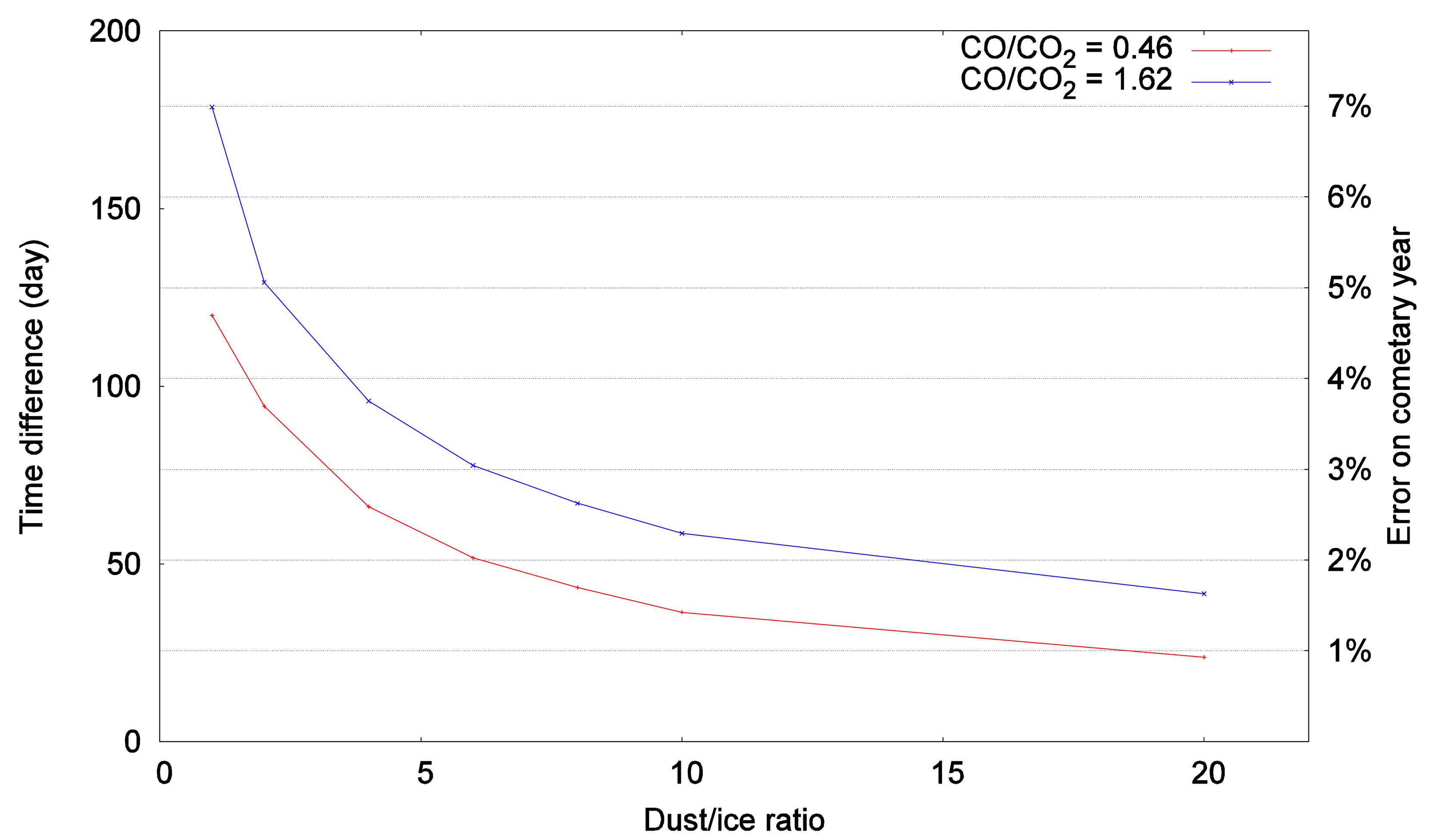

Figure 5. Influence of the dust/ice ratio on the time difference taken by the CO/CO_2 outgassing ratio to match the *Ptolemy* value at *Philae*'s landing epoch. This difference decreases with higher dust/ice ratios. For $CO/CO_2 = 0.46$ and dust/ice > 6, this difference is always under the 2% limit on a comet year.

Results and Discussion

We find that the best match of the *Ptolemy* measurements at a close time period of 67P's orbital evolution corresponds to CO/H_2O and CO_2/H_2O set at minimum and maximum respectively, giving $CO/CO_2 = 0.46$, and with a dust/ice ratio of 6 (porosity of 78%).

Assuming that the 67P's nucleus is a mixture of crystalline ices and dust, we find that high dust/ice ratios are needed at the subsurface of Abydos to match the CO/CO_2 value measured by *Ptolemy* at *Philae*'s landing epoch (November 12, 2014). Higher dust/ice ratios than those found in the comet literature are desirable if one wants to improve the time matching of the data. Our preliminary results suggest that 67P is heterogeneous.

References

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[2] Hässig et al. 2015. *Science 347,* 0276H.

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