Evolution of the subsurface of 67P/Churyumov-Gerasimenko’s Abydos Site

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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$_2$O, 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$_2$O = 0.13±0.07 and CO$_2$/H$_2$O = 0.08±0.05 as a starting composition in the matrix. Two key parameters, the dust/ice mass ratio and the porosity, initially set at 4±2 [%] and 65±20% [%] respectively, are allowed to vary in the model (see Figure 1).

![Figure 1](https://example.com/figure1.png)

**Figure 1.** Nucleus porosity as a function of the dust/ice mass ratio, as to match a density of 510 kg/m$^3$ in the nucleus.

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi-major axis</td>
<td>3.463 UA</td>
</tr>
<tr>
<td>Effective latitude of the Abydos site</td>
<td>-21°</td>
</tr>
<tr>
<td>Eccentricity</td>
<td>0.641</td>
</tr>
<tr>
<td>Semi-major axis of the comet</td>
<td>2.43 km</td>
</tr>
<tr>
<td>Obliquity of the comet</td>
<td>52.25°</td>
</tr>
<tr>
<td>Rotation period of the comet</td>
<td>12.4 h</td>
</tr>
</tbody>
</table>

![Figure 2](https://example.com/figure2.png)

**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](https://example.com/figure3.png)

**Figure 3.** Outgassing profiles of all species at Abydos during one orbital evolution (perihelion occurs at 0 years). Peaks noticed for Q(H$_2$O), 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](https://example.com/figure4.png)

**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](https://example.com/figure5.png)

**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$_2$O and CO$_2$/H$_2$O 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

[3] Fulle et al. 2015. LPI 46, 2420F.