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 [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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eccentricity</td>
<td>0.641</td>
</tr>
<tr>
<td>Initial radius of the nucleus</td>
<td>2.43 km</td>
</tr>
<tr>
<td>Rotational period of the comet</td>
<td>12.4 h</td>
</tr>
<tr>
<td>Argument of sub-solar meridian at perihelion</td>
<td>-111°</td>
</tr>
</tbody>
</table>

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.

RESULTS AND DISCUSSION

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$_2$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. 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.

REFERENCES

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