EPSC Abstracts
Vol. 11, EPSC2017-824, 2017
European Planetary Science Congress 2017

The temporal evolution of exposed water ice-rich areas on the surface of 67P/Churyumov–Gerasimenko: thermal analysis

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1. Introduction

Water ice-rich patches have been detected on the surface of comet 67P/Churyumov– Gerasimenko by the VIRTIS (Visible InfraRed and Thermal Imaging Spectrometer) hyperspectral imager on board the Rosetta spacecraft [1], since the orbital insertion in late 2014 August. Among these, three icy patches have been selected, and VIRTIS data are used to analyse their properties and their temporal evolution while the comet was moving towards the Sun. An extensive analysis of the spectral parameters has been performed by [2], by applying the Hapke radiative transfer model [3] to retrieve the abundance of water ice, and type of mixing. In all three cases, after the first detections at about 3.5-au heliocentric distance, the spatial extension and intensity of the water ice spectral features increased, it reached a maximum after 60–100 d at about 3.0 au, and was followed by an approximately equally timed decrease and disappearance at about 2.2 au, before perihelion (Figure 1). The behaviour of the analysed patches can be assimilated to a seasonal cycle. The similar life cycle of the three icy regions indicates that water ice is uniformly distributed in the subsurface layers, and no large water ice reservoirs are present [2].
Here we perform a thermal analysis in order to derive the total mass of water ice sublimated, and the thickness of the ice-rich layer.

2. Dataset

In the present work we take into account three large patches: the ‘BAPs’ (bright albedo patches) discussed by [4]: BAP1 (longitude: 118°E, latitude: 13°N), BAP2 (longitude: 180°E, latitude: −4°N), and the ‘SPOT 6’ (longitude: 72°E, latitude: 3°N) discussed by [5]. The surface portions that are related to patches are covered by ∼50 to ∼5000 pixels, respectively, from the least to the highest resolved acquisitions.

3. Method

We perform a thermal analysis similar to [6]: to determine the sublimated mass of the water ice we have used a latent heat of sublimation in the vacuum $h_s(T)$ as derived by solving the Clausius-Clapeyron equation as discussed in [7]:
$h_s(T) = (E + FT + GT^2)\, R_0/(10^{-3}M)$
where E, F, G, M are the water ice parameters reported by [7] and R_0 is the universal gas constant.

4. Results

We obtained an upper limit of mass of ice sublimated by assuming that i) the ice starts to sublimate from the patches at the first detection of water ice signatures, ii) the sublimation lasts until the first detection without any ice signature, iii) instantaneous sublimation rate per surface unit = solar flux / $h_s(T)$, and iv) average surface temperature derived from VIRTIS measurement. The obtained total water ice sublimeted from BAP1 is ~200 kg / m^2 (average surface temperature T=175 K for BAP 1) (Figure 2). Similar values are derived for the other two icy patches. The mass sublimated expressed as thickness of a pure water ice layer is ~20 cm.
A more accurate evaluation of the sublimating mass is in progress and shall need a full thermophysical model to describe the surface temperature variation on a daily and seasonal basis.

Acknowledgements

The authors would like to thank the following institutions and agencies, which supported this work: Italian Space Agency (ASI-Italy), Centre National d'Etudes Spatiales (CNES-France), Deutsches Zentrum für Luft und Raumfahrt (DLR-Germany), National Aeronautic and Space Administration (NASA-USA) Rosetta Program, Science and Technology Facilities Council (UK). VIRTIS has been built by a consortium, which includes Italy, France and Germany, under the scientific responsibility of the Istituto di Astrofisica e Planetologia Spaziali of INAF, Italy, which guides also the scientific operations. The VIRTIS instrument development has been funded and managed by ASI, with contributions from Observatoire de Meudon financed by CNES, and from DLR.

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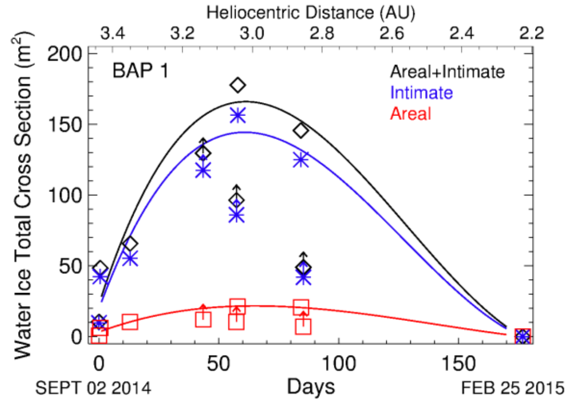

Figure 1. (extracted from [1]) total cross-section of water ice (upper right panel) is plotted as a function of time for the two types of mixtures modelled.

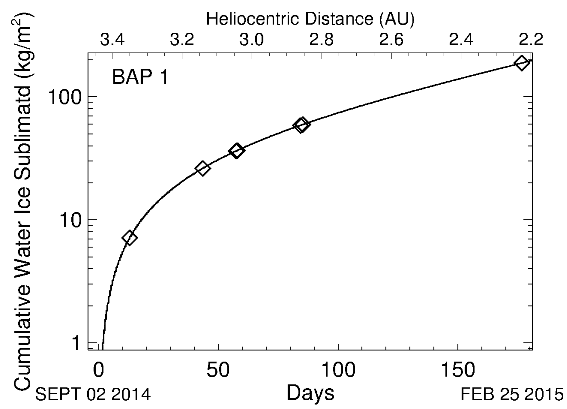

Figure 2. Cumulative water ice mass sublimated, calculated as discussed in the text. Points on the solid line represent the observation times, and correspond to the points in Figure 1.