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Influence of physical properties on the outgassing from the nucleus of 67P/Churyumov-Gerasimenko

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Abstract

Constraining the composition and the internal structure of the nucleus of 67P/Churyumov-Gerasimenko (hereafter 67P) is challenging as we are mainly restricted to use of remote measurements. The ROSINA/DFMS mass spectrometer has measured the local gas densities of various species in the coma of 67P. Results display strong variations of volatile abundances [1]. Several studies, including our previous one [2,3,4], proposed that the large tilt of the rotation axis of 67P imply large seasonal effects driving the species outgassing. Other instruments on board Rosetta have characterized several physical parameters of the nucleus such as the porosity, the density, the dust composition, the albedo, etc. Some of these parameters are difficult to constrain and can have large error bars associated with them [5,6]. Here we provide additional constraints on the composition of the nucleus by exploring the effect of plausible ranges of different physical parameters on the outgassing rate of the volatiles. We compare the data provided by the ROSINA/DFMS instrument with a thermochemical numerical model designed to track the evolution of the stratigraphy of cometary nuclei as a result of outgassing.

1. Data and comet nucleus numerical modelling

The production rates of the species coming out from the nucleus have been investigated via a numerical model described in [7]. This model is designed to compute the thermal and chemical evolution of a single spot at a given latitude on the surface of the nucleus as the comet orbits's the Sun. The nucleus is considered to be a porous sphere with an initially defined radius and made of a mixture of ices and dust in specified proportions. The model solves the conservation of energy and conservation of mass equations via the finite volume method, in spherical coordinates and in one dimension along the radial axis. Errors in the mass conservation do not exceed 0.1% for the global error and 1% for the local error (at a given time t). Our model outputs are compared with the ROSINA/DFMS data, which correspond to the bulk composition of the coma. We focus on H_2O, CO and CO_2, which correspond to three of the major species detected in the coma [1,8] (we are not considering O_2 so far [9]). As the data were collected at different sub-spacecraft latitudes and distances from the nucleus, following the spacecraft orbit, we ran simulations for different latitudes explored by the spacecraft and extracted the results at the corresponding epochs. The nucleus is considered as a mixture of dust and crystalline ice. The initial abundances of the three studied species were modified until we found the best combination to fit the measurements. In addition, characteristic parameters of the nucleus such as the mass ratio between dust and ice (dust/ice), porosity, dust mantle thickness, dust properties have been varied in order to evaluate the sensitivity of the outgassing to these different parameters.

2. Results

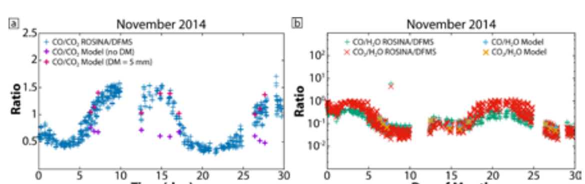

Figure 1: Comparison of the CO/CO_2 (a) and CO/H_2O and CO_2/H_2O (b) ratios computed by the model with the data measured by ROSINA/DFMS for November 2014 (initial molar abundance: 90% H_2O, 4% CO and 6% CO_2).

We have produced simulations that match fairly well the CO/CO_2, CO/H_2O and CO_2/H_2O ratios measured by ROSINA/DFMS at almost all the epochs of the comet orbital evolution for given characteristics. An example, for November 2014, is shown in Fig. 1 [4]. We found that the volatiles composition of the comet is homogeneous to 1st order. Local variation of the coma composition can be ascribed to variation of physical parameters that influences the outgassing. At epochs before the 1st equinox (May 2015), the data require a dust mantle of 5 mm (composed of silicates) corresponding to the top layer of the nucleus. This modifies the thermal inertia and the heat wave propagation. After the 1st equinox the dust mantle is no longer required to fit the data. A different CO/CO_2 ratio (globally) is also required to fit the data at these times. The thickness of the dust mantle influences the value of the ratios without modifying the shape of the trend (Fig. 1a). In addition, the dust/ice ratio appears to be a critical parameter influencing the outgassing pattern as it modifies both, the magnitude of the values, and the shape of the trend (Fig. 2b).

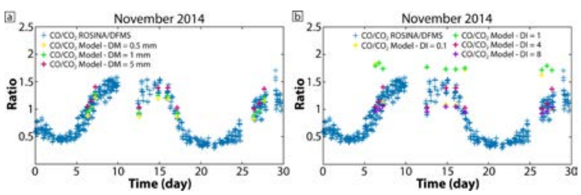

Figure 2: Comparison of the CO/CO_2 ratios computed by the model with the data measured by ROSINA/DFMS for November 2014 (initial molar abundance: 90% H_2O, 4% CO and 6% CO_2) for different (a) dust mantle (DM) thickness and (b) dust/ice ratio (DI).

3. Conclusion

Our study suggests that the nucleus volatile composition of 67P is rather homogenous. The variations in the outgassing rates of the different species seems to be mainly insolation-driven. Here we have explored the sensitivity of different physical parameters on the volatile outgassing. Some of the parameters, such as the dust to ice ratio, which is difficult to constrain, have an important influence on the outgassing rates. Further investigations need to be performed to understand the behaviour of the different physical parameters and to optimize the best match for the plausible value ranges. This study can bring additional constraints on the possible volatiles composition and as well as the physical characteristics of the comet 67P.

Acknowledgements

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