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Introduction: The surface of 67P/Churyumov-Gerasimenko's nucleus has been thoroughly observed and analyzed by the cameras onboard both the Rosetta's main spacecraft [1], [2] and the Philae lander [3], [4] for more than two years. The high resolution of the images acquired revealed at numerous locations at the surface [5], [6] and also on the walls of the deep pits [2] repeating structures at a scale of a-few-meters. To better constrain the comet formation models, it is essential to understand to what extend these structures may be representative of the internal structure of the nucleus. Our purpose is to use CONSERT (Comet Nucleus Sounding Experiment by Radiowave Transmission) data to provide information (at least constraints) about the heterogeneities inside the nucleus at spatial scales up to 10 meters [7] and thus to contribute to a better understanding of the comet formation process.

The heterogeneity inside the nucleus seen by CONSERT: The CONSERT experiment has been designed to sound the interior of the nucleus and collect information on the nucleus internal structure. Actually it provides us with information about the changes in permittivity that may occur inside the sounded volume of the nucleus. Part of the smaller lobe of the nucleus in the vicinity of Abydos has been actually sounded by CONSERT's electromagnetic waves at 90 MHz with a spatial resolution around 10 m [7].

The work presented is based on the CONSERT's data collected during the First Science Sequence (FSS) and marginally during Philae's Separation Descent and Landing (SDL) for comparison. We present results on the shape of the CONSERT's signal transmitted through the small lobe of the nucleus. For a more accurate analysis and interpretation of the data, we split the FSS data into two distinct sets: one corresponding to soundings performed West of Philae and the second one for those acquired East of Philae to investigate potential discrepancies.

We already know from the measured propagation time that the relative permittivity value for the cometary material inside the sounded volume is 1.27 ±0.05, which confirms the high porosity of the nucleus [6]. The narrow shape of the received signals, quantified by the pulse width, suggests that the signal encountered weak diffraction. This indicates that the cometary material is fairly homogeneous on a spatial scale of several of meters. Our purpose is to use simulated data to quantify the level of heterogeneity that would be compatible with the CONSERT data.

Nucleus models: The choice has been made to model the nucleus heterogeneity by a mixture of two different materials: One is the host material, it is close to vacuum with a relative permittivity value ε_1 very close to 1. The second one corresponds to inclusions, it is a mixture of ice and dust with a higher permittivity value ε_2 ranging between 1.3 and 1.6. These values are rather low to account for a non-negligible intrinsic porosity of the material.

The average permittivity value for the resulting nucleus is fixed to be consistent with the average value of 1.27 estimated by CONSERT [7]

Different models of 3D spatial distribution of these two materials can been considered for the heterogeneities. We focus on two very different models that allow us to take into account a potentially wide range of behaviors.

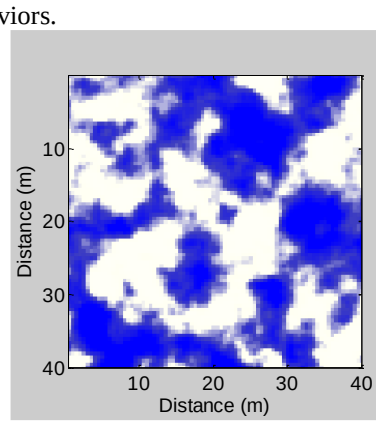

Fig.1 : Random fractal structure (2D slice)

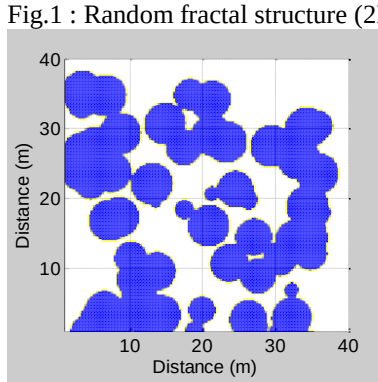

Fig.2 : Aggregates of spheres (2D slice)

On one hand, a band-limited random fractal model (Fig.1) based on the diamond-square method and one the other hand a model based on aggregates of spheres (Fig.2). For each model, a characteristic size of the heterogeneities (correlation length) is chosen. The ranges of the correlation lengths include the typical sizes detected for possible cometesimals on the surface of the comet.

Simulated data and comparision with experimental data : The propagation of CONSERT's waves through the nucleus models described above is simulated using the TEMSI-FD software, based on the Finite Difference Time Domain method [8]. The effect of these heterogeneities on the shape of the CONSERT's pulse can be studied and compared to the experimental values. We run simulations for both models considering a range of permittivity values ($\varepsilon_1 = 1 – 1.1$ and $\varepsilon_2 = 1.3 – 1.6$) and a range of size for the heterogeneities (from 1 to 10 m).

From this quantitative analysis, we will present constraints on the permittivity value and provide an interpretation in terms of porosity and Dust/Ice ratio [9] for sizes of the heterogeneities that are commensurate with the structures observed by the cameras on the surface.

References: [1] Basilevsky et al. (2015) LPSC, [2] Sierks et al., (2015) Science, [3] Bibring et al. (2015) Science, [4] Mottola et al. (2015) Science, [5] Davidsson et al. (2016) A&A, [6] Vincent et al. (2015) Nature, [7] Kofman et al. (2015) Science, [8] Guiffaut (2007) TEMSI-FD, Solver based on the finite difference in the time domain method, [9] Herique et al., (2017) MNRAS.

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