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CONSERT's first constrains on the fine scale heterogeneity inside the nucleus of 67P/Churyumov-Gerasimenko. V. Ciarletti[1], J. Lasue[2], A. Hérique[3], W. Kofman[3], Christophe Guiffaut[4], A-C. Levasseur-Regourd[5] [1] LATMOS/IPSL, UVSQ Université Paris-Saclay, UPMC Univ. Paris 06, CNRS, Guyancourt, France (valerie.ciarletti@latmos.ipsl.fr); [2] Université de Toulouse; UPS-OMP; IRAP; Toulouse, France; [3]Univ. Grenoble Alpes, IPAG, Grenoble, France; [4]XLIM, Limoges, France; [5]LATMOS/IPSL, UPMC Univ. Paris 06 Sorbonne Universités, UVSQ, CNRS, Paris, France

Introduction: Since the arrival of the Rosetta spacecraft at comet 67P/Churyumov-Gerasimenko in August 2014, a series of instruments have been observing the surface of the nucleus at distances ranging from more than 10 000 km down to less than one meter. The cameras onboard the Rosetta's main spacecraft (NAVCAM [1], OSIRIS [2]) and Philae lander (CIVA [3], ROLIS [4]) have revealed details of amazing structures giving some very partial hints about the internal structure of the nucleus. This is the case for the a few hundreds-of-meters-deep pits [5] linked to the comet's activity; and the layers and terraces [6, 7, 8] revealed by the OSIRIS images. The CONSERT (Comet Nucleus Sounding Experiment by Radiowave Transmission) experiment [9] has been specifically designed to sound the interior of the nucleus and provide information on the nucleus structure at depth. The work presented here is based on the CONSERT data collected during the First Science Sequence and aims at constraining the small scale heterogeneity inside the volumes investigated by CONSERT.

The CONSERT data: The CONSERT experiment is a bistatic radar with receivers and transmitters on-board both Rosetta's main spacecraft and Philae lander. The instrument made use of electromagnetic waves at 90 MHz that propagated, during the First Science Sequence, back and forth between the transmitters and receivers onboard the lander and the orbiter through the small lobe of 67P.

The data used here have been acquired with a sufficient enough signal to noise ratio (in green on Fig. 1) thus allowing a quantitative analysis of the measurements performed.

Two data sets are available that correspond to approximately 30 min of measurements at West of Abydos and 90 min at East, at a rate of one sounding each 2.5 sec.

The distances travelled by the CONSERT's waves inside the nucleus are ranging from approximately 200 to 800 m according to the orbiter location. The set of data used here has been collected at depths that reach a maximum of about one hundred meters beneath the surface of the nucleus in the vicinity of Abydos. The CONSERT's raw data are processed to obtain the delay, amplitude and shape of the pulse received after it has propagated through the nucleus.

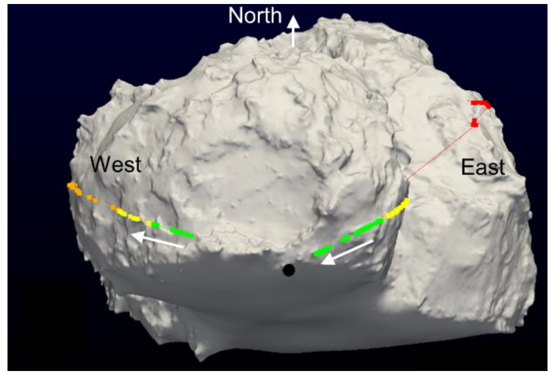

Fig 1.: The colored dots show the intersection of the straight lines joining Orbiter and Lander with the surface of the nucleus shape model. The black dot is the current best estimate of Philae's location [11].

The electromagnetic wave propagation is driven by the permittivity value of the medium, which is, for a given frequency range, a function of the porosity, composition and temperature of the material. As a consequence, CONSERT can be used to retrieve permittivity values and their spatial variations.

The CONSERT data available already allowed us to obtain, for the sounded volumes, a dielectric constant mean value around 1.3 [10] leading to an estimated high porosity value ranging between 78% and 84% for a mixture of analogue materials corresponding to water ice and carbonaceous chondrites. They were also shown to be consistent with a possible decrease of the dielectric constant value with depth over distances of several tens of meters, that would result from an increase of porosity and/or a decrease of the dust/ice ratio with depth [11].

The CONSERT data give access to information about spatial variability on a smaller scale too. In fact, thanks to the 10 MHz frequency bandwidth of the 90 MHz signal used by the instrument, a spatial resolution around 10m is obtained inside the nucleus. In this paper, we specifically focus on local variations in the nucleus subsurface permittivity over scales ranging approximately from 5 m to 50 m that might be responsible for wave scattering and would result in a widening of the pulses received by CONSERT. The data available don't show any spectacular change in the width of the recorded pulses (even if a slight effect might be noticed). This observation provides a means to constrain the heterogeneity inside both sounded volumes.

Electromagnetic Simulations: A number of electromagnetic simulations corresponding to the CONSERT operations have been performed for a variety of subsurface permittivity models having small scale fractal heterogeneities.Several parameters are used to generate the fractal models, among which: the spatial scale (size) of the heterogeneities, the fractal dimension (index of complexity) and the constrast in the dielectric constant values. We make sure that all the models we generate are consistent with the mean permittivity found by CONSERT (i.e. 1.3)

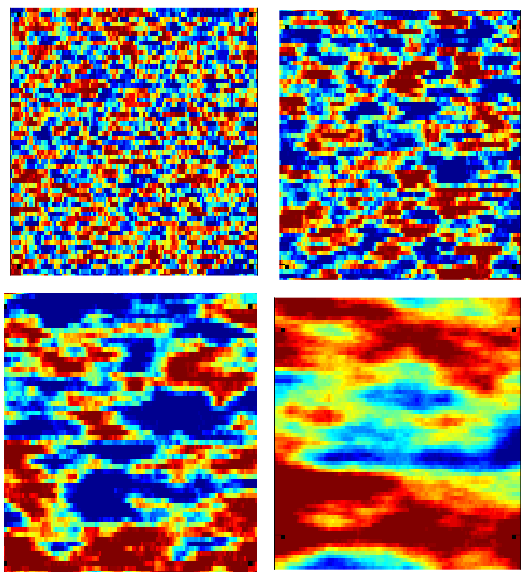

Fig 2.: Examples of permittivity variability generated with the fractal model. The color represents the dielectric constant value (1 for vacuum in blue and 2 in red).

The impact of these kinds of heterogeneity on the CONSERT's response are then simulated using the TEMSI-FD software, based on the Finite Difference Time Domain method (FDTD) [12] . The code is able to handle the propagation of the electromagnetic waves through complex environement and allows us to obtain simulated CONSERT's data.

Comparision between the experimental CONSERT data and simulated ones, with a specific emphasis on the shape and width of the received pulses, will be shown and a preliminary range of possible values for the heterogeneities inside the two volumes investigated (East and West) with be presented. The obtained results will be discussed in light of the observations made available by the OSIRIS team.

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CONSERT is a bistatic radar, between the lander and the orbiter, dedicated to the tomography of the deep interior of the comet nucleus. CONSERT was designed and built by a consortium led by IPAG UJF/CNRS (France), in collaboration with LATMOS (France) and MPS Gottingen (Germany).
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