DIELECTRIC MODEL OF COMET 67P/CHURYUMOV-GERASIMENKO IN SUPPORT OF THE CONSERT RADAR TOMOGRAPHY EXPERIMENT ON BOARD ROSETTA, Heggy E.[1], T. Kataria[2], S. M. Clifford[3], J. Lasue[4] and W. Kofman[4]; [1]Institut de Physique du Globe de Paris, Saint Maur des Fosses, France (heggy@ipgp.jussieu.fr); [2]Stony Brook University, Stony Brook, NY 11790, USA; [2]Lunar and Planetary Institute, Houston, TX 77058-1113, USA; [3]Laboratoire de Planetologie de Grenoble, Grenoble, France

Introduction: The mechanism of formation of the comet nucleus, and its resulting internal structure is dependent on the initial conditions in the region of comet formation. As primitive building blocks of the solar system, an understanding of the composition, structure and formation of cometary nuclei will provide crucial knowledge on the chemical and physical conditions in the early planetary nebula at the time of planet formation. In an attempt to address this objective, ROSETTA, will intercept the orbit of Comet 67P/Churyumov-Gerasimenko in 2014. At a distance of 3 AU from the Sun, the spacecraft will release the Philae lander, which will touch down on the surface of the comet nucleus. Philae's payload of instruments will analyze the surface and interior of the comet nucleus. CONSERT (Comet Nucleus Sounding Experiment by Radiowave Transmission) is a Philae instrument that will transmit radiowaves through the comet to be received by ROSETTA. Coupled with the orbiter, Philae will send radar waves through the comet nucleus, and measure the time delay between the transmitted and received signals to reveal the internal structure of the comet nucleus [1]. The challenge, however, is that the internal dielectric structure of Comet 67P is poorly known. Hence, the expected inversion of the physical properties of the nucleus from the CONSERT radar tomography may be significantly indistinct. Therefore, geoelectrical models of plausible internal structures are crucial to understand and minimize ambiguities on the radar investigations of the comet's interior. The variations of the signal attenuations to be observed in the radar tomographies to be collected in 2014 depend mainly on the variation of the dielectrical properties of the cometary material as a function of porosity, temperature, and mineralogical composition within the comet nucleus. Unfortunately, little to no observations exist on their variability in the comet structure. The potential impact of this variability controls penetration depths and structure identification. Our objective in this work is to integrate dielectric measurements of cometary analog materials under relevant cometary environmental conditions to set comprehensive dielectric models of the nucleus to support future data inversion.

Dielectric properties of cometary analogs: The relation between dielectric permittivity, temperature, and dust fraction has been determined on the basis of laboratory measurements of cometary analogs. Relative dielectric permittivities have been collected from measurements of mixtures of chondrite powder (also referred as dust) and water ice. They are plotted as a function of temperature and dust fraction using Lichteneker's mixing laws [2]. Figure 1 show an example of those measurement for the real part of the relative dielectric permittivity versus dust fraction, taken at a temperature of -60°C (213 K) and extrapolated to 75 and 45 K with an average error range of 13%.

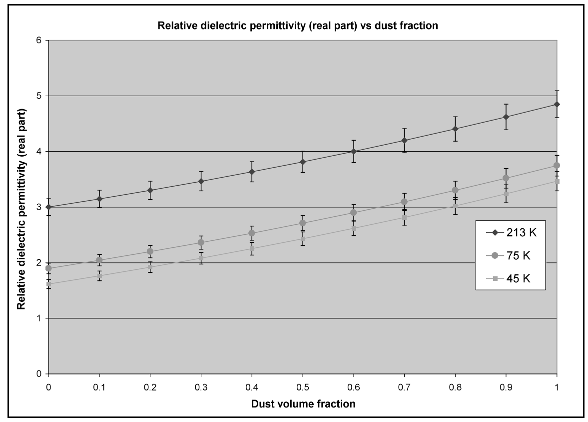

Figure 1: Relative dielectric permittivity as a function of dust fraction (real part).

Our measurements suggest that at 90 MHz, the real part of the relative dielectric permittivity varies with dust fraction and temperature, while the loss tangent varies mainly with dust fraction. Lab measurements have also yielded the relative dielectric permittivity as a function of bulk porosity. This graph is shown in Figure 2. Both the real part and loss tangent are plotted.

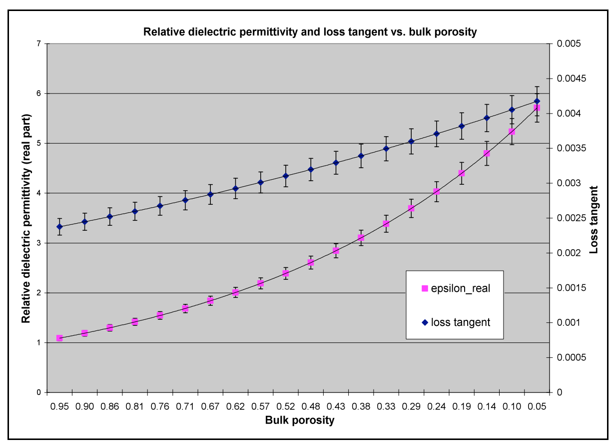

Figure 2: Relative dielectric permittivity as function of bulk porosity

Geoelectrical models: Using the dielectric dependence on the above stated geophysical parameters, we constrain the dielectric properties of each section of our geoelectrical models. Two of the geoelectrical models developed are shown in Figure 3. They are based on the layered pile model proposed by Belton et al. [3], which consists of a primordial core covered by layers of varying thickness (3-50 m), an ice crust (~240 m thick), and a dust mantle (~5 m thick). Thermal simulation has shown that temperature varies only ~20 m underneath the surface [4]. So, all the models have temperature variation within the first two layers of the nucleus: the dust mantle and the crystalline ice crust. There is outgassing present on surface and underneath [3]. Belton's layered pile model has a high porosity on the surface, about 70% [5, 6]. We base our mineralogical composition on the spectral results obtained of Comet 9P/Tempel 1 by Lisse et al. [5]. The porosity profile of the comet nucleus is based on the results of the comet aggregation model by Lasue et al., 2008.

The shape of the nucleus has been modeled after the March 12, 2003 Hubble Space Telescope observations of C67, and later refined by Lamy et al. [7], who detected the thermal emission of C67 using the Spitzer Space Telescope. Radiometric techniques could then be applied to eliminate the earlier assumptions of phase angle and albedo. These observations presented a mean radius of 1.93-2.08 km and a 3-d shape with dimensions 4.40–5.20 km, 4.16–4.30 km, and 3.40–3.50 km, assuming a low thermal inertia on the order of 20 J K^{-1} m^{-2} $s^{-1/2}$ [7]. Using larger thermal inertia yields a mean radius upper limit of 2.3 km. These values are consistent with a similar study by Kelley et al. [8], which yielded a radius of 1.87 ± 0.08 km.

Once the geophysical models were completed, relative dielectric permittivities were assigned to each comet layer on the basis of density, temperature, and dust fraction. In Model A, the dielectric properties varied only with the dust fraction increasing linearly toward the center for a constant porosity of 70%, we have hence observed values between 4.386-*i*0.0121 in the outside dust mantle and 2.081-*i*0.000182 for the inner layers. The dielectric constant in Model B varies for dust fraction decreasing linearly toward the center (and for a constant porosity of 70%) from 3.8205-*i*0.00281 in the dust mantle, to 1.7777-*i*0.00281 in the crystalline ice crust. The modeled dielectric permittivities are consistent with the expected deep penetration of the CONSERT wave through the nucleus. It is also clear that the changes in the physical properties of the nucleus induce substantial variation in the dielectric properties of cometary material that can be identified in the radar tomography. More modeling and wave propagation through those models will be presented at the time of the conference.

References: [1] Kofman W. (2007) *Space Science Reviews, 128*, 413-432 *JGR, 90,* 1151–1154. [2] Parkhomenko, E.I. (1967) Electrical Properties of Rocks, *Plenum Press, New York.* [3] Belton et al. (2007) Icarus 191:573–585. [4] Groussin et al. Icarus (2007) 191:63-72. [5] Lisse et al. Science (2006) 313:635. [6] Kossacki & Szutowicz (2008) Icarus 195:705–724. [7] Lamy, et al. (2008) A&A, in press. [8] Kelley, M. S., Reach, W. T., & Lien, D. J. 2008, Icarus, 193:572.

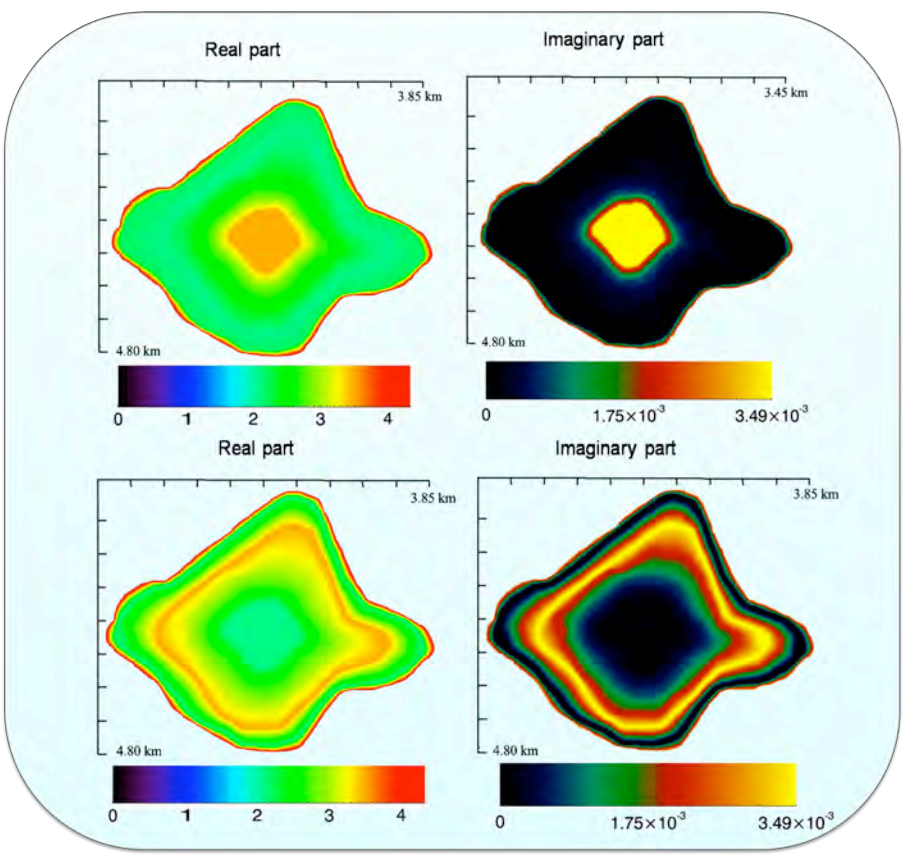

Figure 3: Preliminary results of the two dielectric models of 67P, Top: Model A (dust fraction increase toward the nucleus core); Bottom: Model B (dust fraction decrease toward the nucleus core)