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The interior of 67P/C-G comet as seen by CONSERT bistatic radar on ROSETTA, key results and implications.

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Abstract

The structure of the nucleus is one of the major unknowns in cometary science. The scientific objectives of the Comet Nucleus Sounding Experiment by Radiowave Transmission (CONSERT) [3] aboard ESA's spacecraft Rosetta are to perform an interior characterization of comet 67P/Churyumov-Gerasimenko nucleus. This is done by means of a bistatic sounding between the lander Philae laying on the comet's surface and the orbiter Rosetta. We will describe shortly measurements that explored the interior of the comet, discuss results, their interpretation in terms of the internal structure and composition.

1. Introduction

During the first night after Philae landing in Nov. 2014, CONSERT operated during 9 hours and has made measurements through the small lobe (head) of comet 67P/ C-G. The analyses and interpretation have been done using the shape of the received signals and then 3D modeling of the signal propagation through the comet. The first analyses concerned the propagation time from which the average permittivity of the cometary interior was derived. This was done using the 3D model of wave propagation through the comet. Dielectric data for ices and dusts particles, compared with CONSERT measurements, constrains the possible constituents of comet 67P/C-G [2], [4]. The shape of the signal, which is very close to the shape of the calibration, shows that scattering by inhomogeneities in the medium is not detected. This indicates that the interior is homogenous at the scale of few wavelengths (1 wavelength is about 3.3m in vacuum) [4]. This conclusion lead to 3D simulation of the signal propagation in the non-homogeneous medium, to define the sensitivity of CONSERT to detect the inhomogeneities and to constrain the internal structures in terms of size and composition at a scale commensurate with the wavelength [1]. Properties of meter-scale inhomogeneities inside the comet are essential to understand cometary formation. These major results are discussed during the presentation.

2. Interpretation of results

2.1 Bulk dielectric properties and interior composition.

The measured propagation time permitted to derive the dielectric properties of the interior [4]. The inferred real part of permittivity is 1.27, which is very low (permittivity of vacuum is 1, water ice is about 3.1 and dust constituents even higher). Thus, the interior of the comet is very porous. This value of the permittivity excludes, as expected for primitive small bodies, a major component similar to ordinary chondrites in the refractory component. CONSERT measurements are consistent with dust/ice volume ratio of 0.4 to 2.6, and the porosity range of 75 to 85%. In [2], compositional analyses were developed using a large database of organic materials from the literature and from laboratory measurements. Since many materials have similar permittivity values in CONSERT frequency range, using permittivity does not discriminate materials directly, but allows to exclude some. To this end, one tests different composition models of the nucleus corresponding to cosmochemical end members of 67P/C-G dust. They include pure silicate dust and its mixture with increasing content of a carbonaceous material (comprising both insoluble and soluble species). It was concluded that an important fraction of carbonaceous material is required in the dust in order to match CONSERT permittivity observations. The minimum required content of the carbonaceous material is 75 vol. per cent. This suggests that comets represent a massive carbon reservoir (Figure 1)

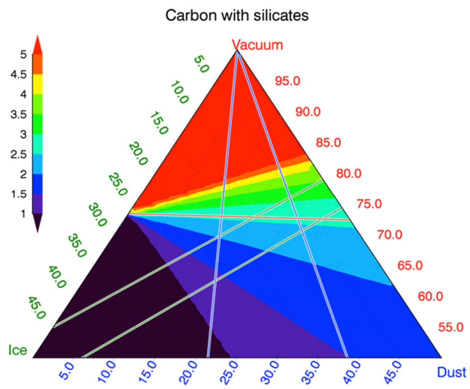

Figure 1: Diagram of the permittivity of the refractory material as a function of the volume proportion of ice (green axis), of dust (blue axis) and of the porosity (red axis): the color scale represents the maximum permittivity value of the refractory material in a given dust-ice-vacuum mixture of permittivity 1.27 (from [2]).

The diagram in Figure 1 shows that a mixture consisting of 75% carbonaceous material and 25% minerals (red line limit on the graph) is compatible with the dielectric constant determined by CONSERT, as well as with other results related to density (green line limits) and dust / ice ratio (blue line limits). The nucleus of the comet must then be very porous (72-87%), with 6-12% ice and 16-21% refractory (dust) by volume [2].

2.2 Interior structure

The measurements of the width of the signal at 3 and 6 dB levels were compared with the 3D simulation in the non-homogenous medium; fractal and spheres based structures. Comparison (figure 2) with the experimental pulse width values have been used to find constraints of the structures inside the nucleus that would be compatible with the CONSERT's data. It was shown that CONSERT's observations cannot exclude or give constraints on any scale of 1 meter or below and the 3-m size scale structures are compatible with CONSERT's measurements provided that the permittivity contrast of the structure is less than 0.25.

Given the high bulk porosity of 75% inside the sounded part of the nucleus, a likely interior model would be obtained by a mixture, at this 3-m size scale, of voids (vacuum) and blobs with material made of ices and dust with a porosity larger than 60% [1]. The absence of any pulse spreading due to scattering allows us to exclude heterogeneity with higher contrast (0.25) and larger size (3m) (but smaller than few wavelengths scale, since larger scales would be responsible for multipath propagation).

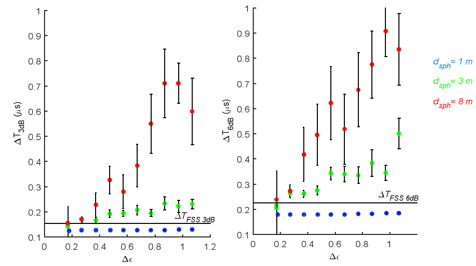

Figure 2: Pulse width at 3 dB (left) and 6 dB (right) versus the permittivity contrast $\Delta\varepsilon$ for 3 sizes of spheres. The travelled distance is L=200 m. the experimental threshold values $\Delta T_{FSS\,3dB}$ and $\Delta T_{FSS\,6dB}$ are represented by the solid horizontal line (figure from [1]).

3. Conclusions

CONSERT is the first successful radar probe to study the sub-surface of a small body. Current interpretation of the signals is consistent with a highly porous carbon rich primitive body. Internal inhomogeneities are not detected at the wavelength scale and are either smaller, or present a low dielectric contrast. The analyses and interpretation of the signals amplitude are still on going and their progress will be presented during the conference.

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