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Unveiling the formation and evolution of comets

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Comet nuclei are considered as the most pristine bodies of the solar system and consequently their study sheds an important light on the processes occurring during the initial stages of the solar system formation. The analysis of the porosity and bulk density of such primordial bodies is especially important to understand their capacity to retain volatile components (organics and ices) present in the early solar nebula. Typical tensile strengths deduced for comet nuclei range from below 10^2N.m^{-2} from the Deep Impact mission [1] up to 10^4N.m^{-2} from the study of comet C/1999 S4 LINEAR breakup [2] and meteoroids [3]. A bulk density of about 350 kg/m^3 has been obtained for 9P/Tempel 1 from the Deep Impact mission [4].

Moreover the properties of dust released from the comets strongly confirm such values. Instruments flying-by comet 1P/Halley had discovered the presence of organics, and pointed out the dust low albedo and extremely low density while analyses of Interplanetary Dust Particles collected in the stratosphere and remote spectroscopic observations have indicated that cometary dust consists of an un-equilibrated heterogeneous mixture of organic refractory materials and of amorphous and crystalline silicate minerals [5], as recently confirmed by Stardust [6]. Observations of the solar scattered light, together with elaborate simulations, give an estimation of the mass ratio between silicates and absorbing organics, the size distribution and the structure of the dust particles, suggesting that a fair amount consists in fluffy aggregates built up from submicronic grains [7,8], as recently confirmed by the analysis of dust craters and aerogel tracks on Stardust collector showing for some large particles (up to 100 μm) an extraordinary fluffy structure [9].

Simulations have been developed in our teams to describe the aspects of comet aggregation and evolution that have not been thoroughly explained yet. Particle aggregation simulations taking into account cohesive energy of the cometesimals and their probable re-accretion after collision events in the Kuiper Belt can be used to interpret the typical layered structure observed for comet 9P/Tempel 1 [10] and evaluate the tensile strengths inside the nucleus. Thermal evolution models of comet nuclei explain the current comet observations with the presence of primordial volatiles [11]. A quasi-3D approach (for non-spherically shaped comet nuclei) is used to interpret the current activity of comets in terms of initial characteristics, and to predict shape and internal stratification evolution of the nucleus. Tensile strength indications and activity predictions from such simulations will provide vital clues for the international Rosetta mission landing on the nucleus of comet 67P/Churyumov-Gerasimenko.

During the Rosetta rendezvous, the CONSERT experiment will investigate the deep interior of the nucleus from measurements of the propagation delay of long wavelength radio waves [12]. The analysis and 3D reconstruction of the waves passing through the nucleus will put constraints on the materials constituting the comet and the inhomogeneities within the nucleus. While it is now established that nuclei have low densities and are significantly fragile, it will then be possible to better constrain their formation process and their evolution.

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