COMETARY NUCLEI INTERNAL STRUCTURE FROM EARLY AGGREGATION SIMULATIONS.

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Introduction: Numerical simulations of accretion of planetesimals in the early solar system nebula suggest that comets could have been formed by collisional aggregation rather than through gravitational instability [1]. Cluster-Cluster Aggregation (CCA) is the model corresponding to the major processes occurring under these conditions [2]. This model is widely used in other areas of physics to describe growth of macroscopic objects from a collection of microscopic units. At the smallest length-scales, the CCA model contains only one relevant parameter: the exponent α, describing scaling of the collisional cross-section with body size.

The CCA model for meter-sized bodies: In the case of macroscopic bodies, one has also to consider kinetic-energy dissipation. Indeed, part of energy is released during a collision, resulting in dispersion of small primary units, which may eventually deposit randomly on the aggregate surface. Along the same line as for the collisional cross-section, we can define the exponent, μ, of the average collisional kinetic energy size-scaling. This simple but realistic model was studied for a range of relevant physical values of the two parameters α and μ [3]. Local sintering is considered as natural ageing process at the long-time scale.

Results from CCA cometesimal accretion: Similarly to phase-diagrams, one can here draw 'morphology'-diagram, from which it is clear that the final body can only exhibit a few different geological structures. The obtainable morphology relevant for comets corresponds to a domain of (α,μ) giving compact but irregularly-shaped bodies, made of a few inner hard cores unevenly coated with smooth thick layered structures of definite cohesion energies. These features appear for particular small-bodies velocity-distribution, different from the thermal equilibrium. Remarkably, this regime of aggregation appears for different polydispersities of the primary units (gaussian or power-law) [4].

Furthermore, the irregular overall shape of the final body is constrained by statistical features reflecting the history of the successive collisions, and presents a typical 'peanut shape' of definite anisotropy ratio when the number of aggregated units is large enough.

Towards a geology of cometary nuclei: These results about appearance of extended smooth layered surfaces dating from early nucleus accretion compare well with the structural and cohesive properties of comets deduced from observations (e.g. Tempel 1).

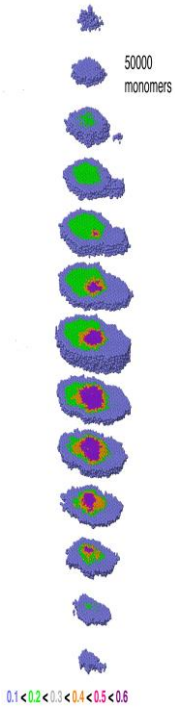

Fig.1. Successive slices of the internal structure of an irregular cometary nucleus modeled with successive aggregation of 50,000 basic units. Colors correspond to cohesive strength scale. One can see on such a representation a cohesive hard core unevenly coated with successive layers of less cohesive material. The outer layers are only lightly packed.

Moreover, the model leads to quantitative prediction about the shape anisotropy of the final nucleus, a point which could provide a key test for the aggregation scenario. At last, the results of the model infer precise patterns of the dielectric permittivity inside the final body. That could give helpful information to radiowave transmission experiments on cometary nuclei, such as in 2014, the CONSERT experiment onboard the Rosetta mission.

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