BUILDING CHONDrites: SPH Simulations of a Jet Flow in a 3D Protoplanetary Disc

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Introduction: Under the influence of the aerodynamic drag force dust grains settle vertically toward the disc midplane and then drift radially inward toward the central star [1]. However, refractory materials resulted from high temperatures processes (HTP), are found in chondrites [2] and cometary samples [3] mixed with components which never experienced such high temperatures. This suggests that a mechanism, which transported HTP grains outward (in the opposite direction of what the gas drag imposes), must have been in place during the early stages of our Solar System formation. Protostellar jet-flows are one of the proposed mechanisms to explain the efficient transport of refractory and reprocessed material toward the colder region of the Solar Nebula [4,5].

Methods: In order to investigate the efficiency of Jet Flows in transporting material toward the outer part of the disc, we performed simulations using our 3D two-phases (gas+dust) Smoothed Particle Hydrodynamics (SPH) code [1]. SPH has been widely used to study the dynamics of single dust component under the effect of the gas drag in protoplanetary discs. One of the powerful aspects of SPH is the Lagrangian formalism which allows to trace particles at any given time and record their properties (such as position and size) and their environment (such as temperature, pressure, gas and dust global densities) [1,6].

Models: We model the inner part of a typical T-Tauri disc (0.5< R (au) < 50). The mass of the central star is equal to the mass of the Sun. The mass of the disc is 0.003 times the mass of the star. The disc is composed of 99% gas and 1% dust by mass. The disc is vertically isothermal and the temperature, gas sound speed and surface density follow power laws. The disc is flared and the ratio between the scale height, H, and radius is H/R=0.031. The viscosity parameter is set to $\alpha=0.01$. We implemented in the code the jet-flow model of [4,5]. The jet is located at 0.1 au, and particle are ejected with a random variable speed (50< v (km/sec) < 280) [4,5].

Grain growth [6] and fragmentation [7] are included. Moreover, we implemented the possibility to assign different intrinsic densities to different groups of SPH dust-particles. This translates in a chemically heterogeneous dust phase. Chemical species included are water-ice, silicates, sulphides, iron oxides, and calcium-aluminum-rich (CAIs-like) particles. This new chemical characterisation of the dust allows to investigate, for the first time in the SPH formalism, the simultaneous contribution of different dust populations in shaping the chemical content of the disc. Our system is evolved for a total time of t~5000 yrs with a time resolution of $\Delta$t~29 days. Our simulations are performed in mid (250 K particles) and in high (400 K particles) resolution.

Results: We find that the jet flow efficiently ejects grains at large distances and that the disc is able to capture a large quantity of material thanks to its flared structure. Grains are captured by the disc at distances up to R~40 au. Moreover, we find that grains can experience fragmentation when enter the gaseous disc at high speeds. Furthermore, the settling and radial drift of the dust coupled with growth and fragmentation, can produce aggregates which mimic the physical properties of the chondrites such as fractionation and size and density sorting.