MAKING THE PLANETARY MATERIAL DIVERSITY DURING THE EARLY ASSEMBLING OF THE SOLAR SYSTEM

F.C. Pignatale[1,2], S. Charnoz[1], M. Chaussidon[1], E. Jacquet[2]
[1]Institut de physique du globe de Paris, Sorbonne Paris Cité, Univ. Paris Diderot, UMR 7154-CNRS, 1 rue Jussieu, 75005 Paris, France (pignatale@ipgp.fr), [2]Muséum national d'Histoire naturelle, UMR 7590, CP52, 57 rue Cuvier, 75005, Paris FRANCE

Introduction: Chondrites are among the most puzzling objects in the Solar System as they are made of components that formed at various temperatures and experienced different thermal histories and were accreted at various locations and times [1]. Among them, carbonaceous chondrites, which are widely believed to have assembled in the outer cooler regions of the Solar System, are paradoxically the richest in refractory material, Ca-Al-rich inclusions (CAIs), which should have formed close to the Sun [1]. The age of CAIs [2], the oldest ones measured for Solar System materials, suggests that their precursors formed concurrently with the Sun, eventually as early as during the collapse of the parent cloud that formed our Solar System [3].

Methods: Here we investigate, for the first time, the dynamical and chemical evolution of the gas and solids present in the presolar cloud, from the start of the collapse to the formation and early evolution of the protoplanetary disk. Our 1D disk model includes several processes such as gas and dust condensation/evaporation [4], dust growth/fragmentation [5], radiative and viscous heating [3], dead zones [6] and cloud infall in the form of a source term [3, 7].

Results: We find that the interplay among (i) the location in which material is injected in the disk from the cloud, (ii) the physical and thermal properties of the considered material, (iii) the disc dynamics and (iv) the occurrence of accretion burst events, naturally produces aggregates where components with different thermal histories can coexist. The disk expansion causes an efficient advection of refractory material towards large radii. The dead zone plays a crucial role in creating and keeping a heterogeneous mixture of dust. We find that the production of highly refractory condensates, that can be considered as precursors of the CAIs, is enhanced by transient events. Massive production of this material occurs in very short time and at the earliest stage. This corresponds to a very short time window, when material in the collapsing cloud is injected in the disk at very high temperatures. All the presolar solids carrying refractory chemical elements are fully evaporated, so that upon spreading outward, the gas can condense into crystalline refractory grains. This process seems to be also connected with accretion bursts of material onto the star following mass loading and instabilities of the dead zone.

Conclusions: We suggest that the interplay between the cloud infall, disk spreading and different vaporisation temperatures of interstellar dust, naturally results in the presence locally in the disk of "solar system" materials having different thermal histories, in qualitative agreement with the compositions of the three main chondrites families. In addition, our results account for the observed short timescales for CAI production and the presence of CAIs in chondrites without requiring any other specific mechanism of outward transport of material in the disk. This works implies that it is now of critical importance to study the protoplanetary disk, not as an isolated object, but in connection with the collapse of the presolar cloud and in the larger context of the early environment of the Sun. This very early epoch has left fingerprints in the diversity of materials in our Solar system.

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