

INVESTIGATING DUST SIZE AND PRESOLAR GRAIN DISTRIBUTION IN THE PROTOPLANETARY DISKS USING SPH SIMULATIONS.

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Introduction: Various isotopic systems studied in meteorites exhibit nucleosynthetic heterogeneity in solar system material. Some of them display a dichotomy between objects formed in the inner solar system (ordinary (OC) and enstatite (EC) chondrite signatures) and those formed further out (carbonaceous chondrites (CC)) [e.g., 1,2]. These heterogeneities stem from presolar grains generated in different stellar environments before they were delivered to our solar system. However, how these presolar grains were originally distributed in the solar system, and how they were subsequently transported or concentrated, and processed in different locations, remains unclear. It has been suggested that the formation of Jupiter's core may explain the observed separation of the two reservoirs defined by the OC+EC and CC chondrites – being located inside and outside of Jupiter's orbit, respectively [e.g., 2]. Large planets carve a gap in the disc, depleting the surrounding orbital region of both gas and dust. The resulting pressure maxima that form on either side of the gap act like dust traps and prevent most of the solid material from being transported between the inner and outer disc. While it is difficult to trace the isotopic abundances themselves, hydrodynamical simulations can track the dynamical evolution of the presolar grains in which they are encapsulated. We use smoothed particle hydrodynamics (SPH) simulations to assess, whether we can replicate the isotopic anomalies observed in the solar system via the interaction between the dust grains and the background gas disk alone when they are (initially) distributed homogeneously through the disk relative to the silicate grains.

Methods: We use the SPH code PHANTOM [4] to perform 3D gas and dust simulations of protoplanetary discs to study how the back-reaction of pebble-sized grains (~mm) affects the (sub-)micron grain population when a Jupiter-mass planet carves a gap in the disc at different radii. We use the MULTIGRAIN algorithm [5] to simultaneously simulate a total of 17 dust phases comprised of ten 'silicate' phases (size: 0.1 microns -- 1 cm; density: 3 g/cm³), four 'silicon-carbide' phases (size: 0.25 -- 4.225 microns; density: 3.16 g/cm³), and three 'oxide' phases (size: 0.1 -- 0.6 microns; density: 3.93 g/cm³). We determine the abundances of the silicate grains with a standard power-law grain-size distribution of slope -3.5 (e.g. [6]). The abundances for the silicate-carbide and oxide phases come from generalised extreme value distributions that fit the catalogued abundances from meteoritic studies [7]. Finally, we attribute different anomalous isotopic tracers to the oxides (r-process elements, e.g., ⁵⁴Cr) and silicon-carbide (s-process elements, e.g., Zr, Mo, Ru, Pd) populations to assess whether variations in intrinsic grain density, grain-size distribution, and/or back-reaction from larger grains in the disc can drive differences in the local concentration of presolar grains and their tracers.

Discussions: Preliminary analysis of single-grain and multi-grain simulations show some visible differences between a few of the larger silicate phases (particularly near the disc/gap edges), but little changes in our presolar grain populations. This suggests that back-reaction and/or variations in the grain-size distribution and intrinsic grain density cannot be the main driver for the sorting of presolar grains in the protoplanetary disk. The pressure maximum just outside of the planet's orbit trap dust grains of all sizes, but with varying levels of concentration. Large grains migrate efficiently towards the middle of the pressure bump, while small grains, more affected by the motions of the gas, show a much looser clustering near the maximum. A similar phenomenon occurs for the pressure maximum interior to the planet's orbit. However, in contrast to the continual accumulation of migrating dust at the inner edge of the outer disc, the combination of viscous accretion onto the star and limited transport of material across the gap leads to a general attenuation of all grain sizes in the inner disc. Consequences for this observed behaviour are twofold. First, the enhanced density in the pressure bumps outside the planets orbit would make them an ideal formation region for CCs, which display much higher matrix contents and thus presolar grain abundances than their EC and OC counterparts. They would also be advantageous regions to concentrate the larger Calcium, Aluminium-rich Inclusions (CAIs) and chondrules found in CCs, in CV especially. Secondly, the strong density variations in the largest dust grains compared to the finer fractions can create regions with increased presolar grain abundances favourable to create CC with particularly enhanced presolar grain abundances such as CR chondrites [8].

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