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Modeling the 3D transport of small solids around a Jovian embryo

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Substructures in disks – including rings, gaps, and spiral wakes – are common in extrasolar protoplanetary disks [1]. In our own Solar System, such substructures, possibly created by gravitational interactions between an embedded giant planet and the surrounding disk, have been invoked to explain the isotopic dichotomy observed between carbonaceous (CC) and non-carbonaceous (NC) meteorites. In this paradigm, Jupiter creates a gap and ring structure in the solar nebula, trapping CC-like material in the outer disk, separate from the NC reservoir interior of Jupiter [2]. While this mechanism works well in 1D models, 2D models accounting for non-axisymmetric structure in the disk find that small particles are able to cross the planet's orbit [e.g. 3,4]. In 3D, models of planet-disk interactions show that planets create large scale gas flows throughout the disk. We examine the paths that small solids take through these flows, allowing us to identify the history and trajectories of individual solids in the disk to examine the details of how materials may move from one reservoir to another [5]. We find that sub-millimeter sized solids are carried by accretionary flows of gas toward the planet, and in some cases past the planet, crossing from the outer to inner disk and vice versa. These crossing solids are consistent with the sizes of CAIs found in NC meteorites [6] as well as the reported NC-like grains found in CC meteorites and comets [7]. Further, we find that a single planet is capable of leading to dust concentrations in multiple locations, and are exploring whether that could lead to the formation of a third isotopic reservoir in the nebula [8].

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