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Particle Paths in the Solar Nebula: Linking Physical and Chemical Models

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Protoplanetary disks are dynamic objects through which mass and angular momentum are transported as part of the final stages of growth of the central stars. Chondritic meteorites and comets record a dynamic history of our own solar nebula, as these primitive bodies contain mixtures of components, each of which formed in distinct chemical and physical environments, yet were transported and mixed to be accreted by common parent bodies. Identifying the driving force (s) is critical to helping us understand both the dynamical evolution of the nebula as well as the chemical evolution of the materials that were accreted into comets, asteroids, and the planets themselves.

To date, models of transport and mixing within the solar nebula have largely focused on showing that it is possible for materials to be carried from one region of the nebula to another. In some cases, the relative fraction of high temperature materials made available for comets to accrete or the level of homogenization within the disk is determined by tracking how well mixed things become with time. While such quantitative analyses demonstrate some of the differences expected between different models, they unfortunately cannot be used as predictions that can be tested by our current collection of primitive materials. It is unclear from the Stardust materials what the relative fraction of material that formed in the inner solar nebula is in comet Wild 2 due to the uncertainty in the abundance of materials that escaped thermal processing prior to being accreted by the comet. Further, telescopic observations of comets result in estimates of the fraction of crystalline silicates they contain varying from comet to comet and from observation to observation for a single comet. Thus, at present, the available data cannot conclusively argue in favor for, or rule out any, one model.

Here a new approach to calculating the transport of solids throughout the solar nebula is explored. Rather than focusing on how the abundance of a species changes with time within the solar nebula, this approach focuses on the path that single particles take through the nebula. That path then can be used to determine what environments (e.g. pressures, temperatures, etc.) a particle was exposed to during transit. This information can then be used as inputs into chemical models in order to determine the level of alteration the grain would have experienced and then compared to what is seen in primitive materials.

To do this, I have developed a random walk model for particles within the solar nebula. The model calculates the velocities that a particle develops through its interactions with the gas, and then superimposes on the resulting motions a random displacement that is dictated by the level of turbulence (diffusivity) within the disk. As a result, particles that start at a given location in the disk will take unique paths through the nebula prior to their incorporation into planetesimals. Similarly, particles that are located at a given location will have taken very different paths and started at different locations, allowing mixing of materials from distinct environments. I will report on preliminary results of this model with basic applications towards understanding how particle transport would have impacted the type of chemical evolution solids would have experienced

within the solar nebula.

Keywords: solar nebula, meteorite, comet