SIMULATION OF CHONDRULE FORMATION USING A RESIZING BOX_TREE CODE. G. S. Swint and T. W. Hyde, Center for Astrophysics, Space Physics and Engineering Research, Baylor University, Waco, TX 76798-7316, USA, phone: 254-710-2511 (email: Truell_Hyde@Baylor.edu).

Introduction: Prevalent protoplanetary development theory holds that planets accumulate through the accretion of planetesimals, bodies ranging in size from meters to hundreds of kilometers. Since dust is the dominant source of opacity in optically thick disks, it is assumed that the precursors to the planetesimals coagulate from dust grains and condensates from the gas of the solar nebula [1]. Although it is possible to simulate the coagulation of dust particles in the protoplanetary nebula, the accuracy of such a simulation is dependent on the number of particles used in the simulation. A large number of particles yields a more accurate simulation, but comes at the expense of considerably longer CPU times. On the other hand, once the number of particles used by the simulation drops below a certain threshold, the model begins to lose relevance. This article presents a scheme whereby the `box_tree` model can significantly enlarge its simulation parameters allowing for more realistic data.

Chondrule Simulation: Chondrules are millimeter-sized, milligram-mass inclusions found in chondritic meteors. The percentage of chondrules present in a chondrite may be as high as 80% [2]. Chondrules themselves are composed of relict grains. These grains and other primitive nebular material found in chondrules may vary in size from 0.05 μm to 100 μm in size. Assuming a chondrule were composed solely of large 100 μm relict grains, it would consist of approximately 1000 of the smaller particles. Attempting to simulate the formation of even as few as 100 chondrules from the smaller grains would thus be prohibitive in terms of computational time as it would require well over 100,000 particles at the beginning of the simulation. To avoid this problem, a simulation is needed which can increase the number of particles used in the simulation as particles are removed due to their being coalesced into aggregates.

box_tree: To accurately model the coagulation of dust grains in a protoplanetary environment, it is necessary to keep track of a large number of particles while noting collisions that result in sticking. This is accomplished using a numerical model based on the `box_tree` code [3]. The `box_tree` code models a ring or disk by first dividing it into self-similar patches orbiting the planet or star, where the box size is much greater than the radial mean excursions of the constituent dust grains. Boundary conditions are met using twenty-six ghost boxes. A tree code is incorporated into the `box_tree` routine to allow it to deal with gravitational and electrostatic interactions between the particles. A full treatment of rigid body dynamics, including rotation, is therefore possible allowing for both cluster trajectories and the orientation of fractal aggregates to be determined.

`box_tree` also provides a method for including timers and system events. This allows for the generation of statistics, images, and other data collection mechanisms. Additionally, the timers may be used for simulating transient heating events and/or the melting of chondrules.

Self growing simulation: The self-growing version of `box_tree` was created by doubling the dimensions of the central box. This new box is superimposed over the old central box and particles from the original are placed within the new box. Any particles resident within the ghost boxes which fall inside the new box are also added to the new box. Finally, the tree is regenerated using the new box, and the old central box is discarded. Since the linear dimensions of the new box have been doubled, it will, in general, contain four times as many particles as the original box it replaced. This implies that the box size should be doubled only when the number of particles in the simulation drops below the original number divided by four.

Because the boxes are in a rotating ring, they will have Keplerian velocities dependent on the distance form the center of rotation. This will cause the side of the boxes parallel to the x-axis not to line up in general. In order to determine which particles from ghost boxes are included in the simulation, it is easiest to compute the position vector from the origin to determine whether or not it lies inside the new box.

In order to quantify the efficiency of the coagulation process, it is necessary to know the number of simple particles and the total mass involved at the outset of the simulation. However, each time the box is grown the number of particles in the simulation changes. By having each coagulated particle keep track of the number of particles it has accumulated over the course of the simulation, it is possible to keep track of the number of simple particles which might have been involved in a larger simulation. These quantities are kept for both simple, melted particles and for fractal agglomerations. Because mass is conserved in the system through boundary conditions, the ending mass of the simulation will always reflect the beginning mass of an analogous larger simulation.

Simulation Results: Simulations involved two sets of 5000 particles. In the first simulation, fractal agglomeration is allowed, but no transient heating events are simulated. In the second simulation, transient heating events are simulated. The results of the simulations will be presented.

References:

[1] Weidenschilling, S.J. and J.N. Cuzzi, (1993) *Protostars and Planets III*, eds. E.H. Levy and Lunine, J.I., pp. 1031-1061, The University of Arizona Press. [2] Morfill, G. E., G. H. Spruit, and E. H. Levy, (1993) *Protostars and Planets III*, ed. E.H. Levy and J. I. Lunine, pp. 939-978, The University of Arizona Press. [3] Richardson, Derek C., (1995) *Icarus*, 115, pp. 320-335.