Abstract

There are still many questions associated with the process of building planets from the dust of protoplanetary disks. We present the results of simulations of small patches of clusters of millimeter sized spheres. The clusters are on the order of a centimeter in radius. Some simulations use clusters formed as regular lattices of uniform spheres while others use clusters formed by letting a cold distribution naturally accrete. Separate work by Whizin et al. looks at how two clusters behave when they collide given different impact velocities, magnitudes of the adhesive force, and coefficients of restitution. In this work, we scale up to thousands of these clusters to explore how effective the adhesive force is at causing the clusters to accrete into larger structures. For numerical purposes, the initial clusters all start in the orbital plane because simulation times don’t allow following the system for multiple orbits to allow particles to pass through the plane repeatedly. A single order of magnitude in either the impact velocities or the adhesive force leads to dramatic changes in the outcome of the simulations. A discussion of the building efficiency of occasional low velocity impacts in a distribution where most impacts are destructive is included.

Introduction

This project is a fun numerical exploration to compliment the work that Akbar Whizin is doing with Josh Colwell to systematically look at the behavior of colliding clusters of millimeter sized particles that have adhesive forces. Instead of systematically looking at collisions, this work starts with 2500 of more clusters in the midplane with random velocities in the plane to see what happens to the material.

The collision rate is inevitably inflated because everything is co-planar, but this is needed to account for the short physical time periods (a few hundred seconds) that can be simulated at the needed resolution.

Simulations

Particles are in orbit at 1 AU and feel self-gravity and an adhesion force as a 4th order polynomial that is zero when touching and beyond a specified distance limit.

Hard sphere collisions are processed using a discrete event model with a velocity dependent normal coefficient of restitution. Particles have spin and perpendicular coefficient of restitution is 0.5.

Most simulations involve 1.32 million particles in 2500 lattice clusters. Numbers vary when size distributions are included.

Results

Initial configuration

Size Distribution

Artificially High Adhesion

You really need to see the movies.

Conclusions

This work isn't really about conclusions yet. From what we have done, it would seem that using the force law we have in the code with a strength that roughly fits lab measurements the simulations indicate that only rather slow collisions will be non-destructive. More work can certainly go into making a more physically accurate adhesive force and playing with other parameters of the simulations.

At this point we are more interested in suggestions of what we could do to improve these simulations of other questions of interest that we could explore with modest modifications of the simulation framework.

Acknowledgements

This work was supported by NASA Origins.