Simulating Dust in Protoplanetary Disks

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Abstract: Planets form out out of the dust in a protostellar disk. However, there are many impediments to this process of collisional growth, especially in the early stages when trying to grow micron and millimeter-sized grains into planetesimals. First of all, the dust density is small, and as a result actual collisions are rare. Secondly, collisions between dust particles with relative velocities greather than a few meters per second are more likely to shatter the fragile grains rather than cause them to stick together. Finally, particles a few centimeters in size to a few meters in size are vulnerable to gas drag that leads them to spiral inwards to the central star in relatively short periods of time. These impediments to the growth of planetesimals can be ameliorated if a mechanism exists that can greatly enhance the densities and growth rates of dust grains to planetesimal sizes. We have performed a series of numerical simulations that explore the evolution of dust grains of various sizes throughout a protostellar disk, and we show that a relatively simple model of dust-gas interaction can cause a collective streaming instability to develop that can greatly enhance the dust density in the midplane of a disk. Furthermore, this process can easily reduce the relative motions of the dust grains from several tens of meters per second to a few meters per second, allowing grains to grow through collisions rather than shatter.

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