Dust and gas co-evolution with dust-gas backreaction in protoplanetary disks

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Planetesimal formation has to overcome two major barriers. The first one is the radial drift barrier. Dust particles in protoplanetary disks feel a headwind from the surrounding disk gas. Due to the gas-dust friction, dust particles lose their angular momentum and drift inward. The second one is the fragmentation barrier. The collision velocity of dust particles can be too high for the particles to stick together.
Recently, Gonzalez et al. (2017) have shown in their 3D SPH simulations that the backreaction from dust to gas affects the disk gas structure so that the dust particles can overcome these barriers. In their simulations, dust particles pile up due to the fragmentation or rapid growth. This dust concentration provides a positive torque for the surrounding gas and makes the gas moving outward. The modified gas structure prevents dust particles from drifting inward. However, Gonzalez et al. (2017) have only performed simulations with large viscosity and specific disk conditions, hence how the effect of the backreaction depends on disk parameters is still unclear.
Here we present analytic expressions of gas and dust velocities in protoplanetary disks including the effect of backreaction from dust to gas. These analytic formulas allow us to describe the dust and gas co-evolution including the effect of the frictional force from dust particles. The analytic formulas suggest that the backreaction forces the gas move outward even if the dust-to-gas mass ratio is lower than the standard value of 10^{-2}, as long as the gas viscosity is small. We also present the results of 1D and 2D dust-gas two-fluid simulations to demonstrate the backreaction changes their evolution. We find that when the viscosity is small or the dust-to-gas mass ratio is high, the outward motion of the gas provides a positive surface density gradient in some part of the disk.

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