INFLUENCE OF GROWTH ON DUST SETTLING AND MIGRATION IN PROTOPLANETARY DISCS

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ABSTRACT:
CONTEXT - To form meter-sized pre-planetesimals in protoplanetary discs, dust aggregates have to decouple from the gas at a distance far enough from the central star so that they are not accreted. Dust grains are affected by the gas drag, which results in a vertical settling towards the mid-plane, followed by radial migration.

AIMS: To use a simple grain growth model to study how growth affects the dynamics in order to compare dust distribution in observed discs.

METHOD: We implement a constant growth rate into a gas-dust hydrodynamics (SPH) code and vary the growth rate to study the resulting effects on the dust distribution. The growth rate allows us to determine the relative importance between friction and growth.

RESULTS: We show that depending on the growth rate, a range of dust distribution can result. For large enough growth rates, grains can decouple from the gas before being accreted onto the central star, thus contributing as planetary building blocks.

REFERENCES:
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GAS-DUST DYNAMICS:
Gas-dust interactions:
- Sub-kilometre gas velocity due to the pressure gradient, keplerian grain velocity.
- There exists a differential velocity between gas and dust. DRAG FORCE
- Dust settles in the mid-plane and migrates in the inner region of the disc.

Dust behaviour:
- Small grains (s < 100 µm): grains are strongly coupled to the gas and evolve in the same way.
- Intermediate Sizes (s > 10 cm): grains have an important effect on dust dynamics. We introduce a characteristic size for which migration and settling processes are optimized: saopt.
- Large grains (s > 1 m): grains are weakly coupled to the gas and evolve on nearly keplerian orbits.

Intermediate Small Dust To form meter-sized pre-planetesimals in protoplanetary discs, remain at a quasi-constant radius. Gas and evolve on keplerian orbits. They orbit. Therefore, particles decouple from the gas and become larger than saopt and evolve in the regime of large grains. sufficient, grains can decouple from the gas and evolve like large grains, decouple from the gas and move on keplerian orbits.

Intermediate Large Dust As growth is moderately efficient, grains can reach larger sizes. Their regime of evolution changes and they can evolve like small grains, decouple from the gas and move on keplerian orbits.

B. RADIAL AND VERTICAL DISTRIBUTIONS (Figure 1)
The gas (resp. dust) distribution in the (r,z) plane is shown by black (resp. light blue) dots. Varying the value of γ we conclude that:
- Small growth rate: grains are strongly coupled to the gas and evolve in the same way. They are distributed in a large part of the disc and experience little settling or radial drift.
- Intermediate growth rate: grains reaching intermediate sizes settle efficiently and are concentrated in the mid-plane. Particles experience a radial drift but are not depleted if coming from the outer part of the disc.
- Large growth rate: grains decouple from the gas early in the disc lifetime. They are distributed in the entire disc as they were initially.

C. TRAJECTORIES (Figure 2)
Trajectories of SPH particles in the disc for various values of γ:
- Small growth rate: grains are highly coupled to the turbulent gas. They are driven by the gas motion.
- Intermediate growth rate: sedimentation and migration in the mid-plane. Grains grow as they fall to the mid-plane. Then, they start their radial drift. If the growth is sufficient, grains can decouple from the gas and evolve in the regime of large grains.
- Large growth rate: grains grow quickly and become larger than saopt in less than one orbit. Therefore, particles decouple from the gas and evolve on keplerian orbits. They remain at a quasi-constant radius.

D. GRAIN SIZE DISTRIBUTIONS (Figure 3)
- Small growth rate: growth rate is dominated by drag. Grains do not have time to grow and are accreted onto the central star.
- Intermediate growth rate: grains reach intermediate sizes settle efficiently and are concentrated in the mid-plane. Particles experience a radial drift but are not depleted if coming from the outer part of the disc.
- Large growth rate (γ > 1): Grains are highly coupled to the turbulent gas and are distributed over the entire disc. The growth is not sufficient to change the regime of evolution. Grains migrate slowly towards the inner part of the disc and can be accreted onto the central star.

CONCLUSION:
We consider the case of a constant grain growth rate γ to study the influence of growth on dust dynamics. The analytical study of the grain dynamics is detailed in Laibe et al. (2010a) for non-growing grains and is generalized for the case of growing grains in Laibe et al. (2010b). A constant grain growth rate allows us to determine the relative influence of growth and drag processes. 3D SPH simulations validate the analytical results and the direct numerical integration performed in Laibe et al. (2010b). We distinguish three major behaviours for growing grains.

Small value of γ: dust grains are highly coupled to the turbulent gas and are distributed over the entire disc. The growth is not sufficient to change the regime of evolution. Grains migrate slowly towards the inner part of the disc and can be accreted onto the central star.

Intermediate value of γ: grains grow slowly as they settle to the mid-plane of the disc. Then, they experience a radial drift toward the inner part of the disc. As the growth is moderately efficient, grains can reach larger sizes. Their regime of evolution changes and they can evolve like large grains, decouple from the gas and move on keplerian orbits.

Large value of γ: growth is very efficient and grains do not have the time to feel the gas, decoupling in less than one orbit. They experience little radial drift and are distributed in the whole disc, as they were initially.