Dust grains shattering in protoplanetary discs: collisional fragmentation or rotational disruption ?

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Résumé

In the theory of planetary formation, growth of sub-μm to mm dust aggregates in protoplanetary discs into planetesimals is still poorly understood. Coagulation of grains is hampered by problems known as the radial drift barrier and the fragmentation barrier, preventing dust grains to survive and ultimately form planets. A solution to overcome these barriers is to consider grain porosity, which allows dust to grow faster and longer while being less sensitive to fragmentation than compact grains (Garcia 2018). Recently, rotational disruption of porous dust grains was proposed as another possible barrier and has been investigated by Tatsuuma & Kataoka (2021), in the framework of aggregates growing at fixed locations. They found that grains can be disrupted by gas-flow torque when aggregates tend to be highly porous, before they can decouple from the gas. Grains are also subject to collisional fragmentation. In this study, we consider the combined effects of collisional fragmentation, rotational disruption plus radial drift on aggregates and how it affects their evolution in the disc. We have developed a 1D code to understand the behaviour of porous grains under the influence of different physical processes such as gas drag and grain growth. We incorporate the physics of a simplified rotational disruption model based on Tatsuuma & Kataoka (2021). In several simulations, we studied the behaviour of dust grains in different models of discs to understand in which case each shattering process dominates, fragmentation due to collision between grains or rotational disruption, using different tensile strength formulation. For typical values of fragmentation threshold velocities, we show that collisional fragmentation dominates for highly viscous discs, while for intermediate or low turbulent viscosity, rotational disruption is effective at destroying aggregates, if the radial drift is slow enough. When considering a disc model that reproduces observations, we point out that the rotational disruption barrier is not negligible compared to the fragmentation and radial drift. With the tensile strength formulation of Kimura & al. (2020), the story depicted is similar. Collisional fragmentation remains dominant at high viscosity, but grains growth is prevented by rotational disruption for any lower turbulent viscosity.

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