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DUST DYNAMICS ON ADAPTIVE-MESH-REFINEMENT GRIDS: APPLICATION TO PROTOSTELLAR COLLAPSE

Introduction

Dust grains contribute in about 1% of the mass of the diffuse interstellar medium (Mathis et al. 1977). Despite their relatively small abundance, they are extremely important as they play a role in the thermal evolution and chemistry of the interstellar medium and the stellar and planet formation. As the coupling between the gas and the dust is not perfect, grains dynamics is not trivial during the protostellar collapse (Bate & Lorén-Aguilar 2017) or in molecular clouds (Tricco et al. 2017). Hence it needs to be treated if one wants to understand the impact of dust on star formation. In that perspective, we developed an algorithm for the adaptive-mesh-refinement code RAMSES (Teyssier, 2002). It solves the equation of gas and dust mixtures with multiple species in the diffusion approximation (see blue panel, Laibe & Price 2014b).

Dusty-gas hydrodynamics

$$\frac{\partial \rho}{\partial t} + \vec{\nabla} \cdot [\rho \vec{v}] = 0,$$

$$\frac{\partial \rho \vec{v}}{\partial t} + \vec{\nabla} \cdot [P_{\mathrm{g}} \mathbb{I} + \rho (\vec{v} \otimes \vec{v})] = \rho \vec{f},$$

$$\frac{\partial \rho_{\mathrm{d},k}}{\partial t} + \vec{\nabla} \cdot \left[\rho_{\mathrm{d},k} \left(\vec{v} + \frac{T_{\mathrm{s},k} \vec{\nabla} P_{\mathrm{g}}}{\rho} \right) \right] = 0,$$

$$\frac{\partial E}{\partial t} + \vec{\nabla} \cdot [(E + P_{\mathrm{g}}) \vec{v}] = 0.$$

Multiple grain species

The implementation of the simultaneous treatment of multiple species is tested (Lebreuilly et al., Submitted).

The same test is performed with multiple species (figure 1, top) and a single species (figure 1, bottom). As expected the results of both tests agree to machine precision.

Figure 2 shows the CPU time as a function of the number of species N. It scales with the square root of N. This shows how efficient the solver is at treating multiple dust species.

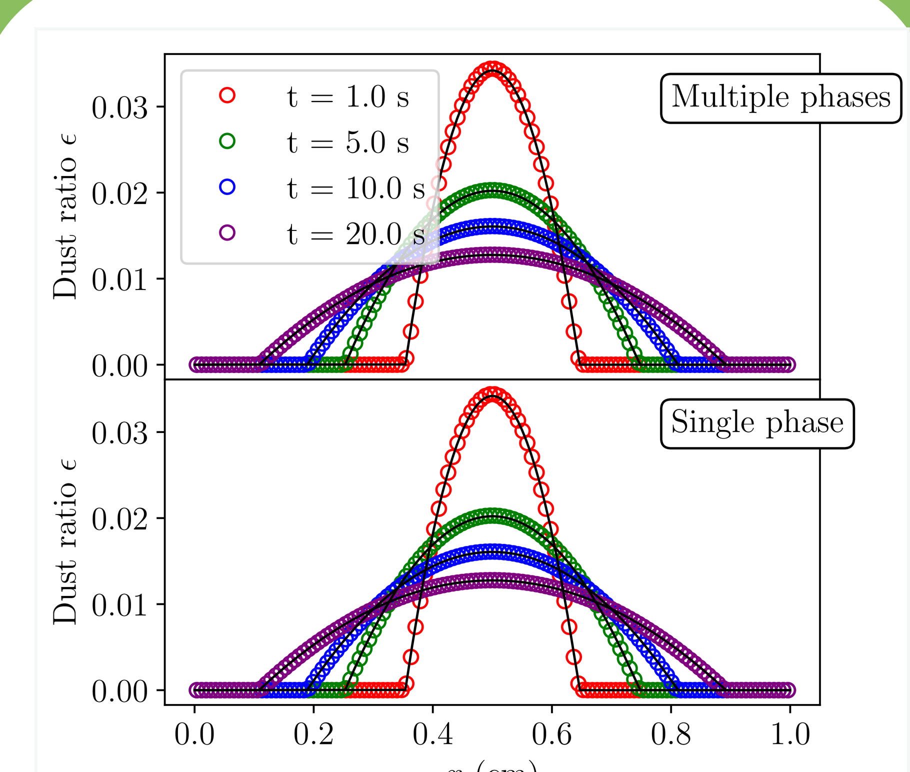

Figure 1

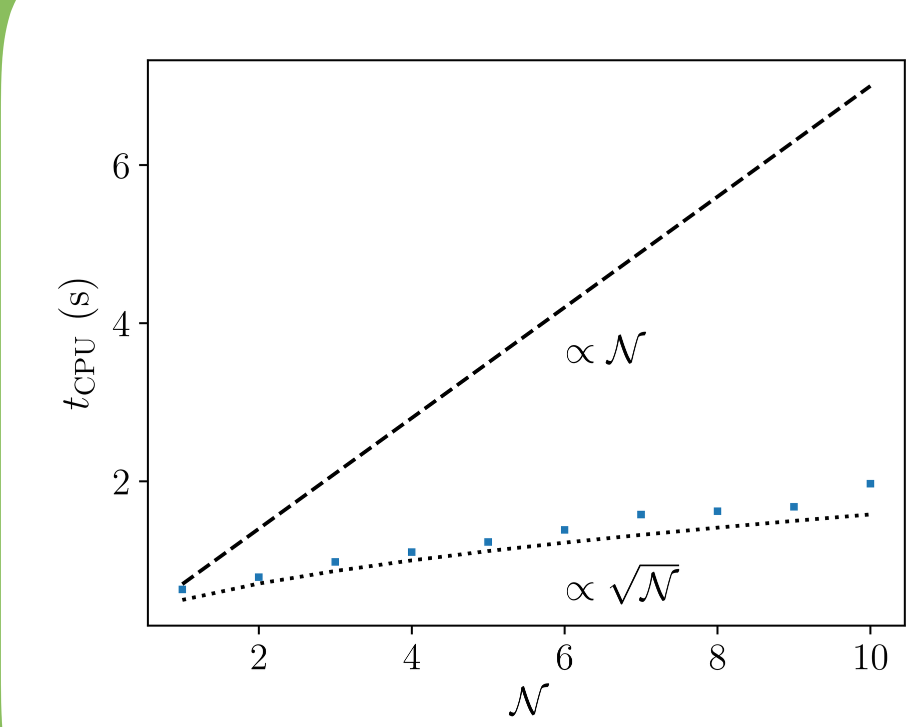

Figure 2

Dusty protostellar collapse with multiple species

Figure 3 shows the densities of gas and dust for a simulation of protostellar collapse with multiple species at t=114 kyr. The color range has been set so that the dust maps would be similar to the gas map is the dust ratio was constant. Dust starts to decouple from the gas for grain larger than 100 microns (Bate & Lorén-Aguilar 2017,Lebreuilly et al., Submitted). 0.5 mm grains settle very fast and form a disk earlier than the gas.

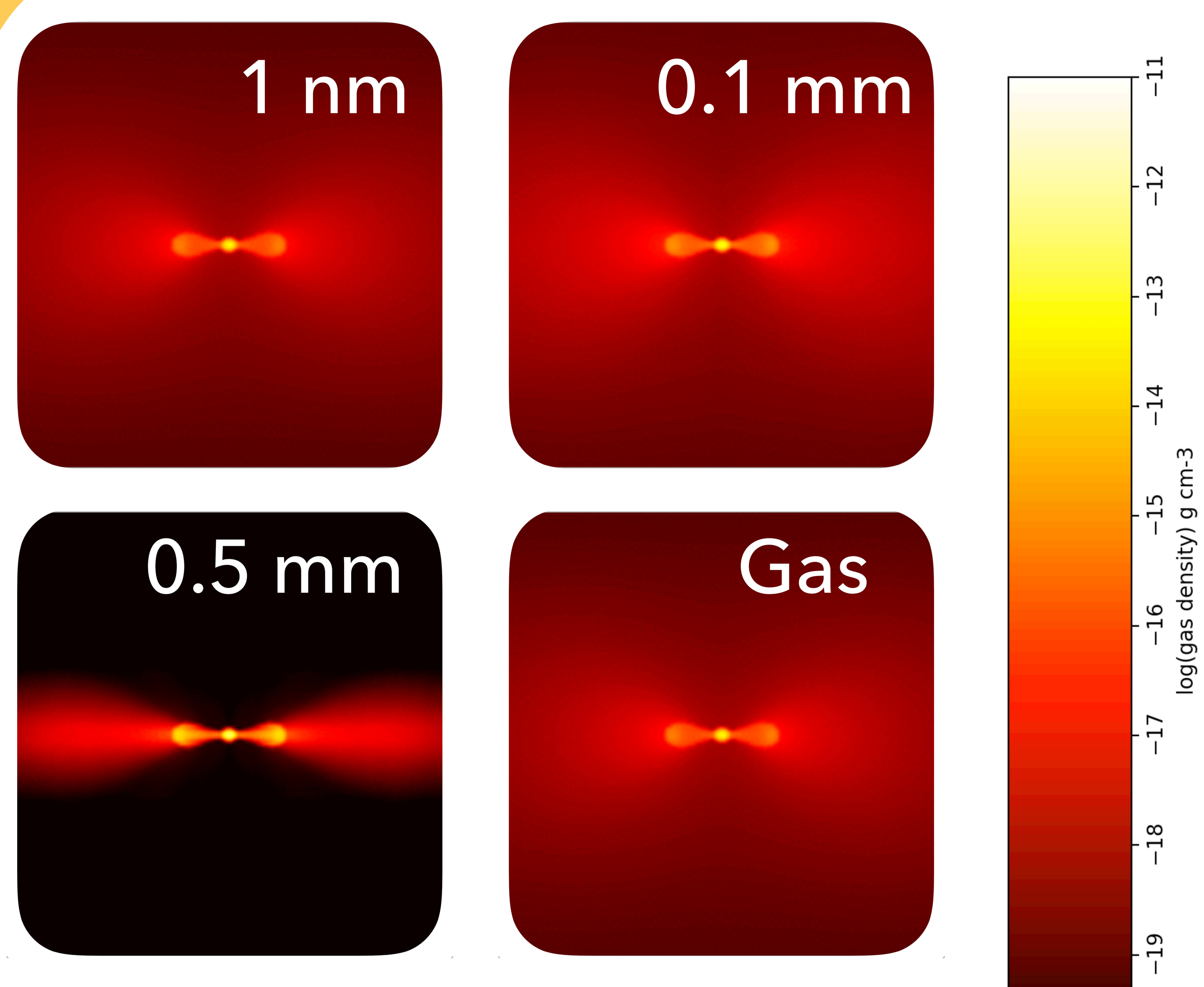

Figure 3

Conclusion

Our algorithm allows a fast and efficient treatment of the dynamics of multiple dust species in the diffusion approximation. Applied to protostellar collapses simulations, it shows that dust starts to decouple from the gas for grains that are larger than 0.1 mm. Above this limit, the settling is important and produces variations of the dust ratio by up to an order of magnitude.

References

Bate, M. R. & Loren-Aguilar, P. 2017, MNRAS, 465, 1089
Laibe, G. & Price, D. 2014b, MNRAS,444, 1940
Lebreuilly, U. & Commerçon, B. & Laibe G., A&A, submitted
Mathis, J. S. & Rumpl, W. & Nordsieck, K. H 1977, ApJ, 217, 425
Teyssier, R. 2002, A&A, 385, 337
Tricco, S.T. & Price, J.D. & Laibe, G., 2017, MNRAS, 471, 52, 56