Numerical simulations of drop impacts

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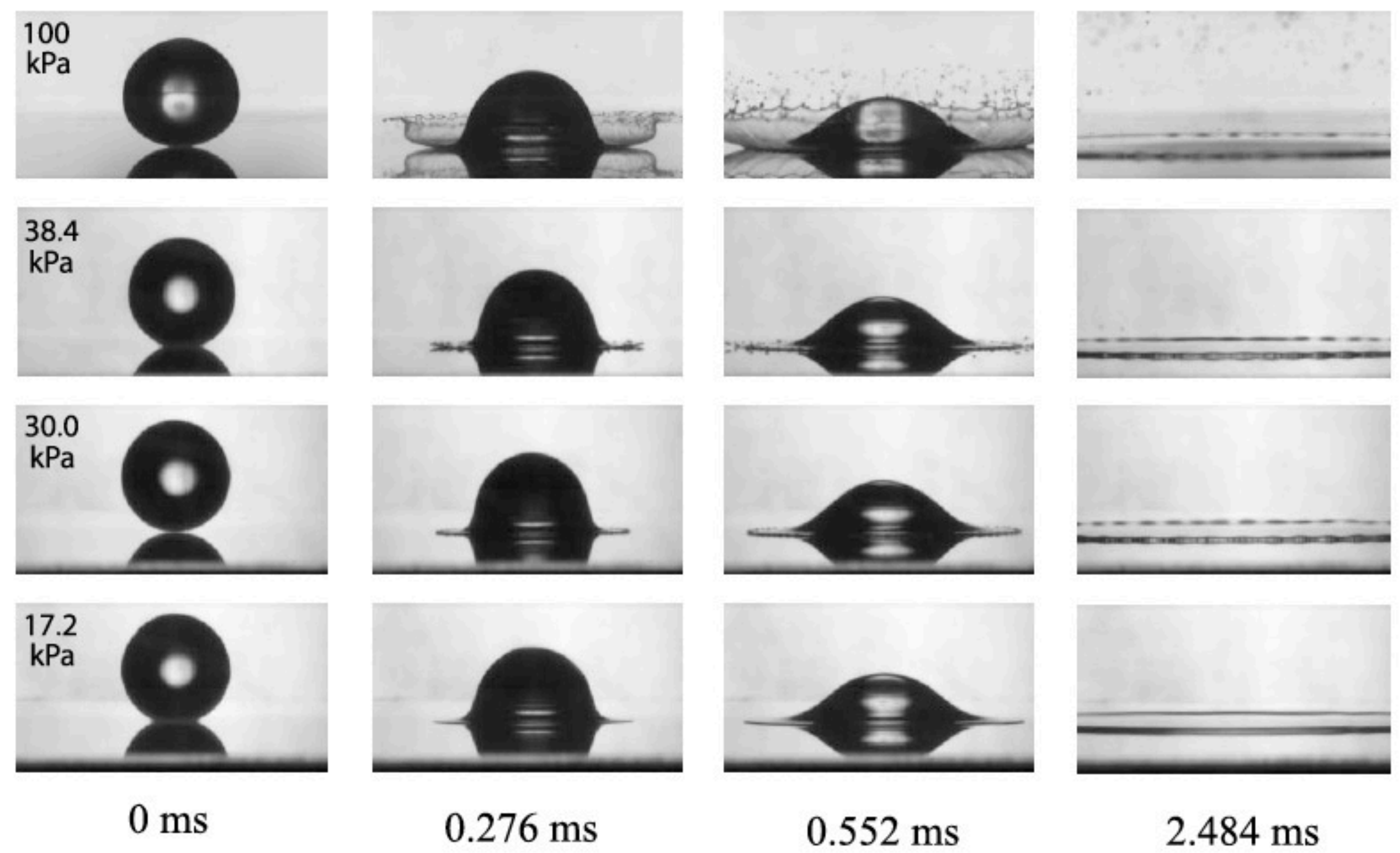
General motivations

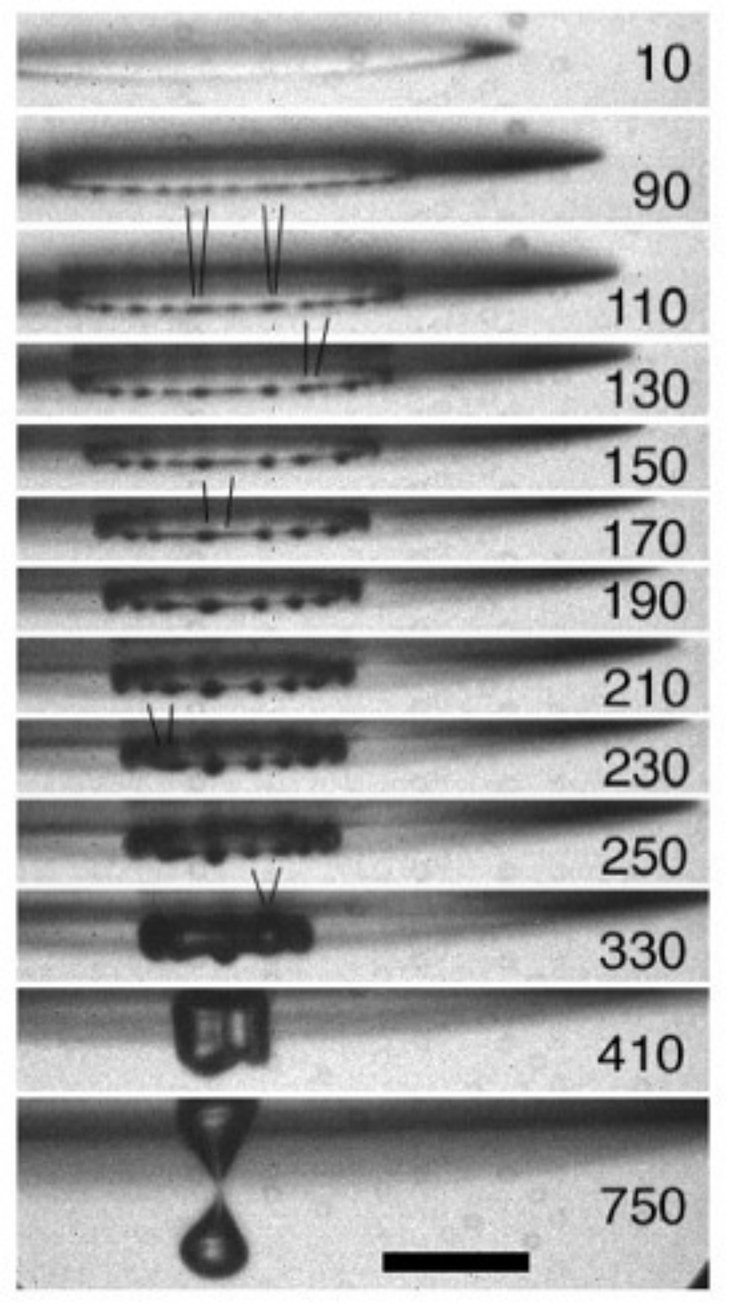
- Why drop impacts?
- Numerous contexts from everyday-life situations to industrial applications
- large spatial range: from ink-jet printers and nanojet to comets
- typical applications: raindrop, atomisation, combustion chambers...

Outline

- what is the influence of the surrounding gas during impacts?
- important in the «late» time dynamics, corolla, droplets, etc...
- recently it has been shown to be crucial for the short time dynamics although it was usually neglected before.

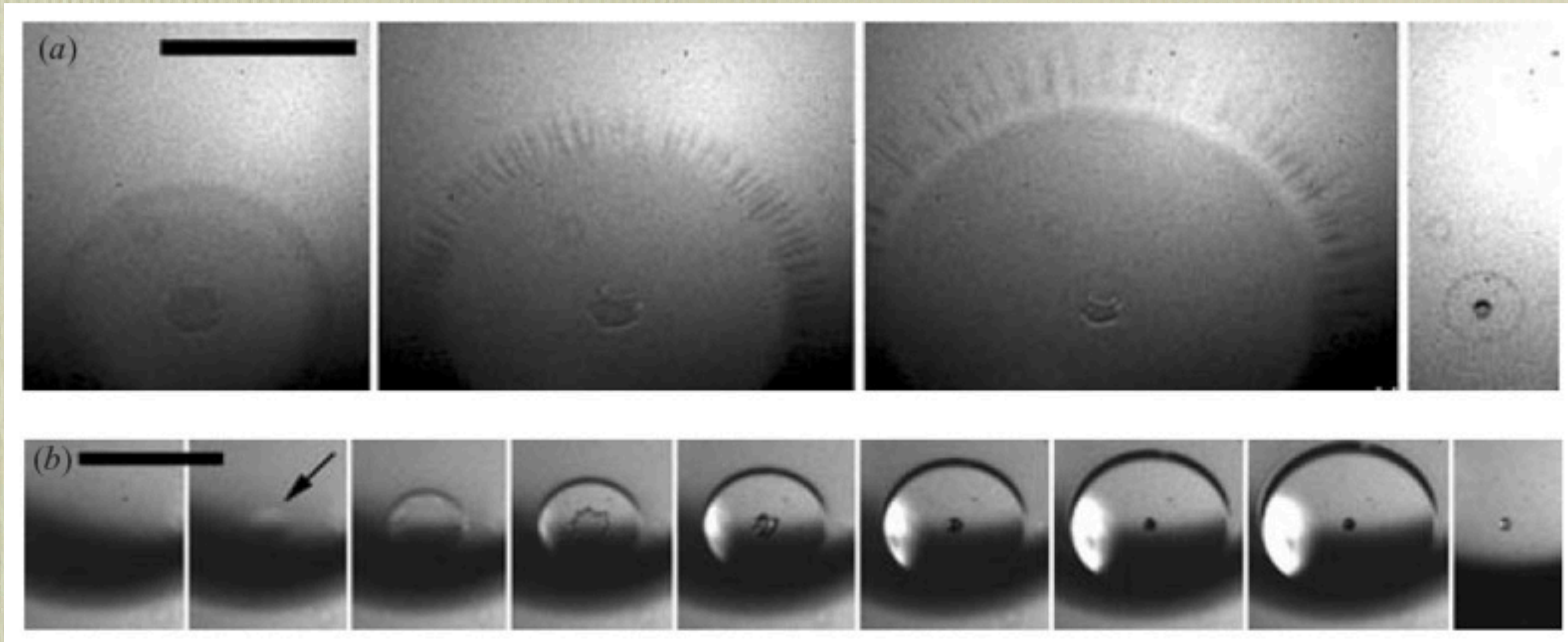


L. Xu , W.W. Zhang and S.R. Nagel, «Drop splashing on a dry smooth surface», Phys. Rev. Lett. 94, 184505 (2005).



Thoroddsen, S. T., Etoh, T. G. & Takehara, K., 2003, «Air entrapment under and impacting drop.» J. Fluid Mech. Vol. 478, 125-134.

Also on solid surfaces.



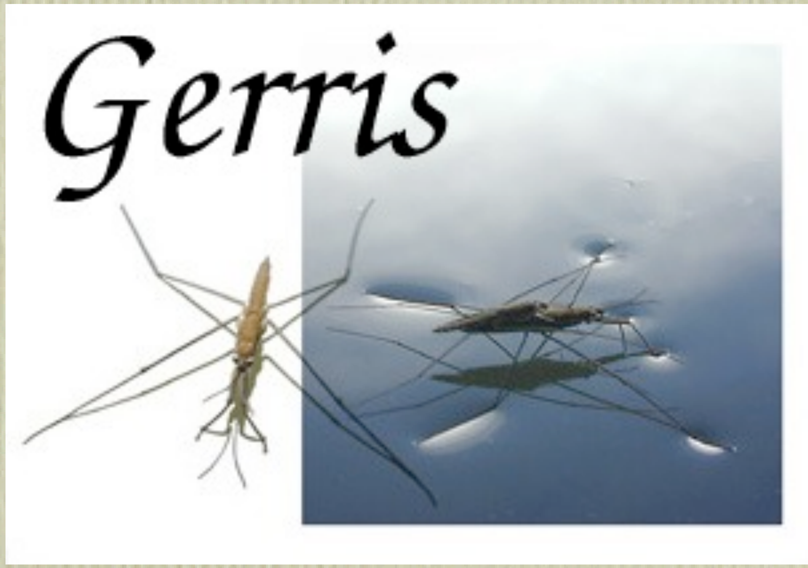
S.T. Thoroddsen, T.G. Etoh, K. Takehara, N. Ootsuka and Y. Hatsuki, "The air bubble entrapped under a drop impacting on a solid surface", J. Fluid Mech. 545, 203-212 (2005).

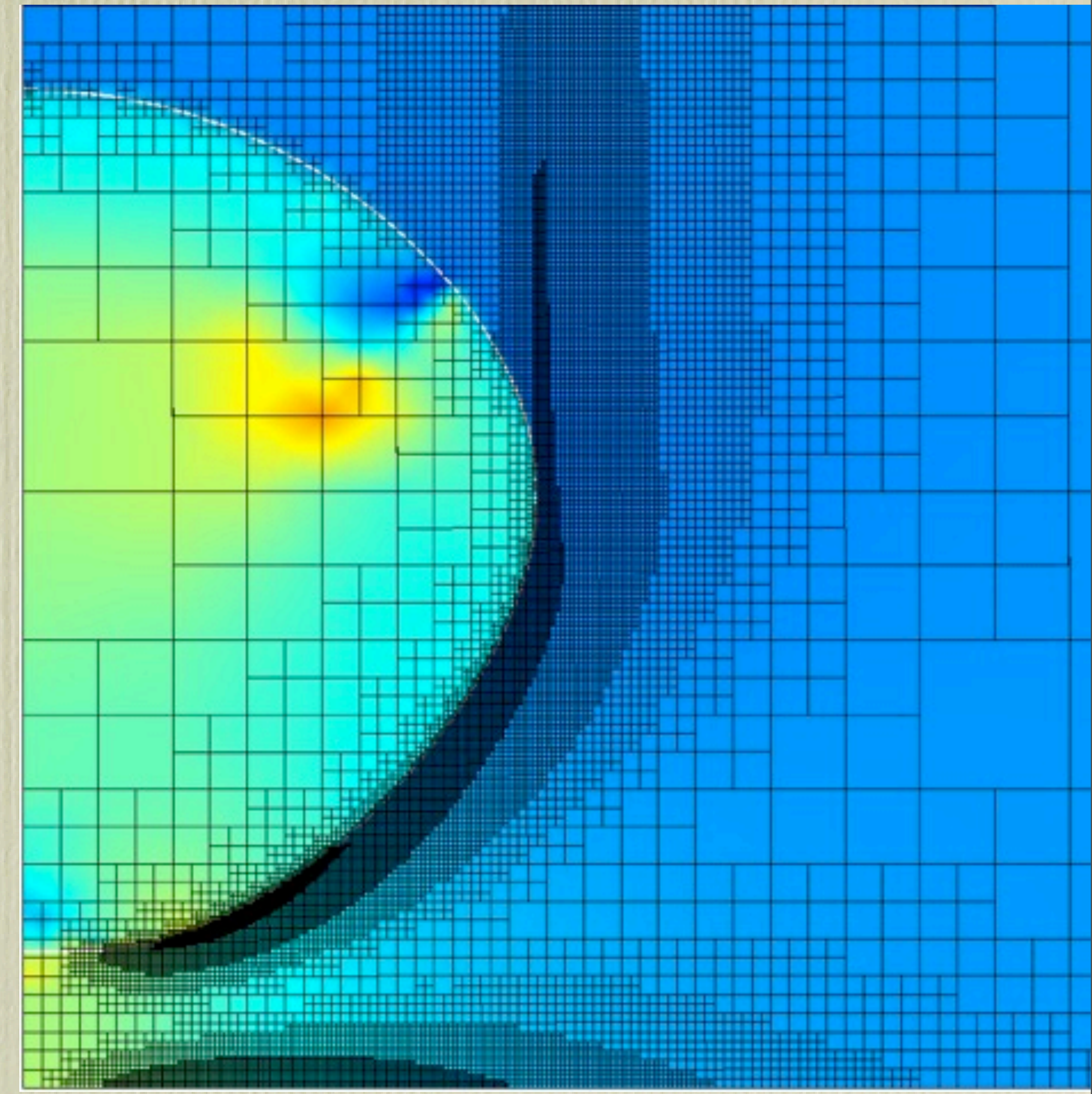
Surrounding gas effects?

- compressibility?
- bubble entrapment
- moving contact line-air entrapment
- aerodynamical instability
- two different theoretical/numerical approaches

- can the initial liquid-solid contact trigger the splash?
- simplified model coupling inviscid flow in the drop with lubrication equation in the gas (S. Mandre, M. Mani, and M. P. Brenner. Precursors to splashing of liquid droplets on a solid surface. Phys. Rev. Lett., 102, 2009).
- In this 2D version, a finite time singularity is observed in the no surface tension case. With surface tension, the singularity disappears and the capillary waves look as precursors of the jets.
- Problem: alone, it cannot explain the experiment!

Aerodynamical mechanism

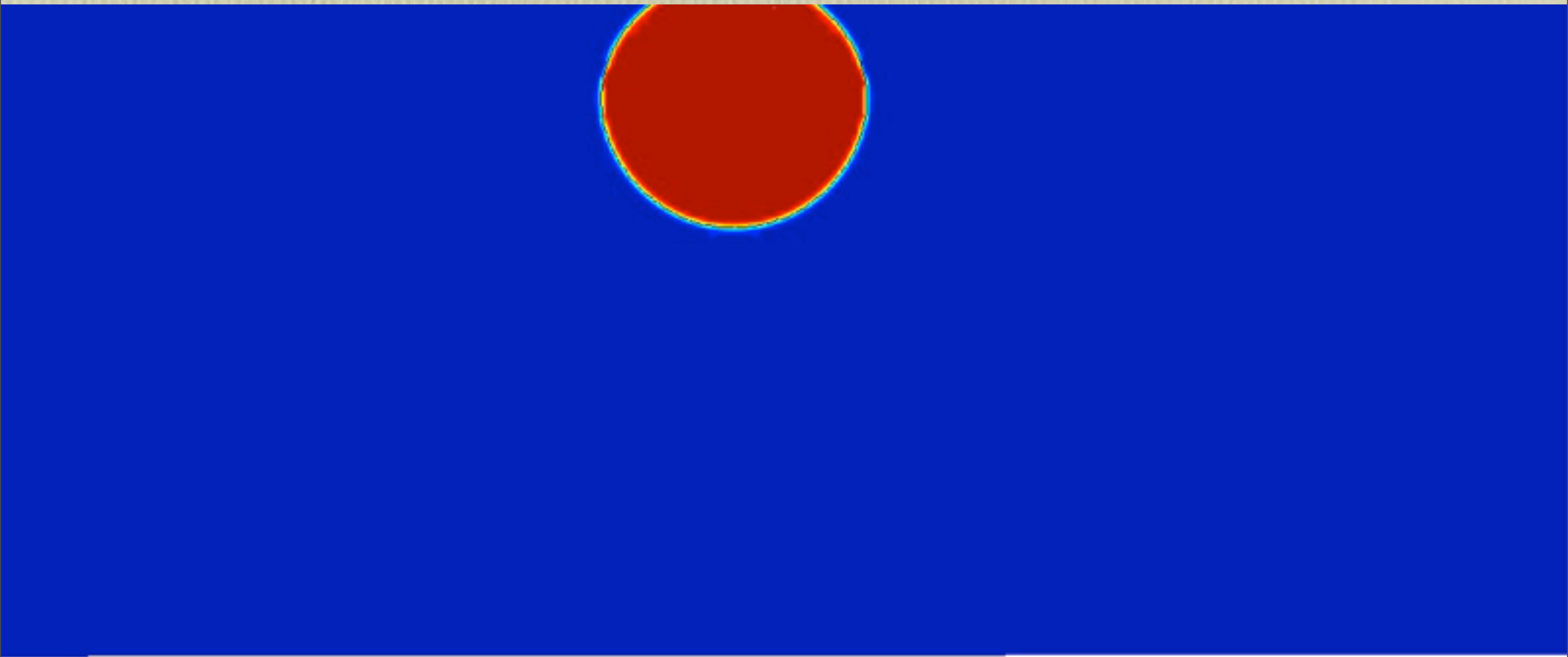




GERRIS hints

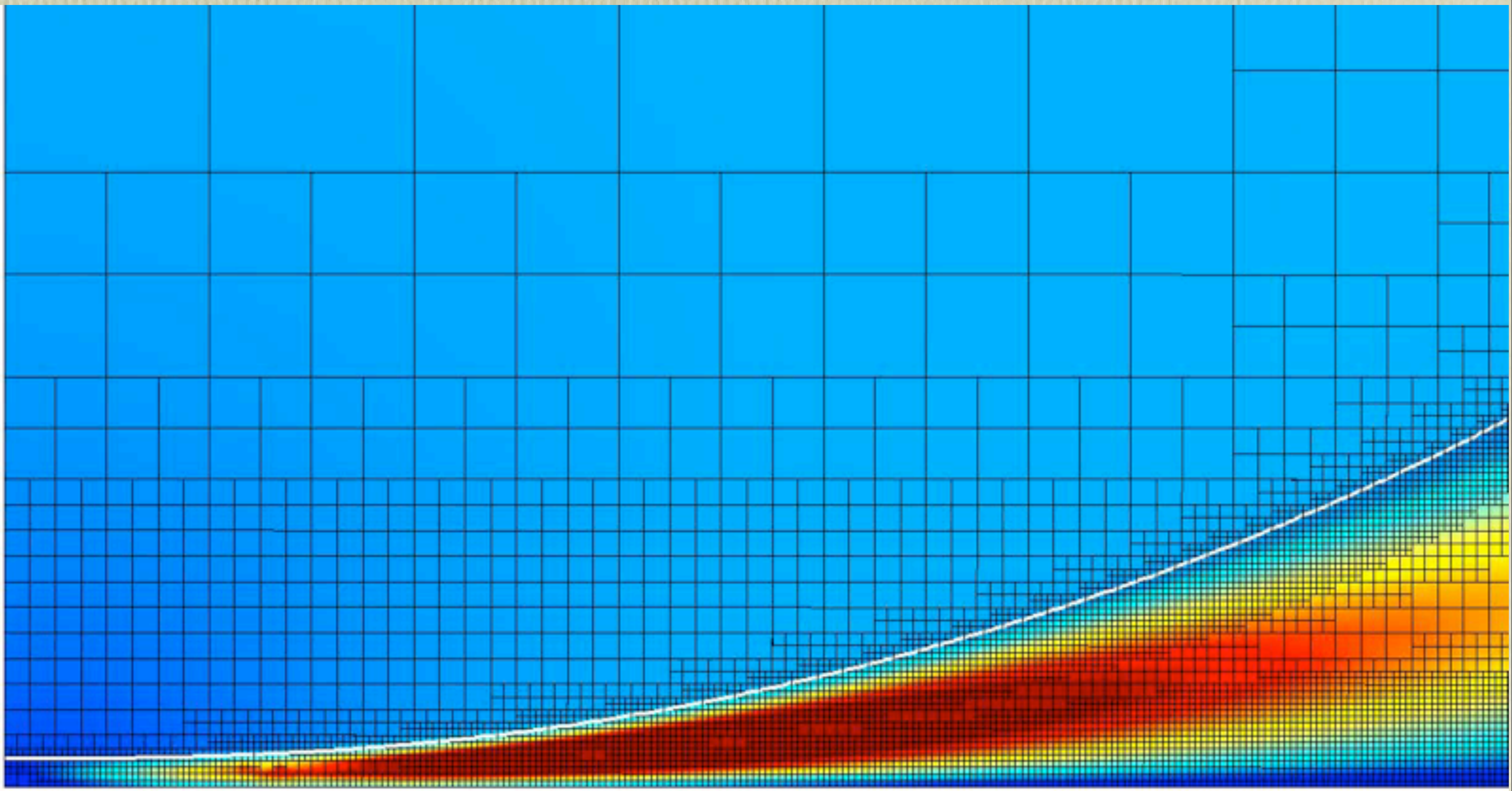
- 2 fluids incompressible Navier-Stokes equation with solid boundaries
- VOF method (PLIC interface reconstruction)
- Adaptive mesh refinement (quad-oct-tress, dynamical)
- multigrid Poisson solver

$$\rho\left(\frac{\partial u}{\partial t} + u \cdot \nabla u\right) = -\nabla p + \mu \Delta u + \sigma \kappa \delta_s n$$

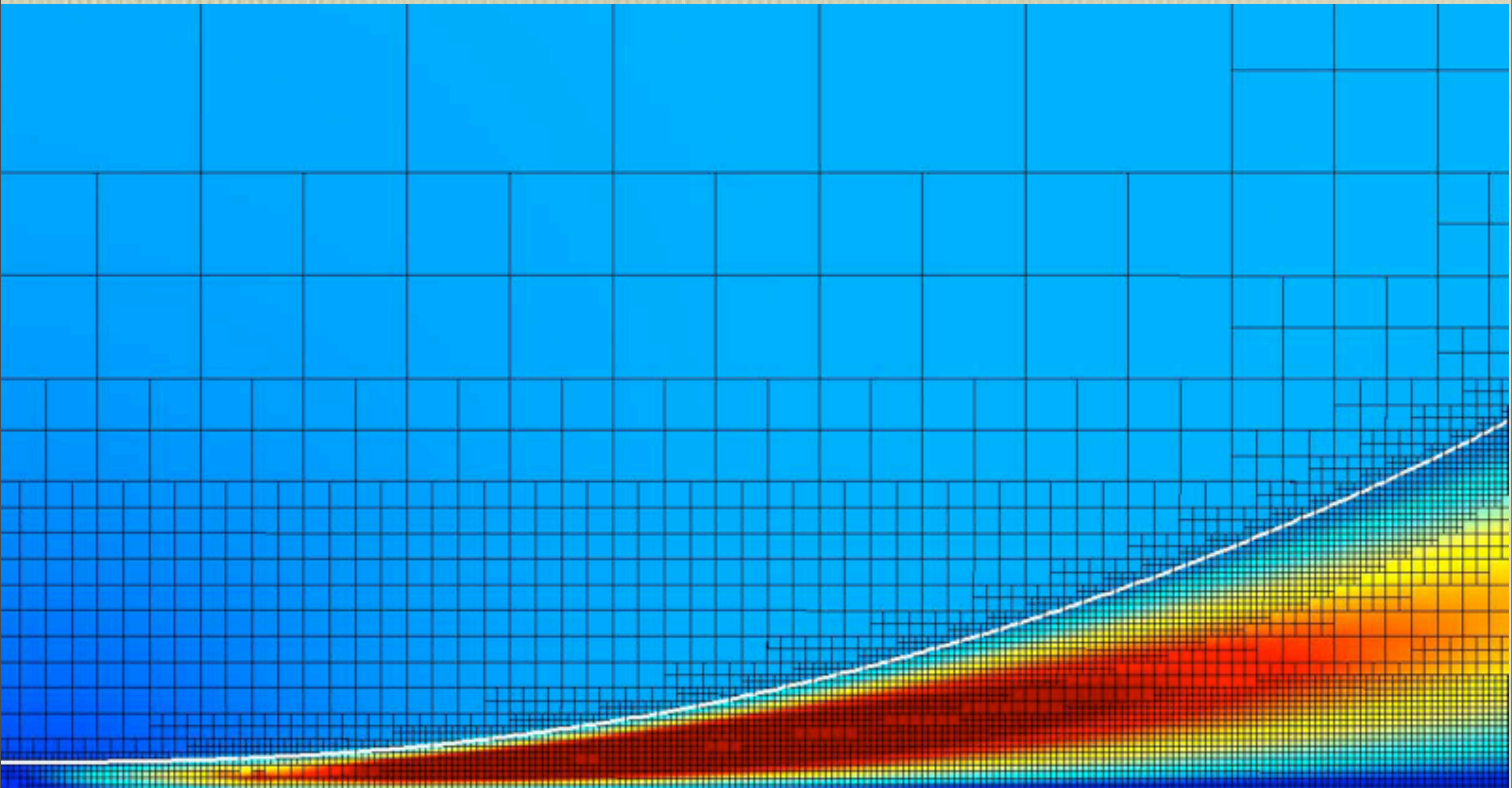


How is the dynamics affected when the gas density and viscosity vary.

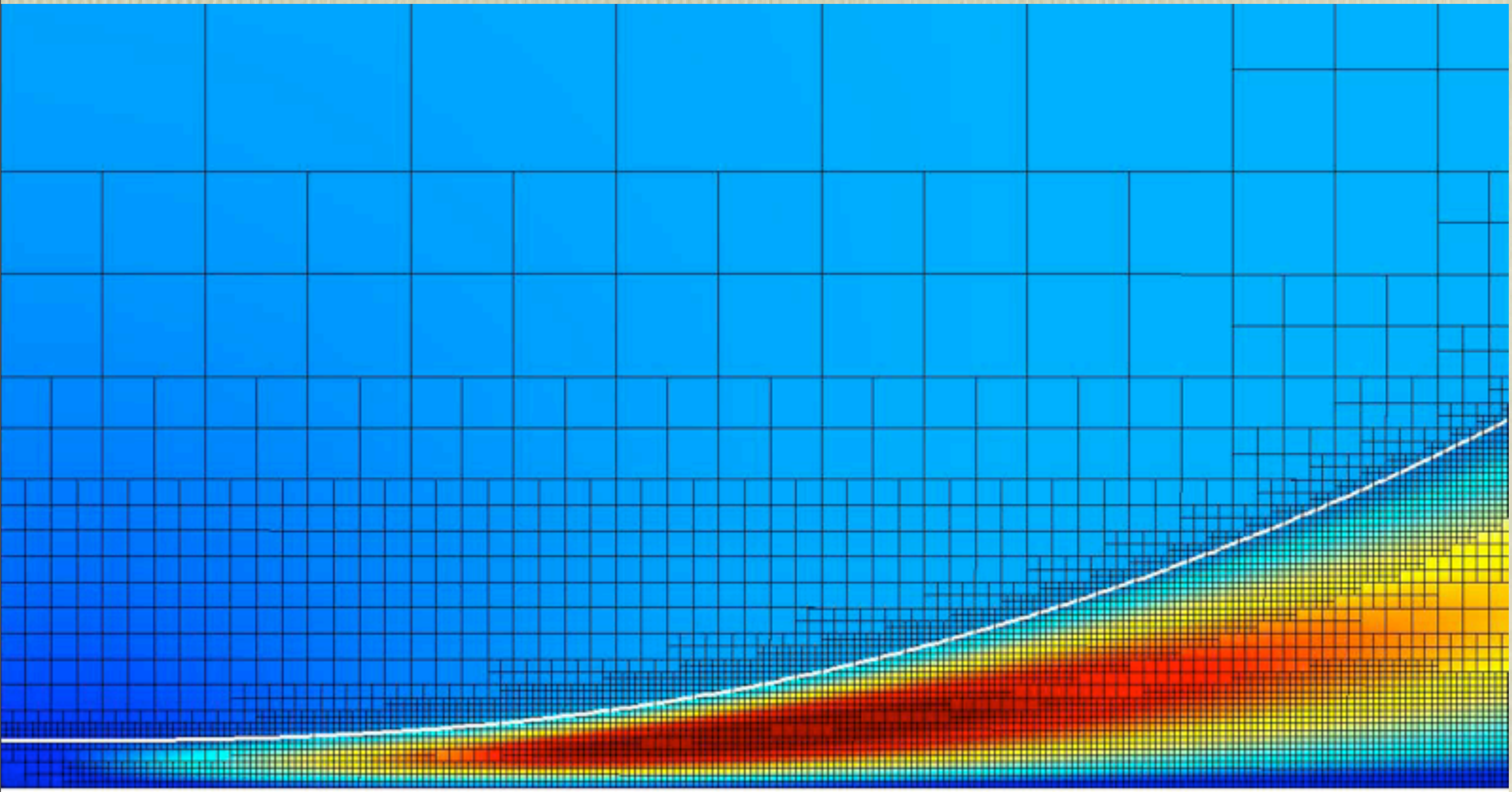
Changing the viscosity ratio for fixed density ratio 0.003



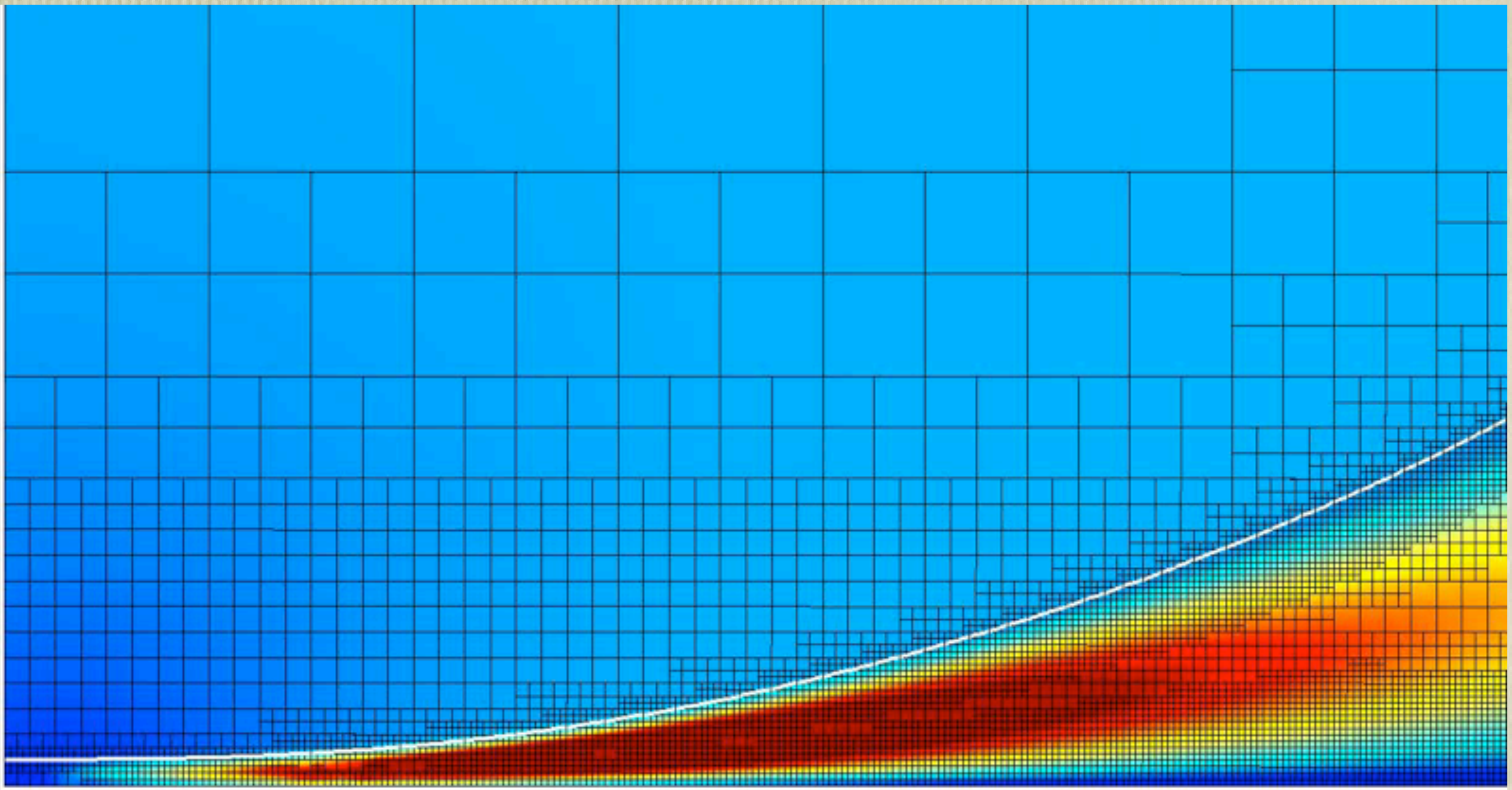
Increasing gas viscosity

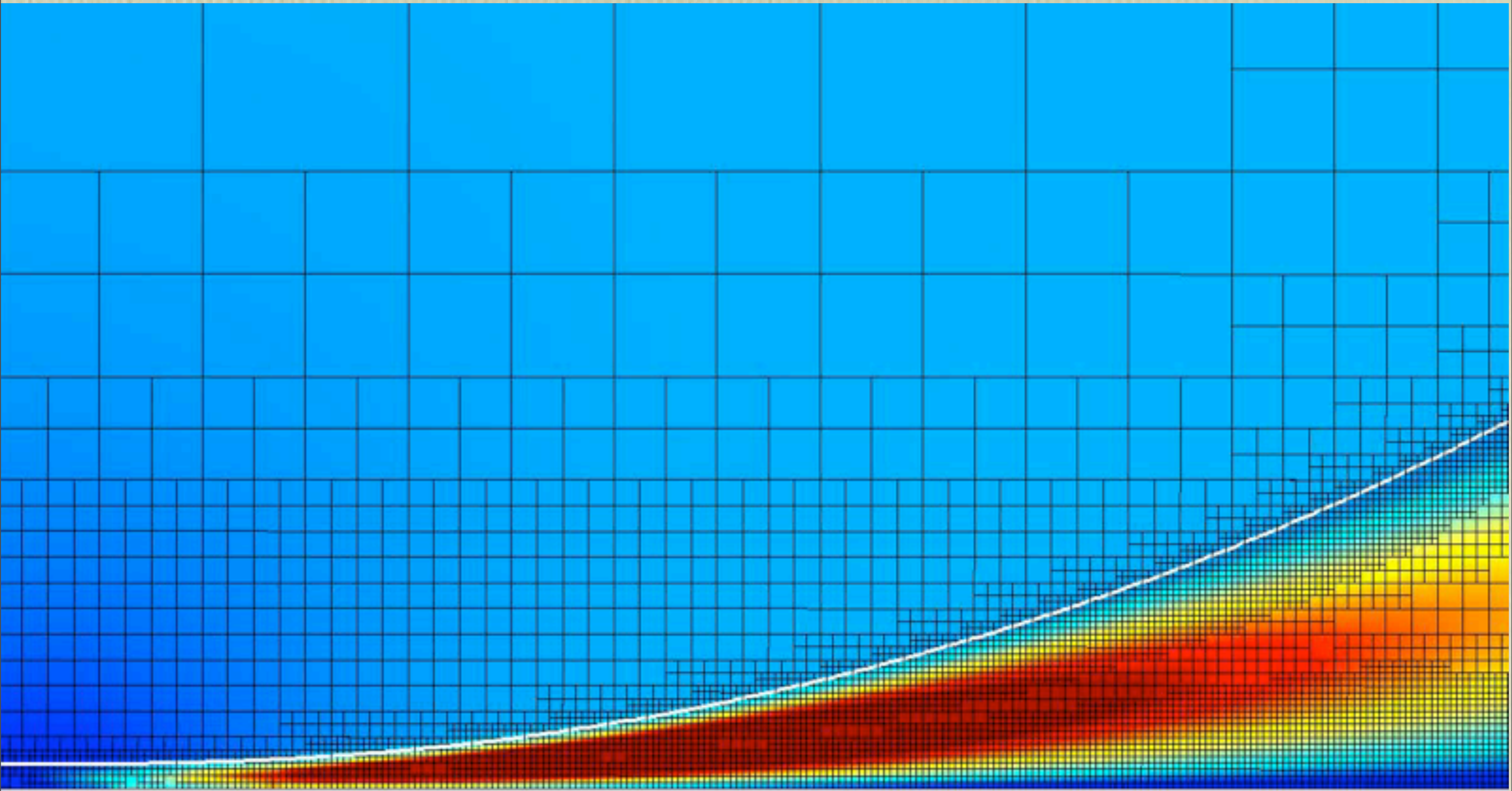


Increasing again

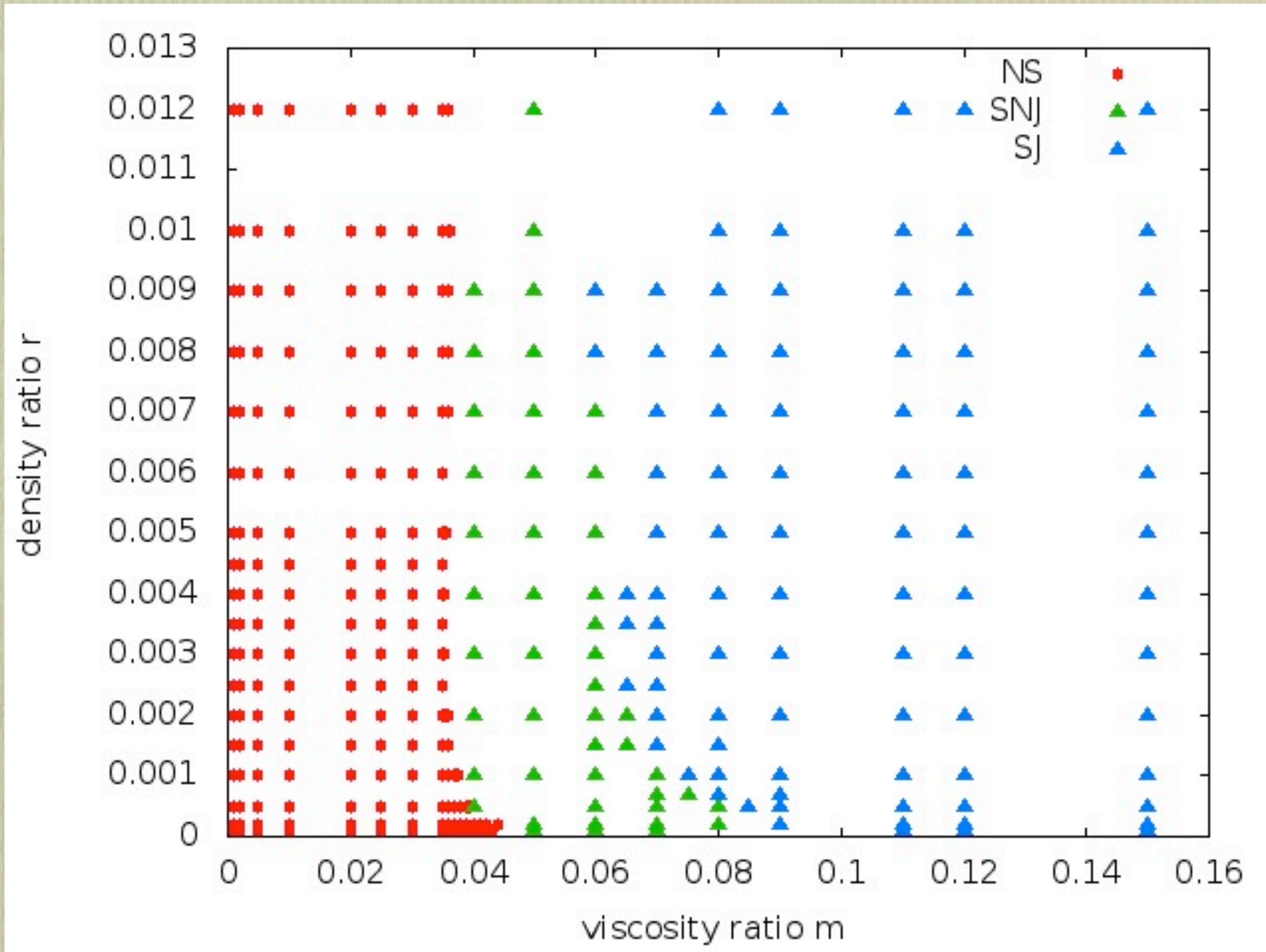


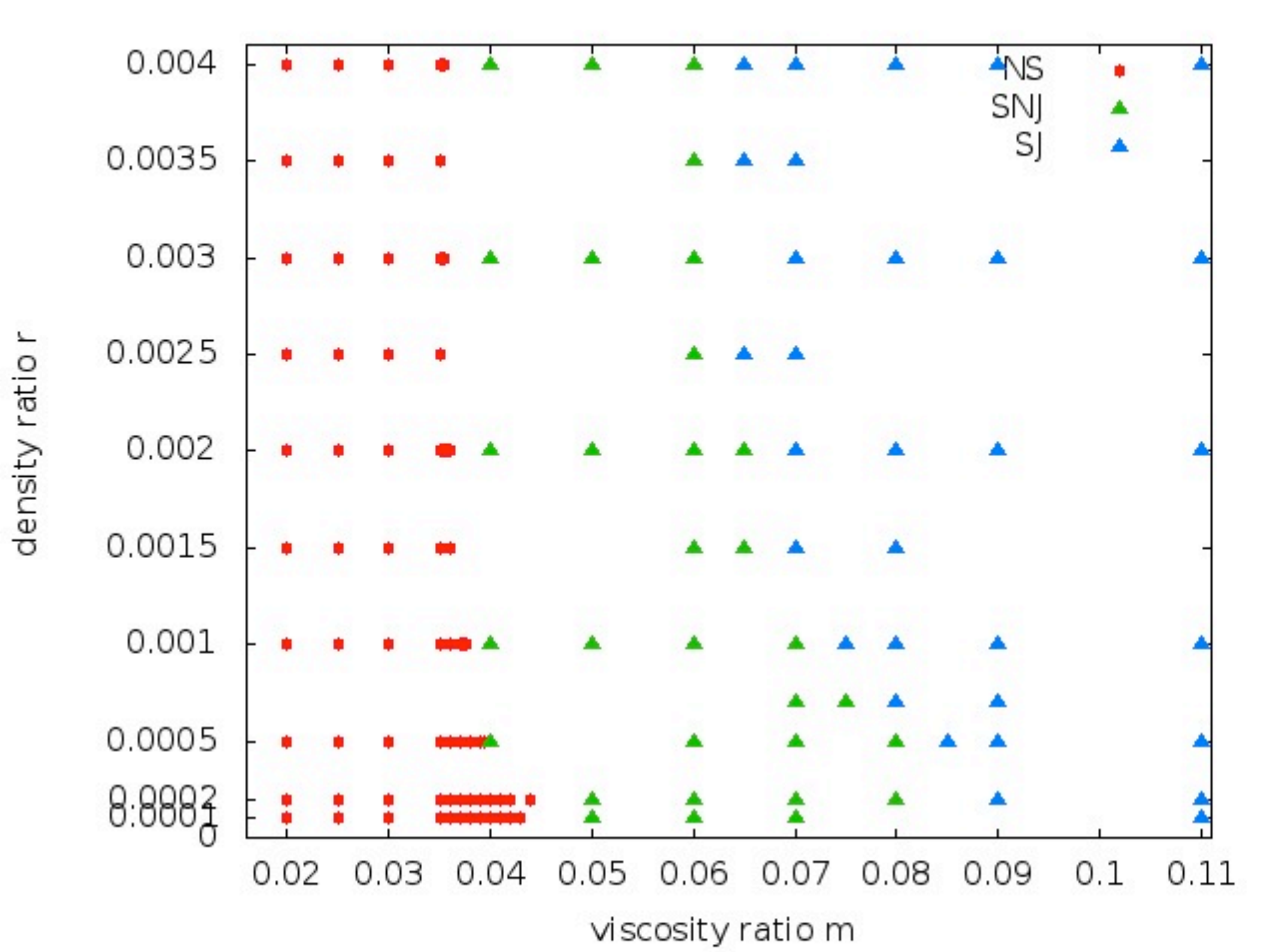
Fixed viscosity ratio, decreasing gas density





- changing the density and viscosity ratios, we can scanned the different impact dynamics
- we observe splashing and spreading behaviors
- we discriminate two type of splashing dynamics
- they differ whether a jet is formed before or after the liquid wets the substrate.
- we can deduce a phase diagram of splashing


NS
SNJ
SJ
density ratio r
0.013
0.012
0.011
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
viscosity ratio m


0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0.0002
0.0001
0
density ratio r
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
0.11
viscosity ratio m
NS
SNJ
SJ

Gas density dependence?

- aerodynamical force due to air/liquid velocity: it deflects the liquid ejecta once formed
- qualitative good agreement with the splashing jet bending
- How can the density change the appearance of the jet: instability?
- it can also be a source of instability to the rapid horizontal expanding jet (second type of splash)
- further studies need to be done!

Conclusions

- simplified model and full resolved numerical simulation of bubble entrapment
- strong pressure gradients «expelled» the liquid into a jet
- jet skating but no clear gas pressure
- different explanations need to be disentangled: gas compressibility, non-continuum effects, aerodynamical instability.