Atomisation of a pulsed Jet: morphology and thin sheet rupture

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Overview

- Jet atomisation is a multi-scale phenomenon and hence a challenging problem for numerical simulations, even in isothermal and incompressible setting [1,2].
- Direct numerical simulation of atomisation of a pulsating jet is performed at highest ever resolution** giving direct evidence of underlying mechanisms of droplet formation and various novel characteristic physical (A,B,C,E) and numerical phenomenon (D).
- Bimodal grid dependent pdf is obtained and histogram of droplet size distribution is seen to converge for largest of droplets.
- Numerical curvature provides the diagnostic of thin sheet rupture and origin of numerical droplets is revealed along with characteristic short-lived ligament networks.

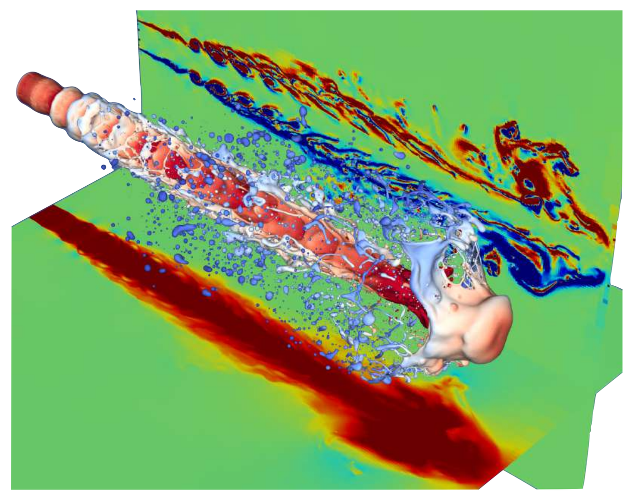
Methodology

- The Momentum-Conserving VOF solver of *Basilisk* code is used with octree adaptive mesh refinement.
- The mathematical model is based on two phase Navier-Stokes equations with surface tension.

$$\nabla \cdot \vec{u} = 0 \qquad (1)$$

$$\frac{\partial \rho \vec{u}}{\partial t} + \nabla \cdot (\rho \vec{u}\vec{u}) = -\nabla p + \nabla \cdot (2\mu \mathbf{D}) + f_\sigma \qquad (2)$$

Setup



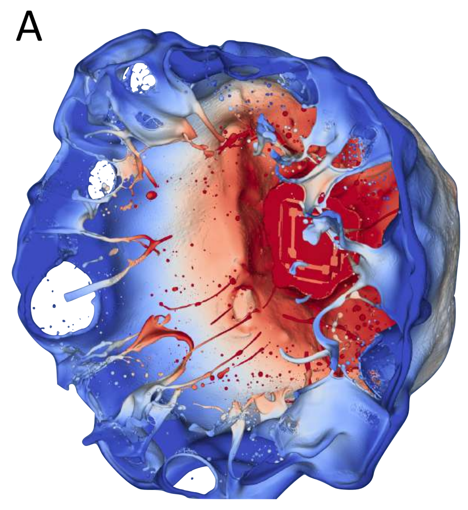
- A circular jet is injected in a gas filled chamber with sinusoidal injection velocity.

$$u_x(t) = U\left[1 + A\sin\left(\omega_{pulse} t\right)\right]$$

- Relevant non-dimensional numbers are:

$$We = 5555 \qquad Re = 5800 \qquad \rho_{ratio} = 28$$

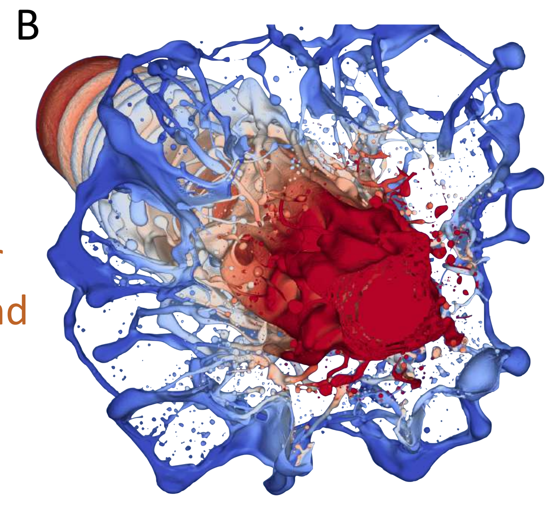
A



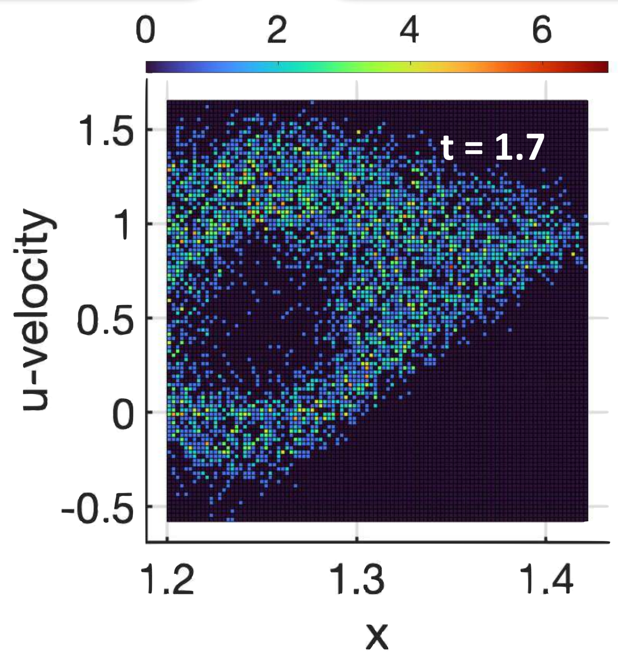
t = 1.12

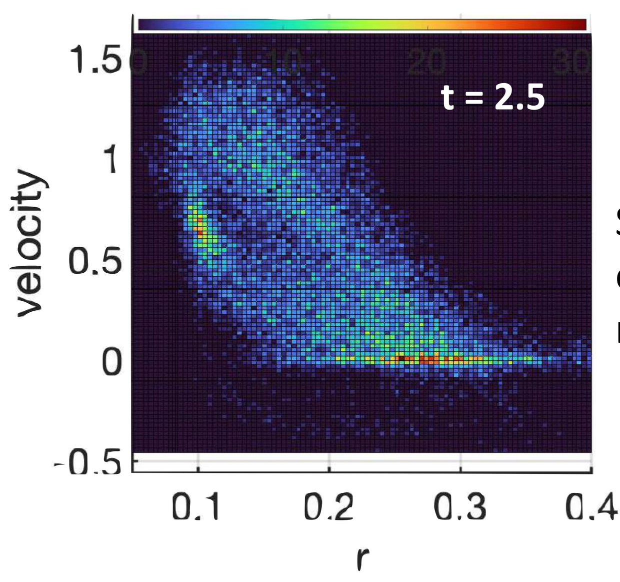
Point of views showing holes formed and expanding after sheet collapse and resulting in tentacle like ligaments.

B

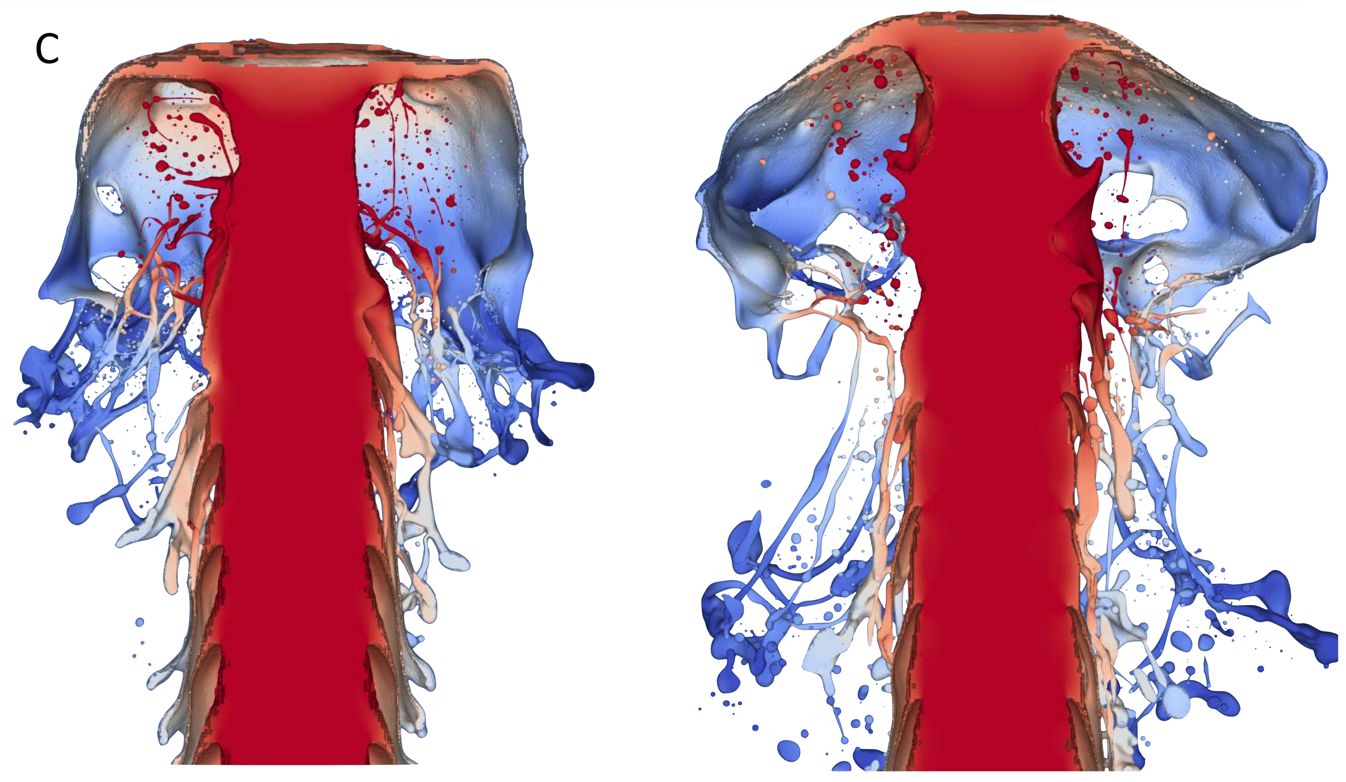


t = 1.42





C

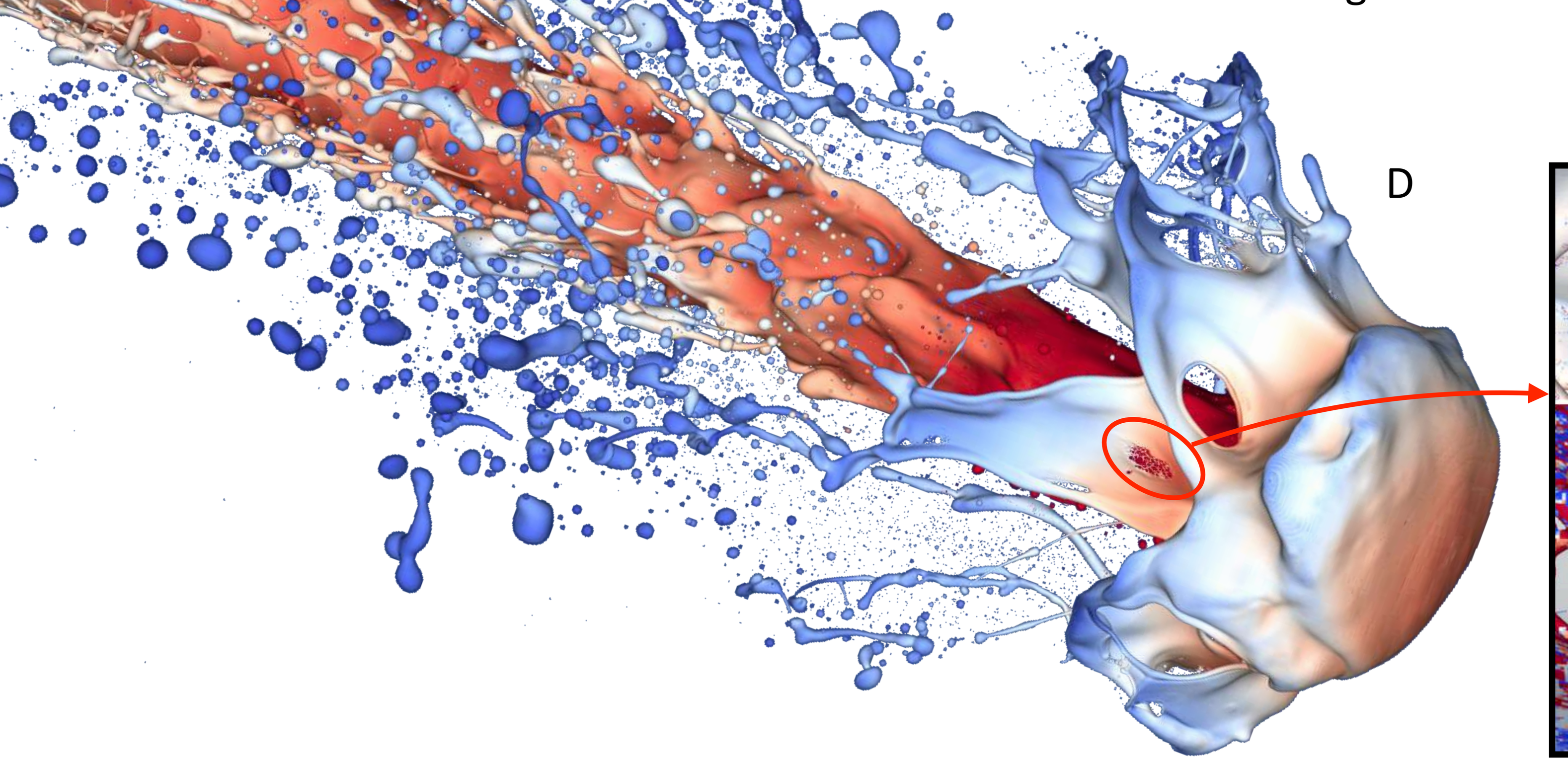


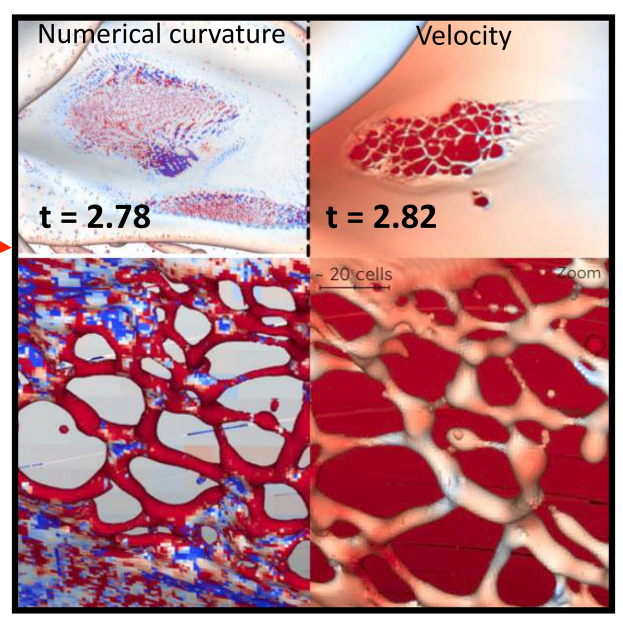
t = 1.22 t = 1.54

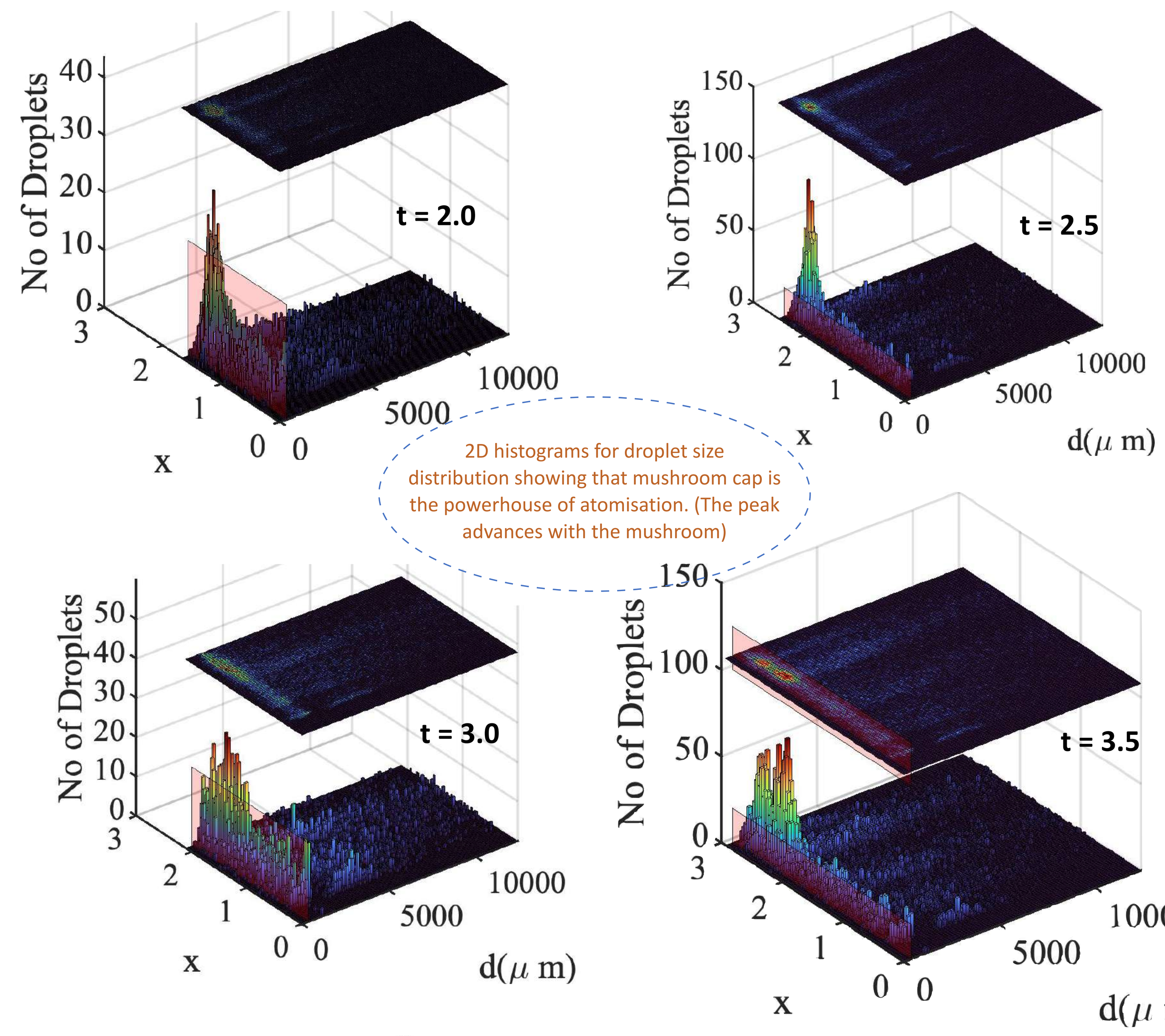
Sheet blowing effect causes recirculation and reversal of corona fingers. Hollow ellipse like histogram is obtained due to sheet blowing effect. Color gradient reveals ligament stretching.

The holes expand and the sheet collapses, leaving ligaments (A). Droplets originating from ligament breakup near the jet core impact the jet head from behind (B). If a liquid layer becomes thinner than a few cells, the numerical curvature oscillates and triggers perforation, this leads to ligament networks with a short lifetime ($\Delta t \sim 0.02$). fingers.

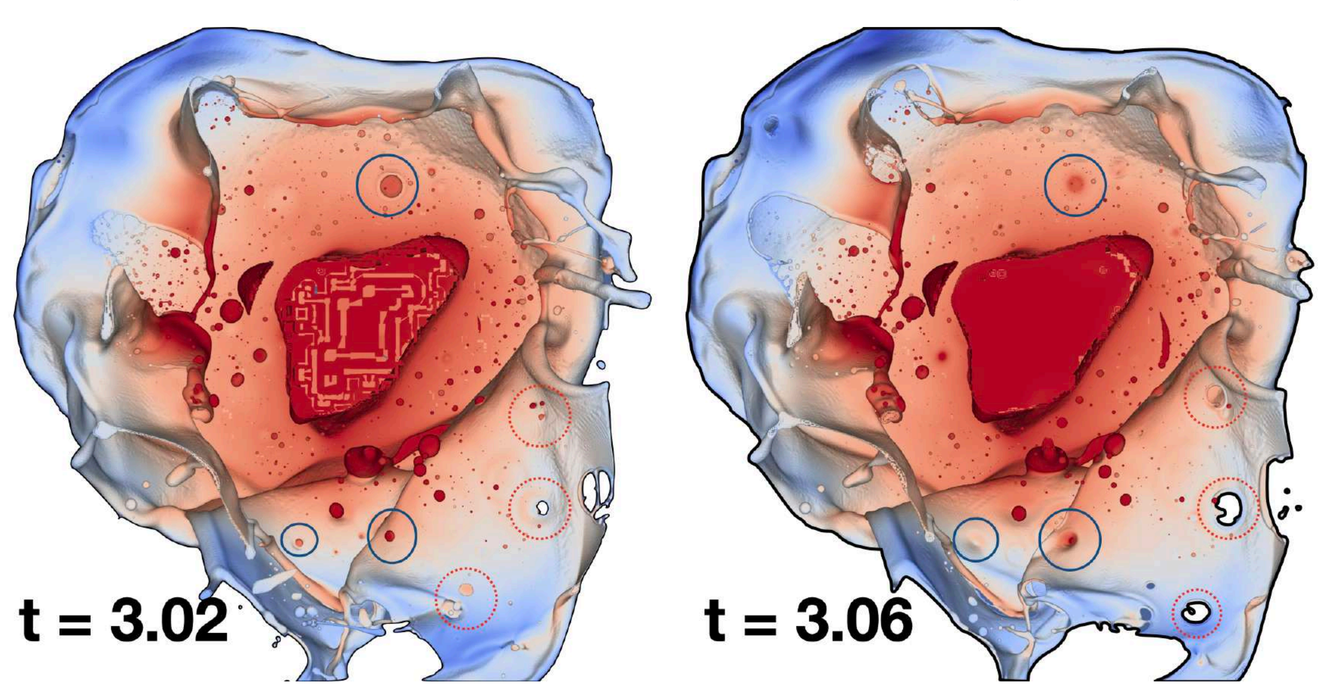
D



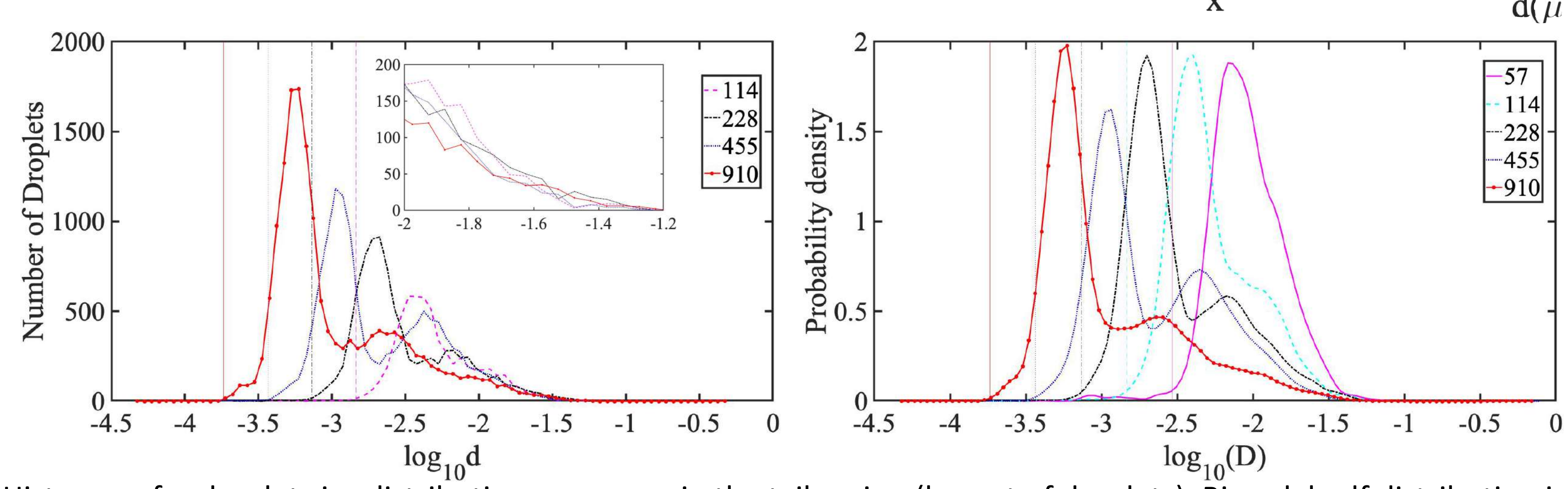




E



Charecteristic finger-like ligament formed when drop perforates thin sheet (red-circle). Merging happens when drop impacts a thicker sheet (blue-circle).



Histogram for droplet size distribution converges in the tail region (largest of droplets). Bimodal pdf distribution is obtained with peaks shifting with grid refinement. Note that shift is reducing for larger diameter peak. (Legend indicates number of grid points per initial diameter)

References

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[3]X. Yang, A. Turan, Simulation of liquid jet atomization coupled with forced perturbation, Physics of Fluids 29 (2017) 022103. doi:10.10163/1.4976621

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** The ratio of nozzle diameter to smallest grid size achieved in present simulation is around 910, which is 16 times more than previous study on pulsating jet [3]. This is also more than any previous study on jet atomisation to the best of authors knowledge.

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