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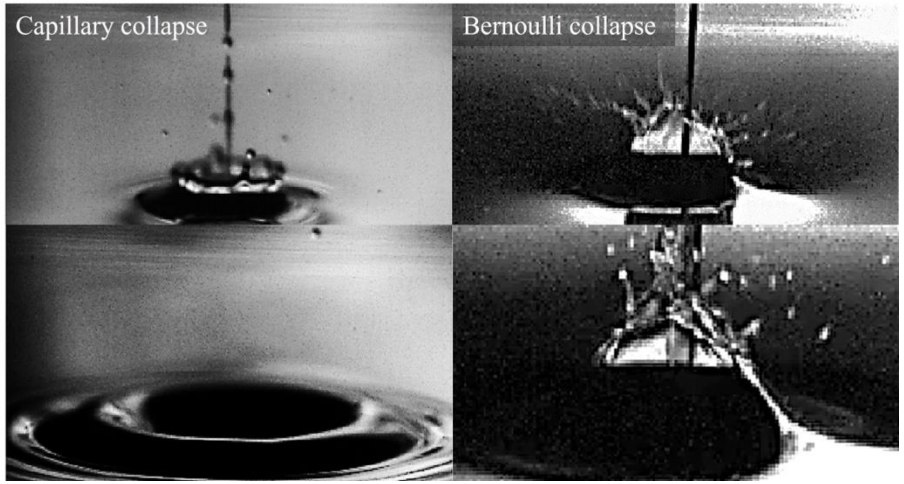
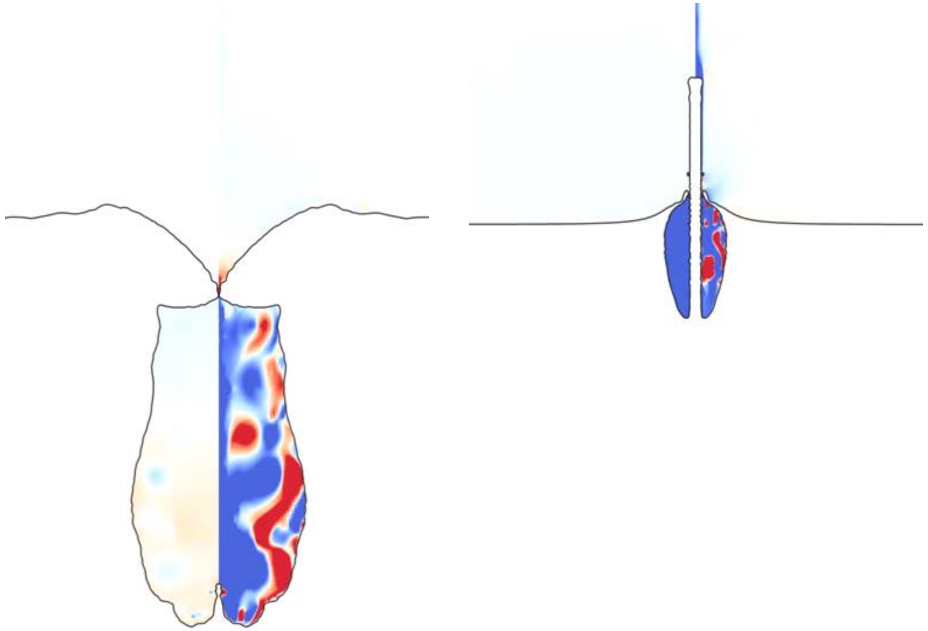


Numerical investigation of jet impact cavity dynamics



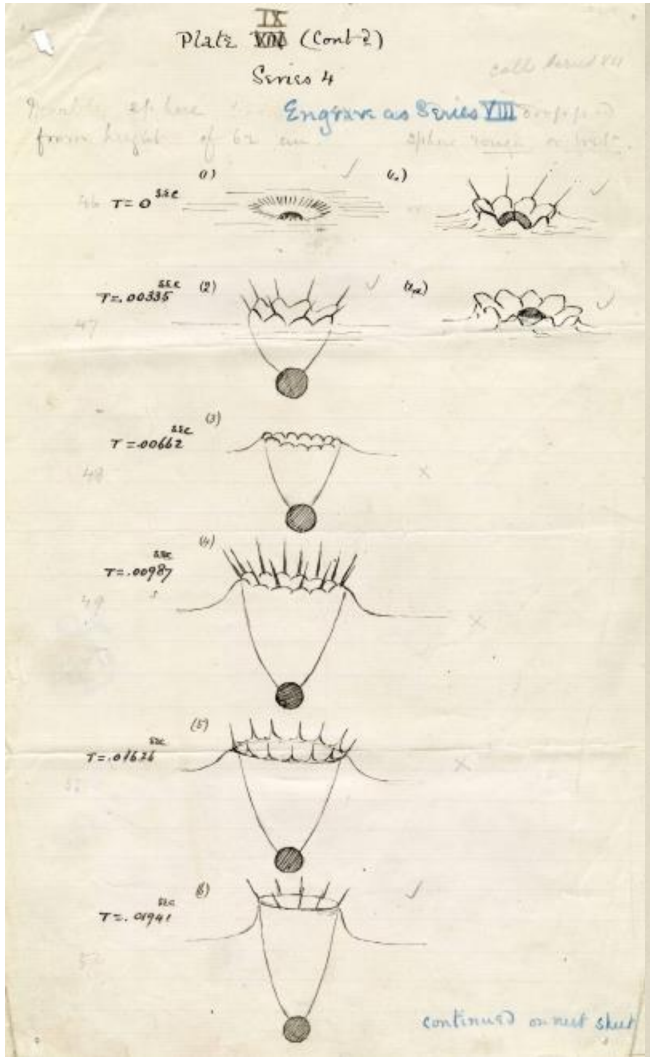
Miguel A. Quetzeri-Santiago

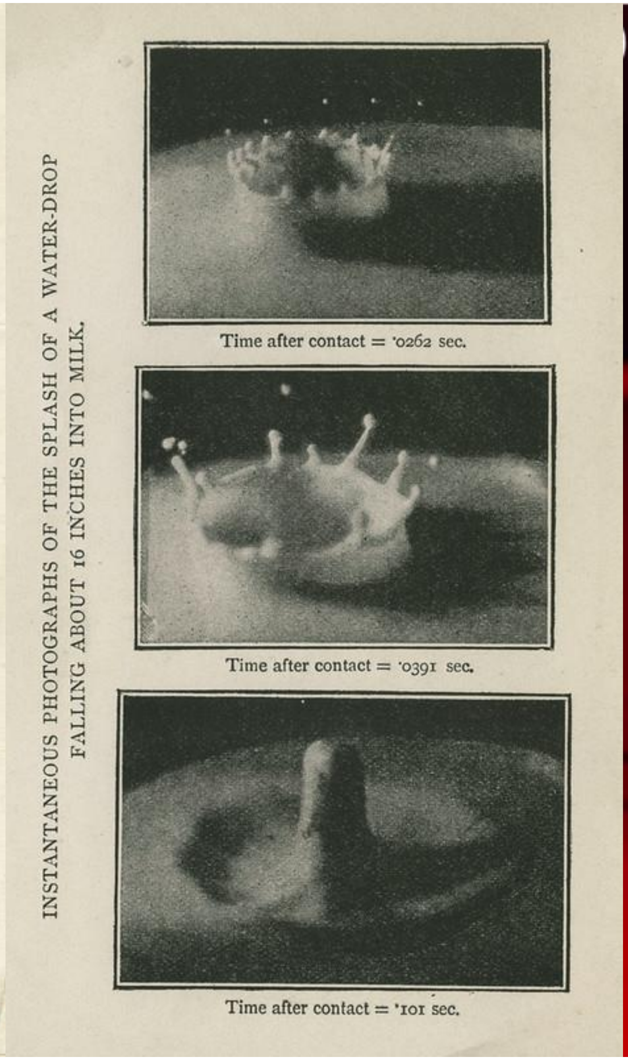
Thijmen Kroeze

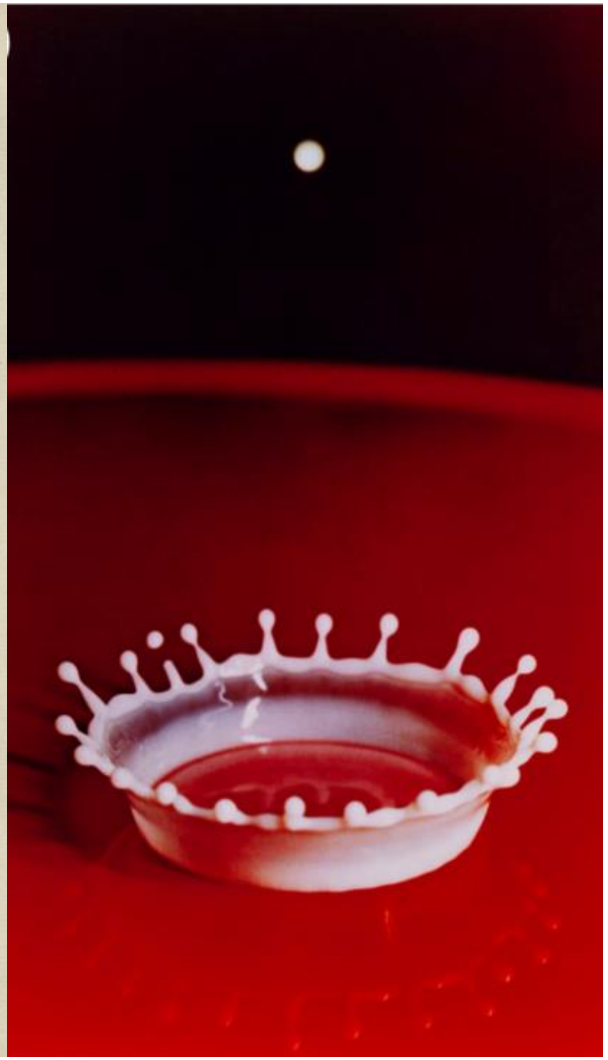
David Fernandez Rivas

Basilisk (Gerris) Users' Meeting 2025

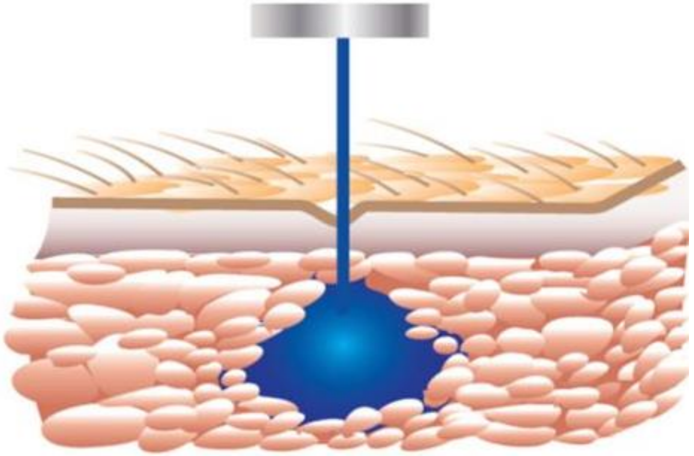
Impact on pools

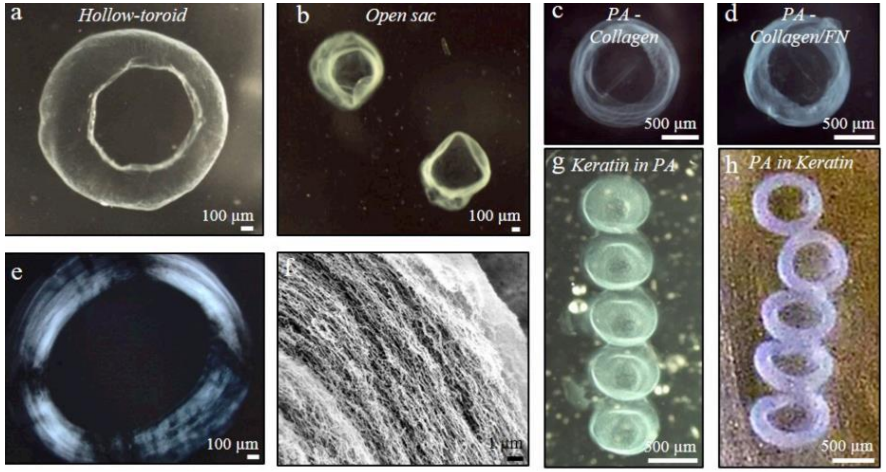




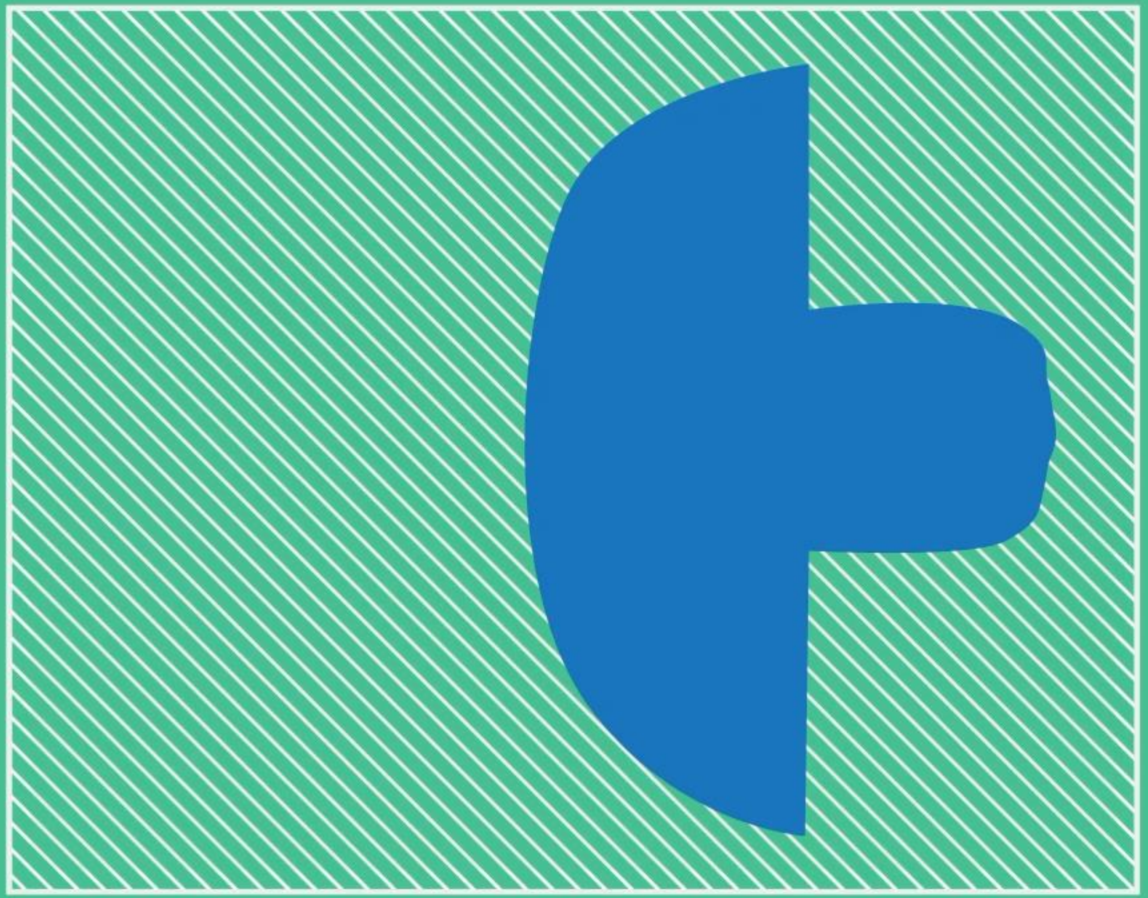


Applications

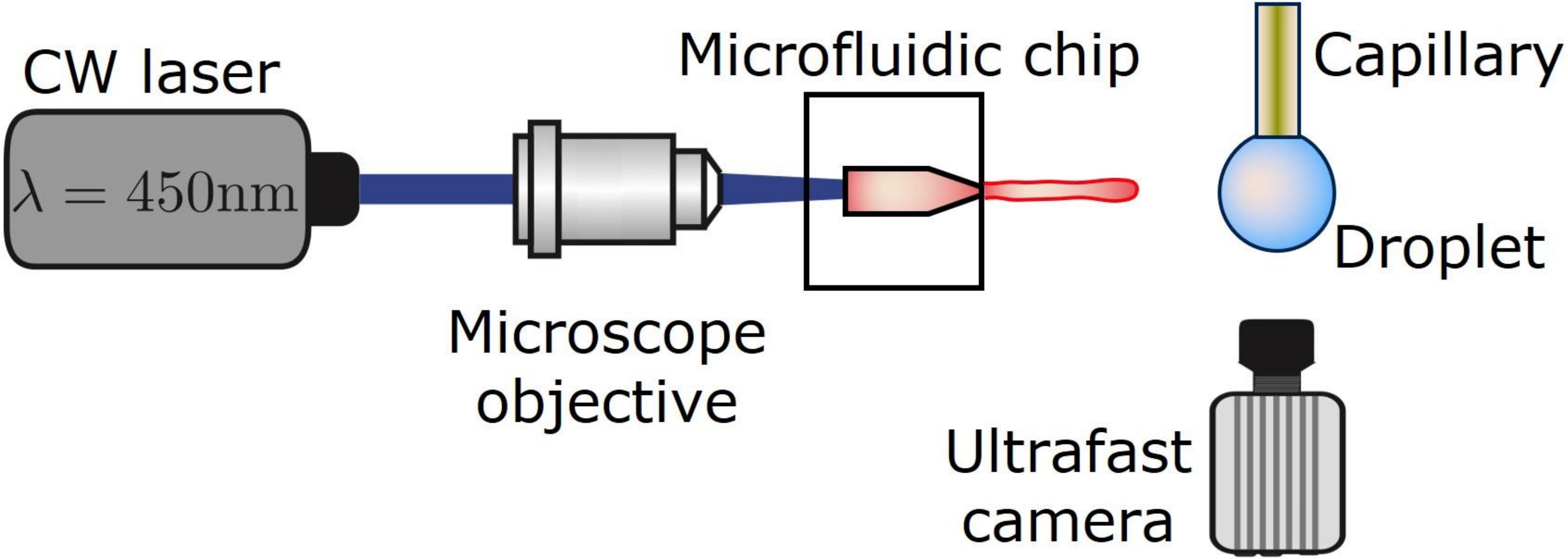




Hedegaard, Clara L., et al. "Hydrodynamically guided hierarchical self-assembly of peptide–protein bioinks." *Advanced Functional Materials* 28.16 (2018): 1703716.

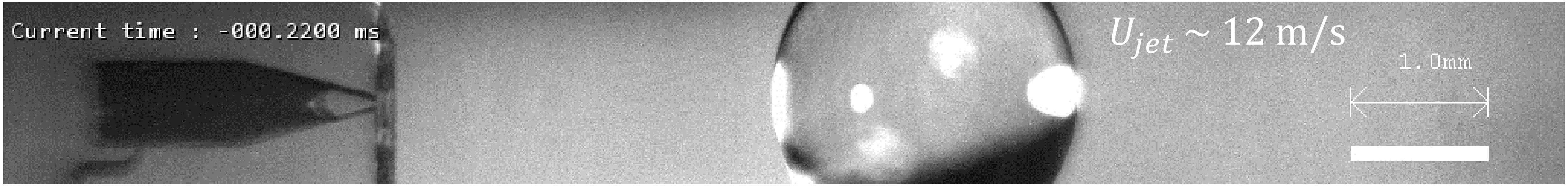


Jets impacting drops

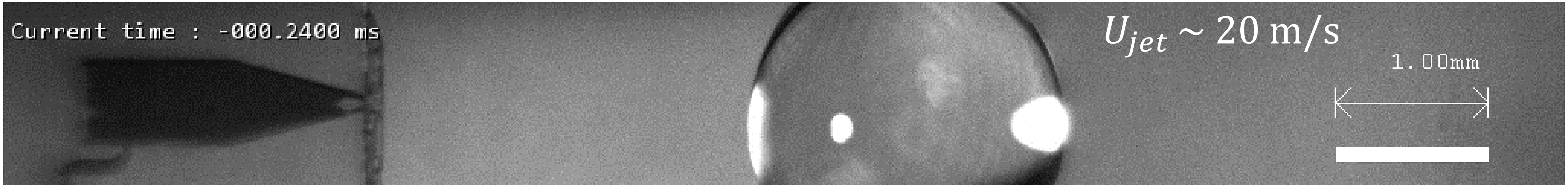


Experimental results

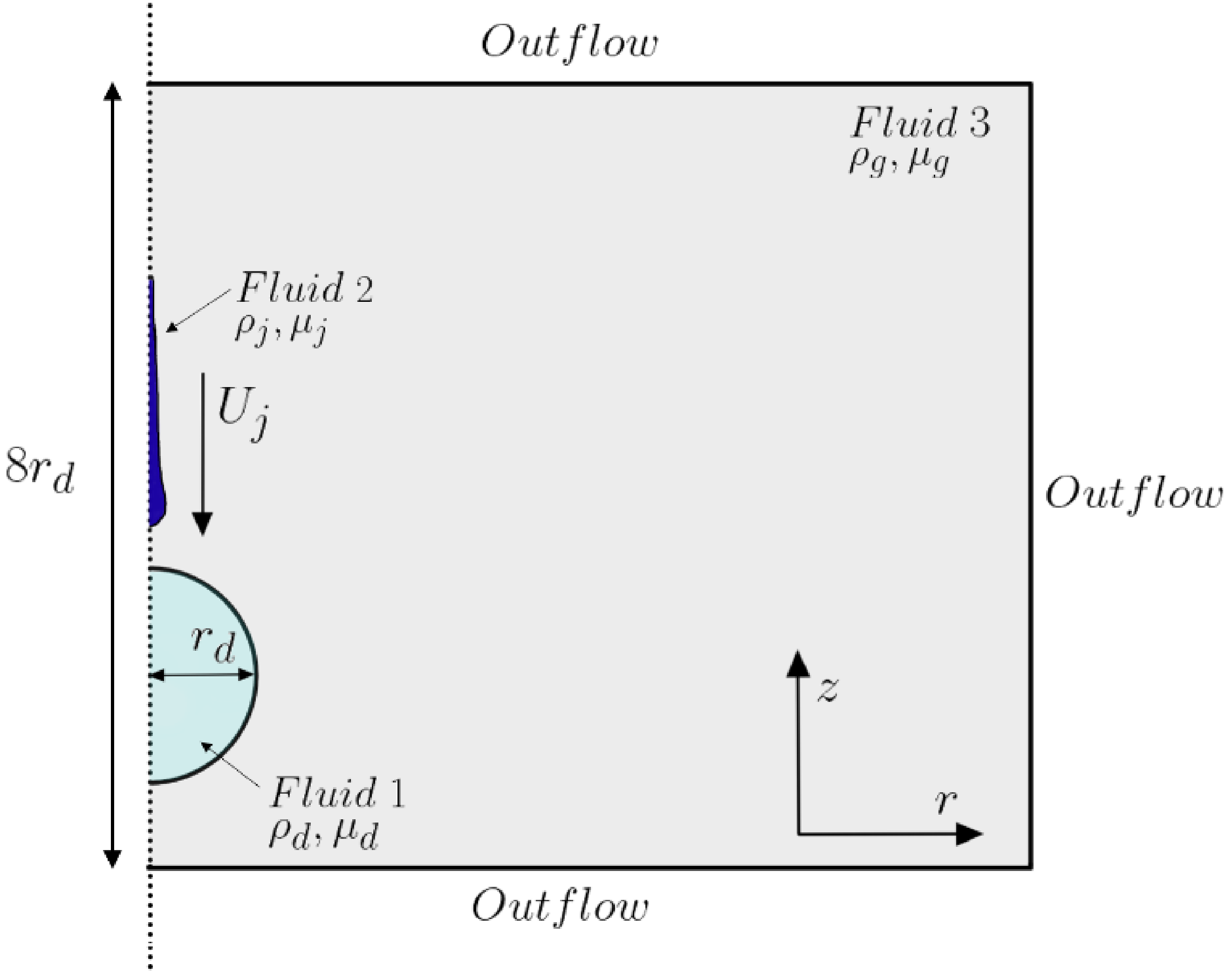
Embedding



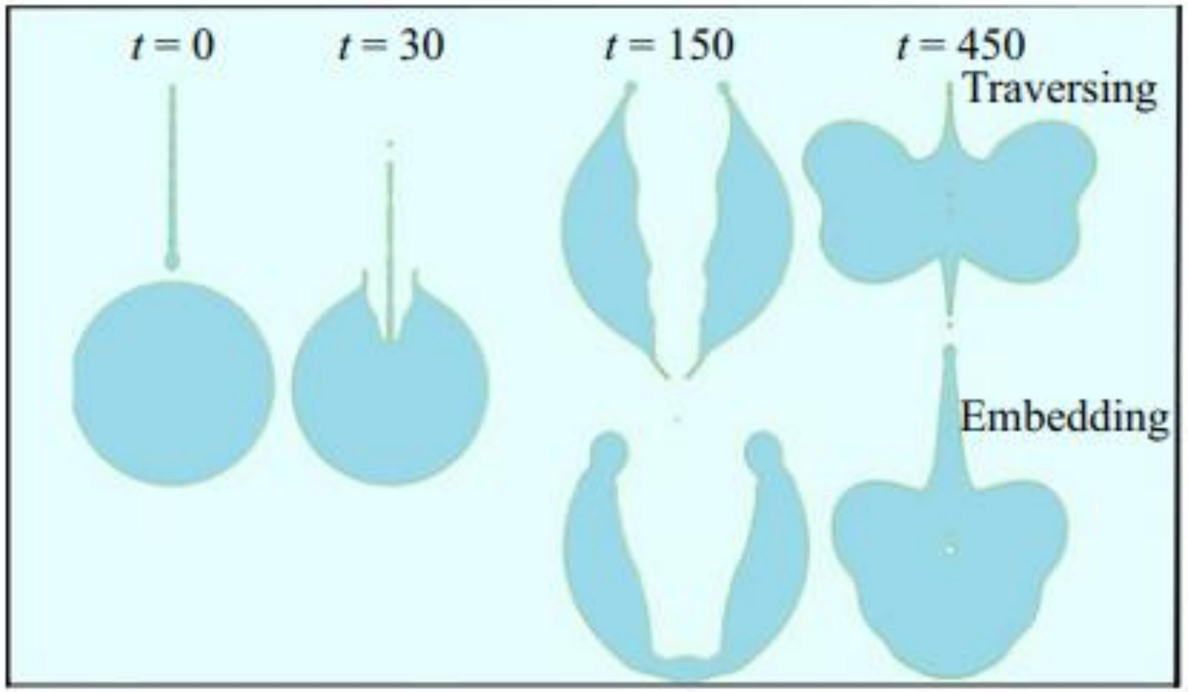
Traversing

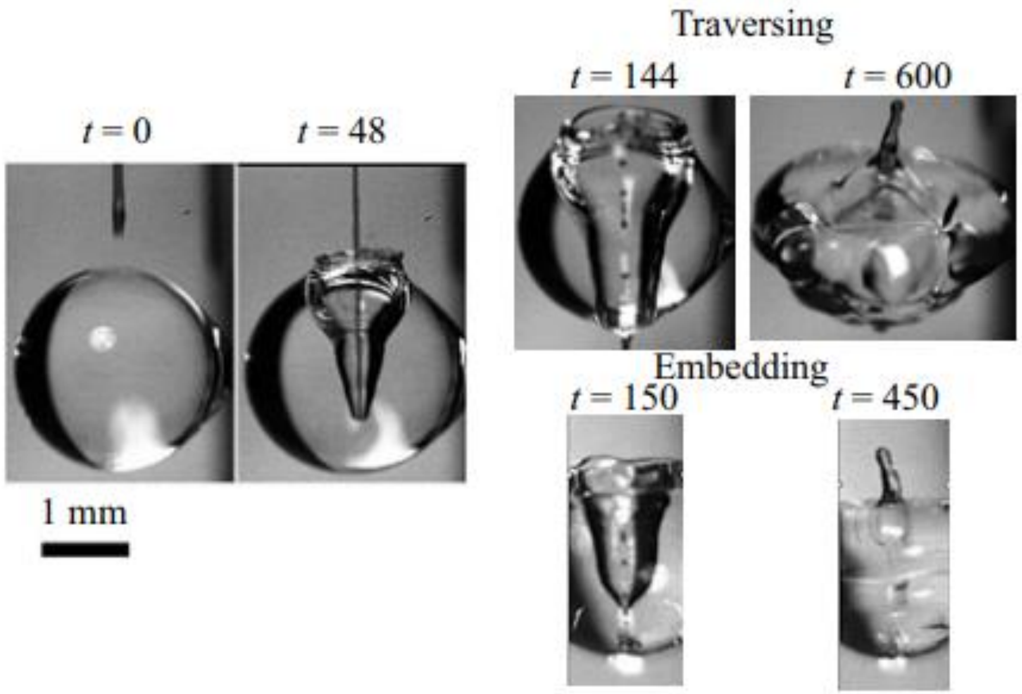


Numerical setup

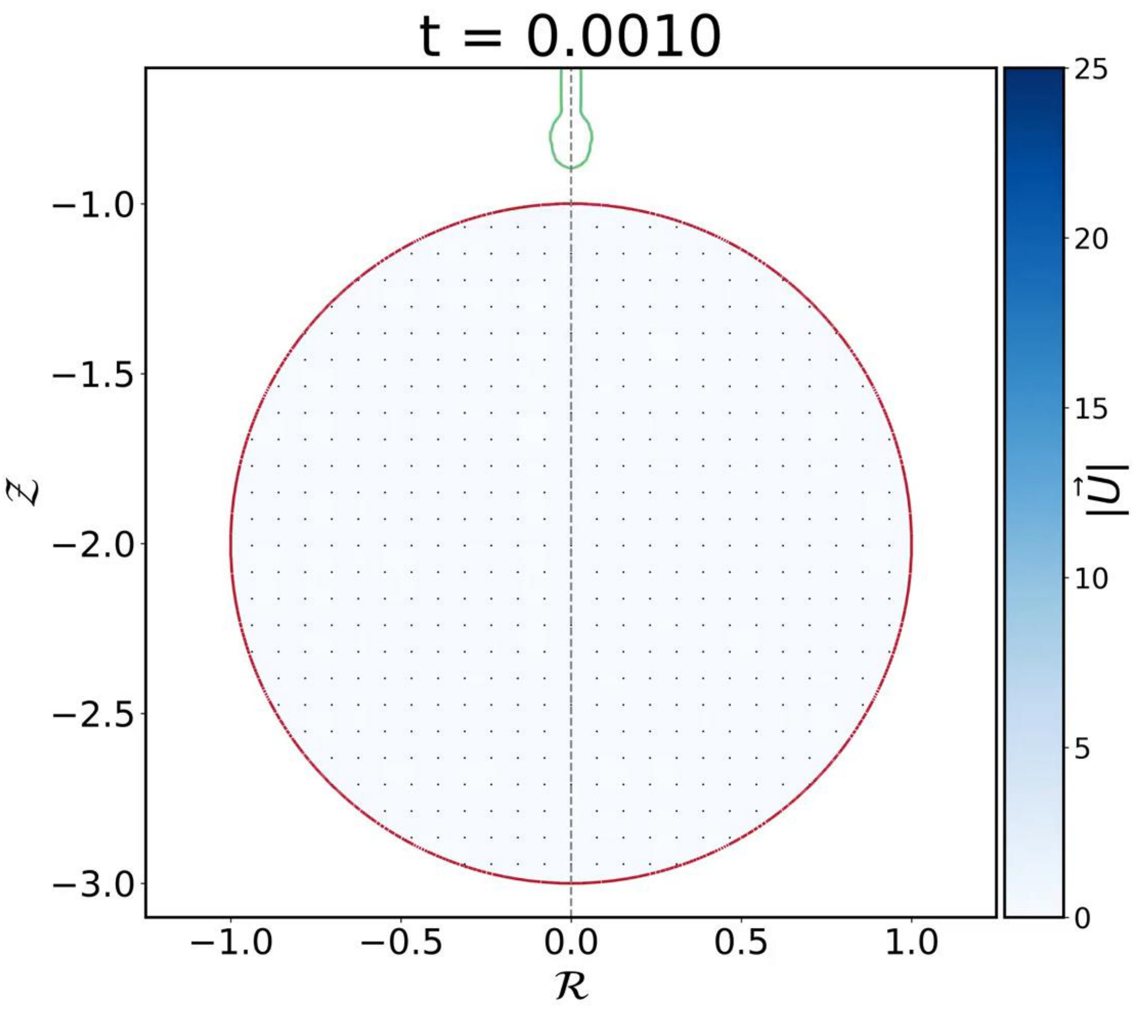


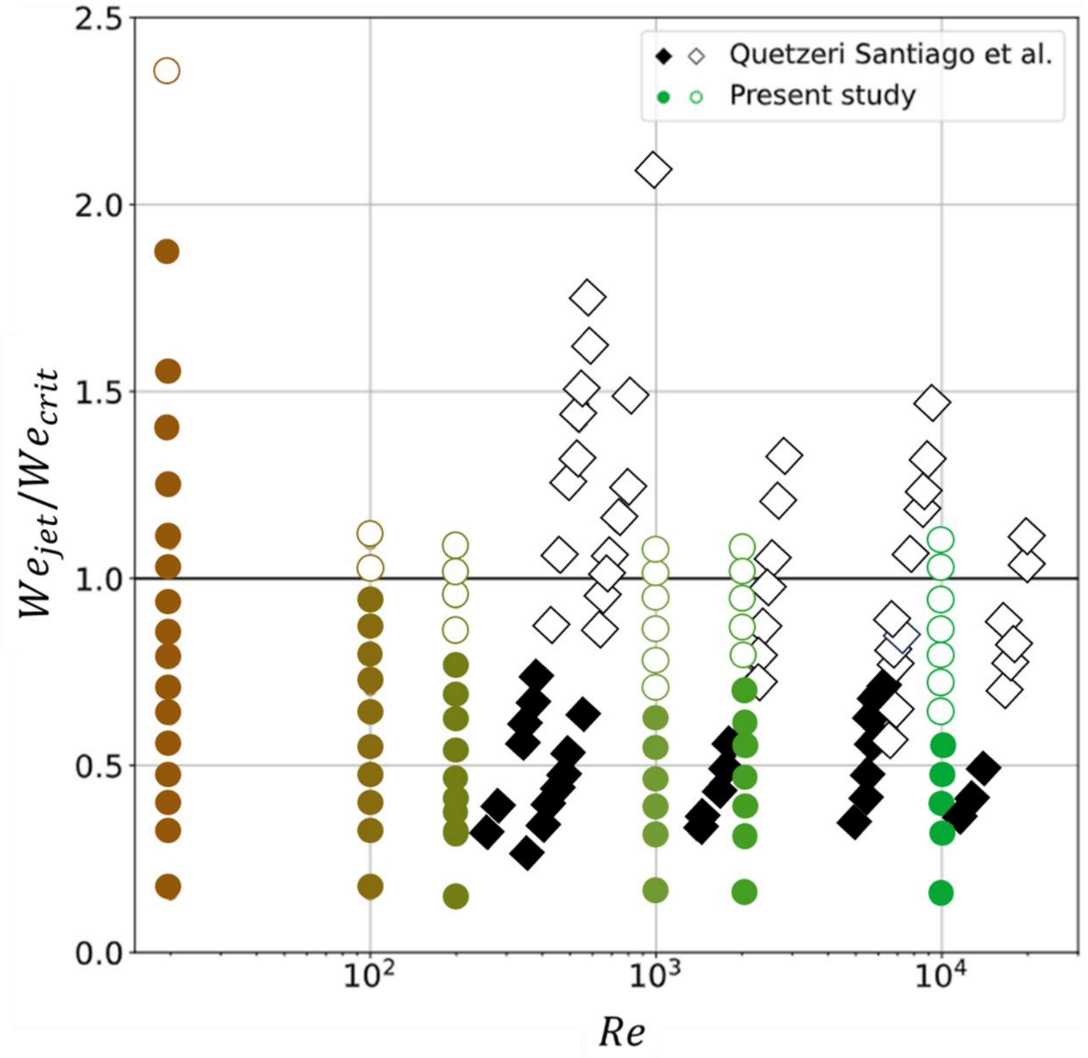
Qualitative comparison between experiments and simulations





Quantitative comparison





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Impact of a microfluidic jet on a pendant droplet†

Miguel A. Quetzeri-Santiago, *[a] Ian W. Hunter,[b] Devaraj van der Meer[c] and David Fernandez Rivas *[ab]

High speed microfluidic jets can be generated by a thermocavitation process: from the evaporation of the liquid inside a microfluidic channel, a rapidly expanding bubble is formed and generates a jet through a flow focusing effect. Here, we study the impact and traversing of such jets on a pendant liquid droplet. Upon impact, an expanding cavity is created, and, above a critical impact velocity, the jet traverses the entire droplet. We predict the critical traversing velocity (i) from a simple energy balance and (ii) by comparing the Young–Laplace and dynamic pressures in the cavity that is created during the impact. We contrast the model predictions against experiments, in which we vary the liquid properties of the pendant droplet and find good agreement. In addition, we assess how surfactants and viscoelastic effects influence the critical impact velocity. Our results increase the knowledge of the jet interaction with materials of well-known physical properties.

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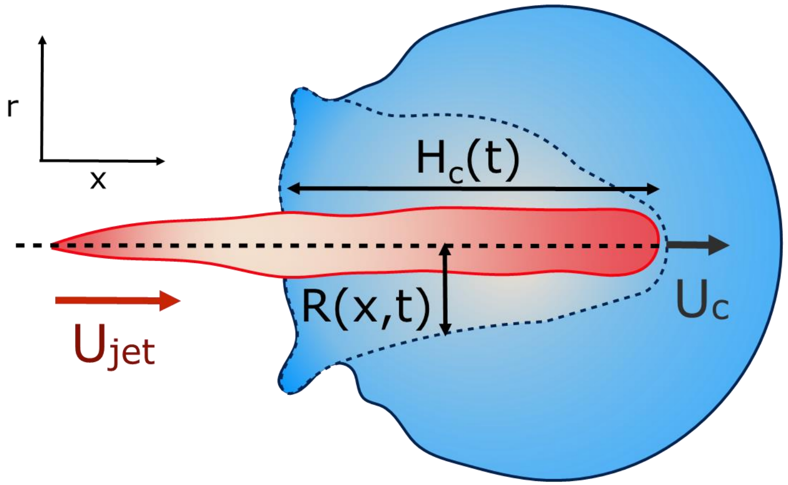
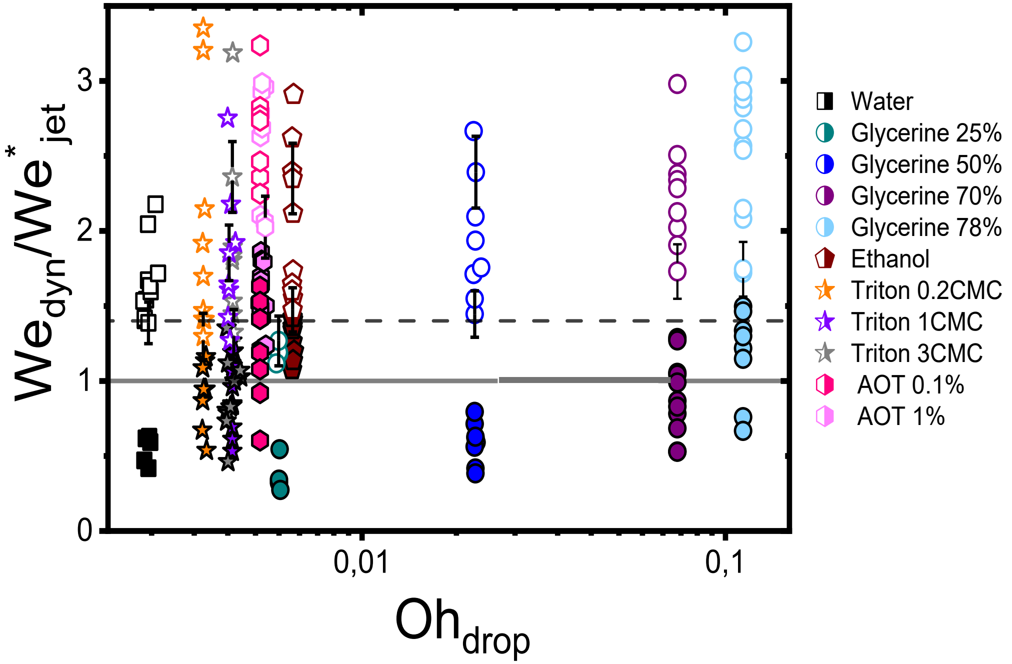
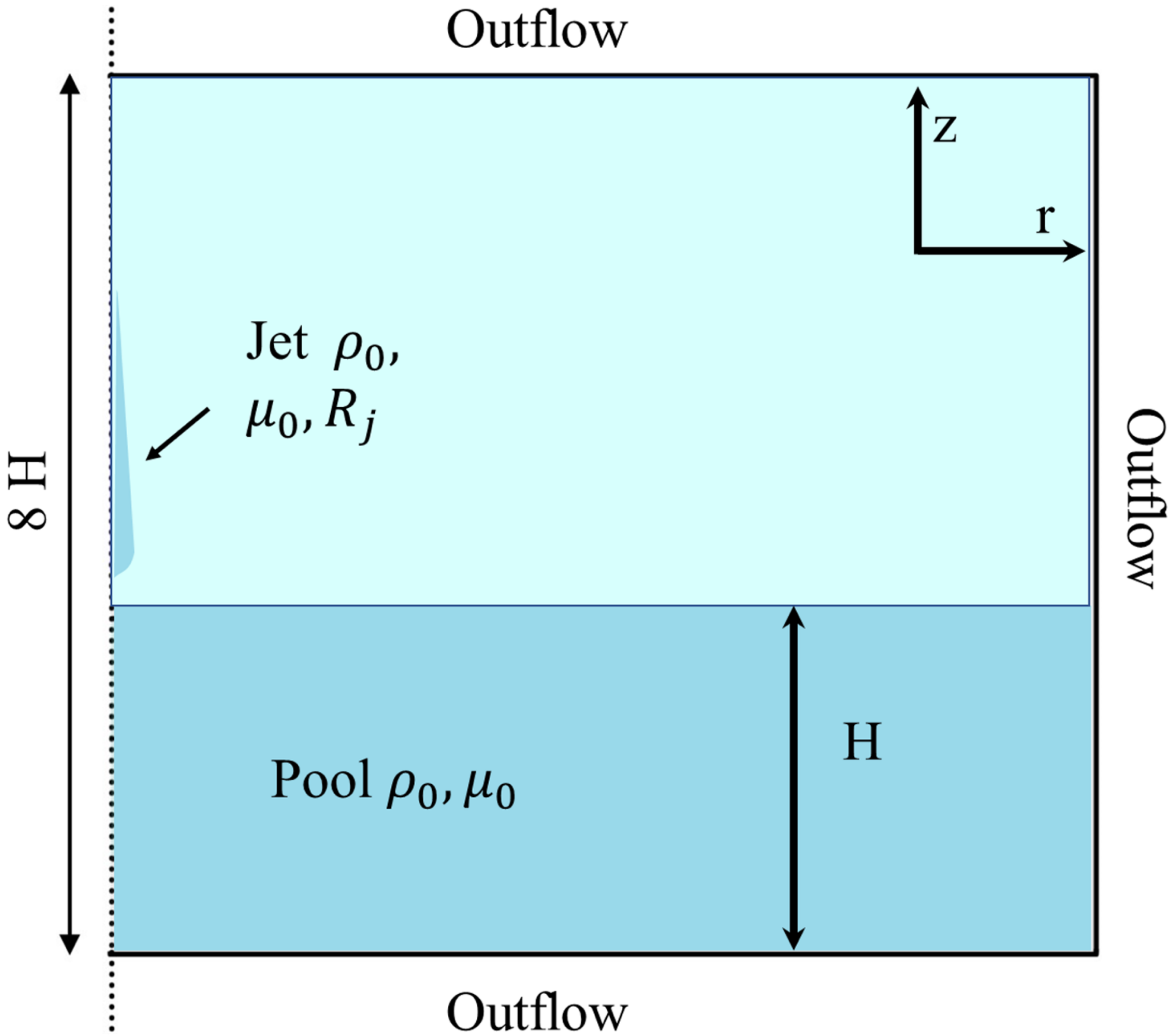




Jet impacting on pools



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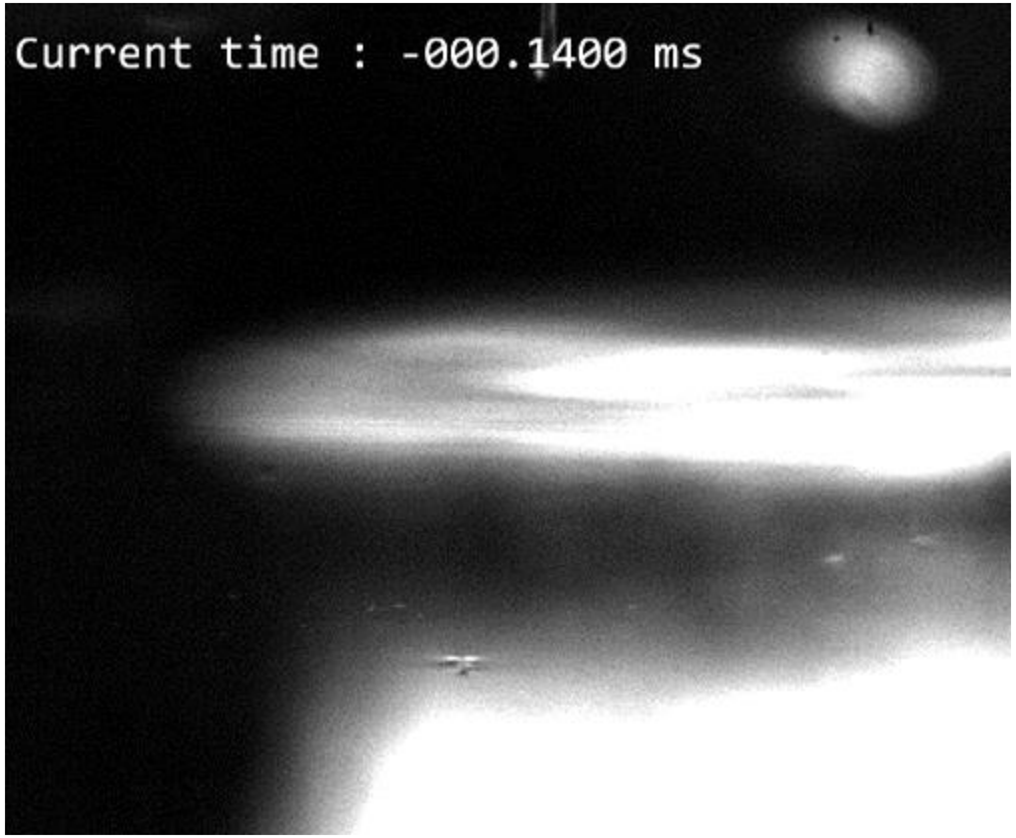
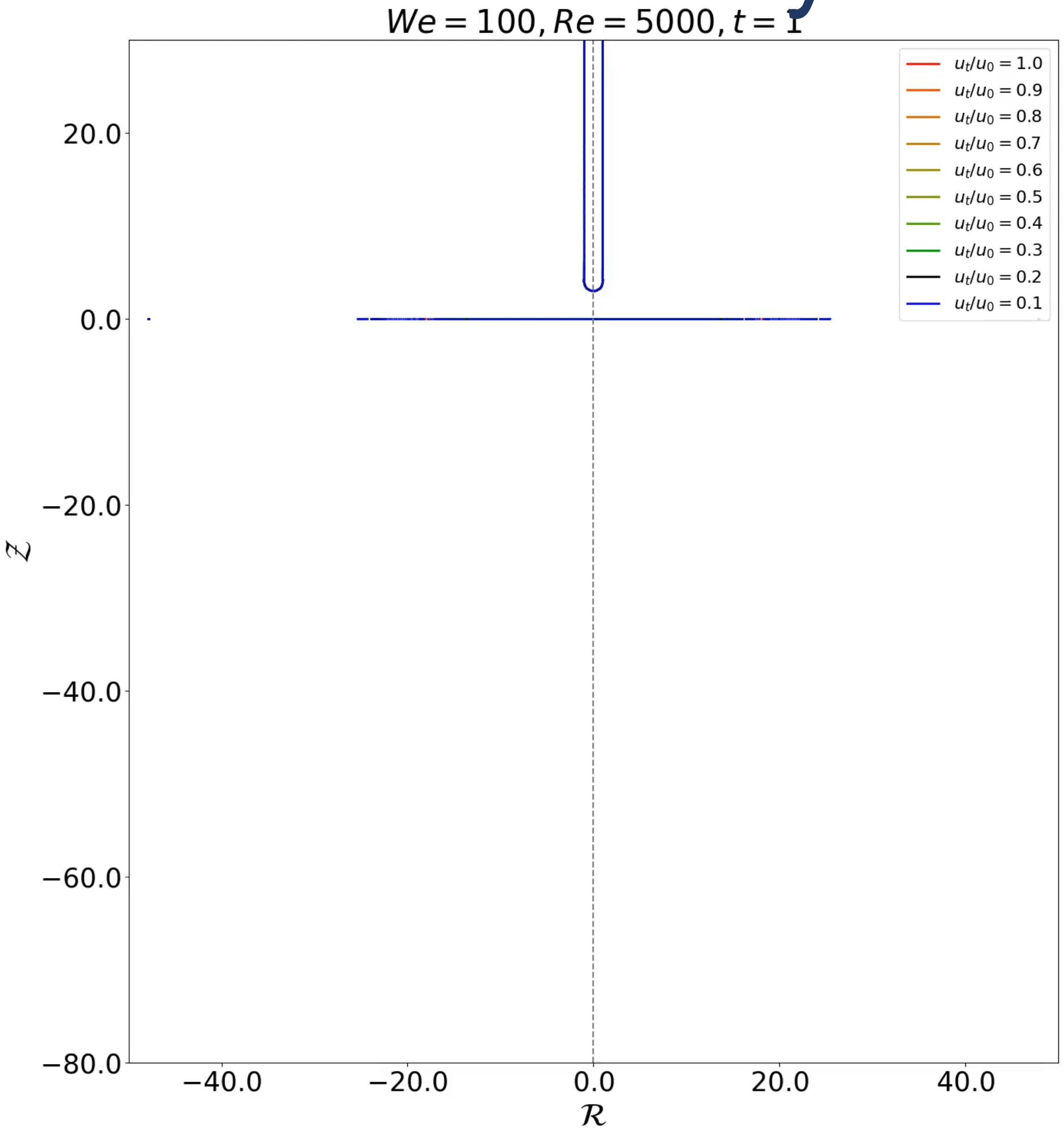
Experimental results

We = 200

We = 400

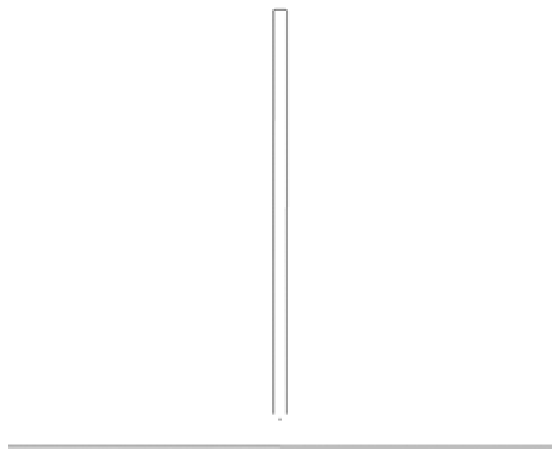


Influence of the tail velocity

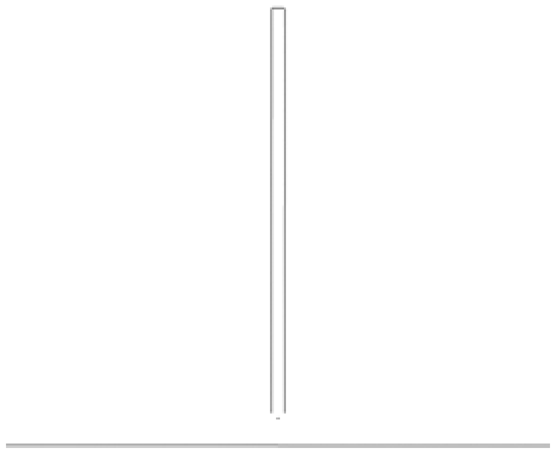


Numerical results

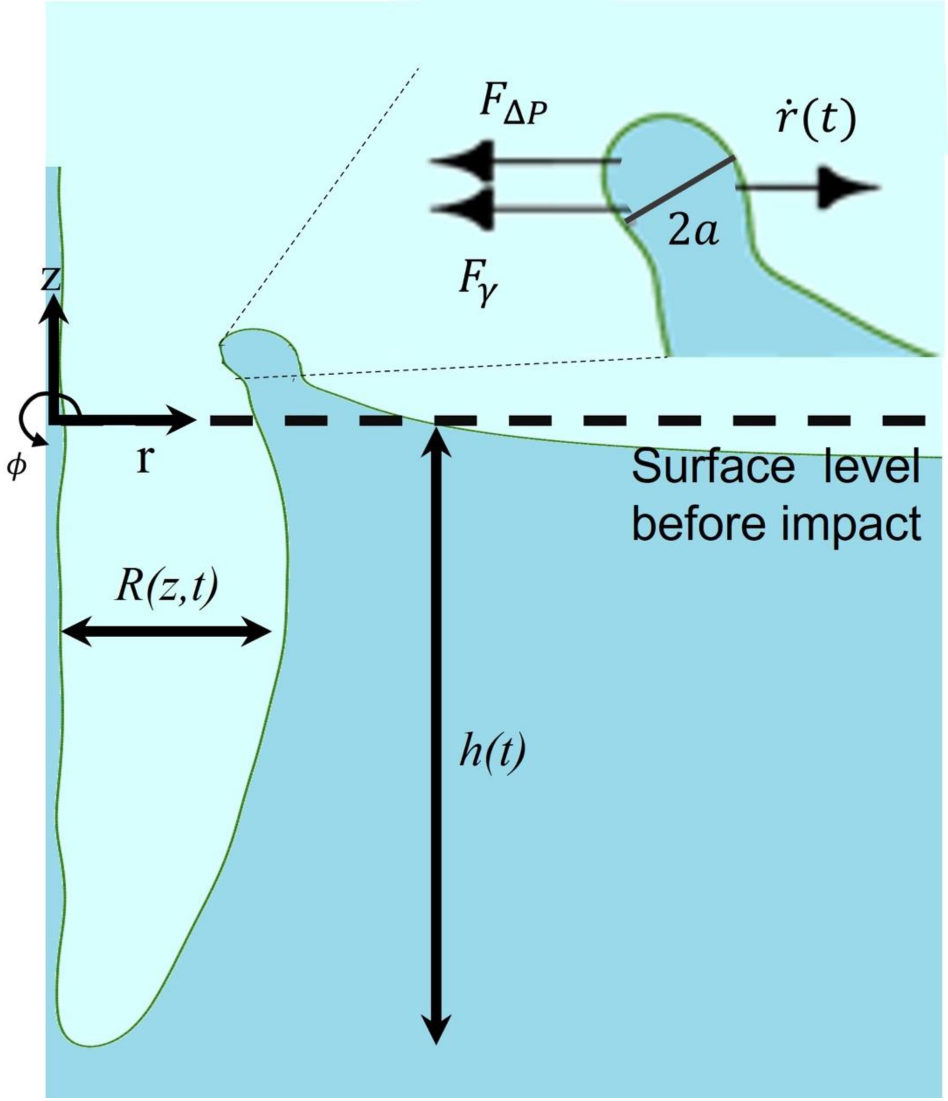
We = 150, Re = 1e4, u_t/U_0 = 0.3



We = 500, Re = 1e4, u_t/U_0 = 0.3



Model for cavity collapse



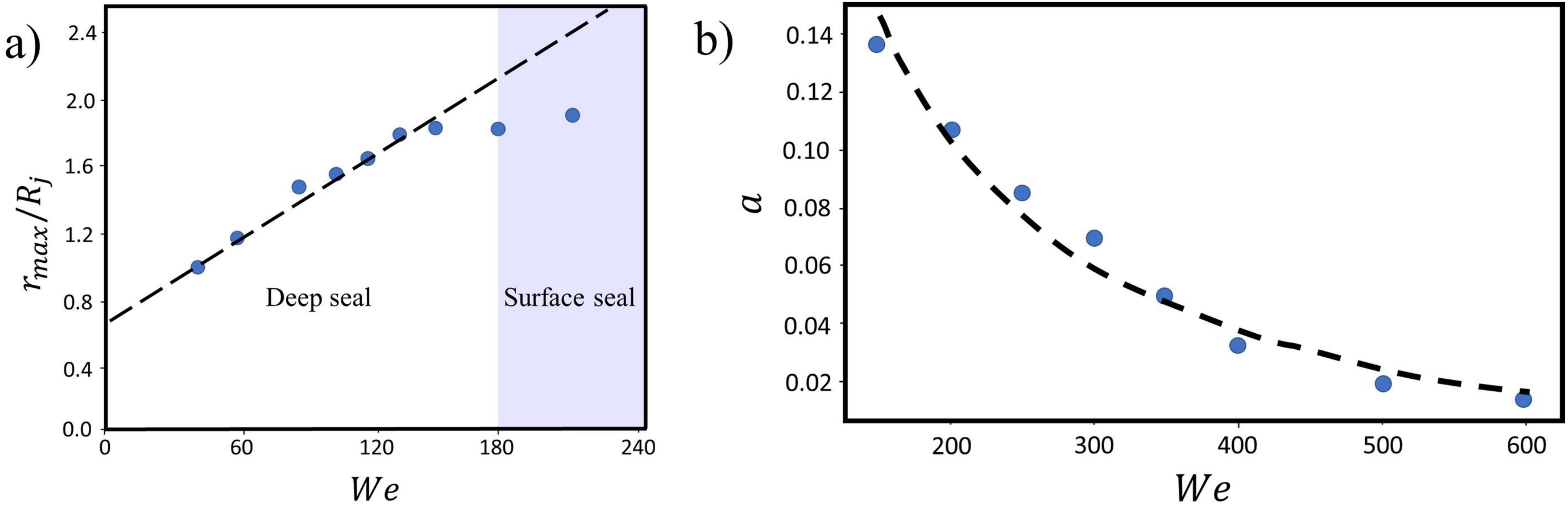
$$m\ddot{r} = F_{\Delta P} + F_\gamma = -2ar(t)d\phi\Delta P - 4\gamma a d\phi$$

$$\ddot{r} = -\frac{2\Delta P}{\rho_g \pi a} - \frac{4\gamma}{\rho_g a r(t)}$$

Using Bernoulli

$$\Delta P \approx \frac{1}{2}\rho_g u_g^2$$

$r_{max} \sim We,\ a \sim 1/We$



Régimen dominado por la tension superficial $We \sim 1$

$$\ddot{r} = -\frac{2\gamma}{\rho_0 r_{max} a_0}$$

$$r(t) = r_{max} - \frac{\gamma}{\rho_0 r_{max} a_0} t^2$$

$$t_c = \sqrt{\frac{\rho_0 r_{max}^2 a_0}{\gamma}} \qquad r_{max} \sim \frac{\rho_0 R_j^2 U_0^2}{\gamma} = R_j We \qquad t_c \sim r_{max} \sim We$$

Régimen dominado por el gradiente de presión $We \gg 1$

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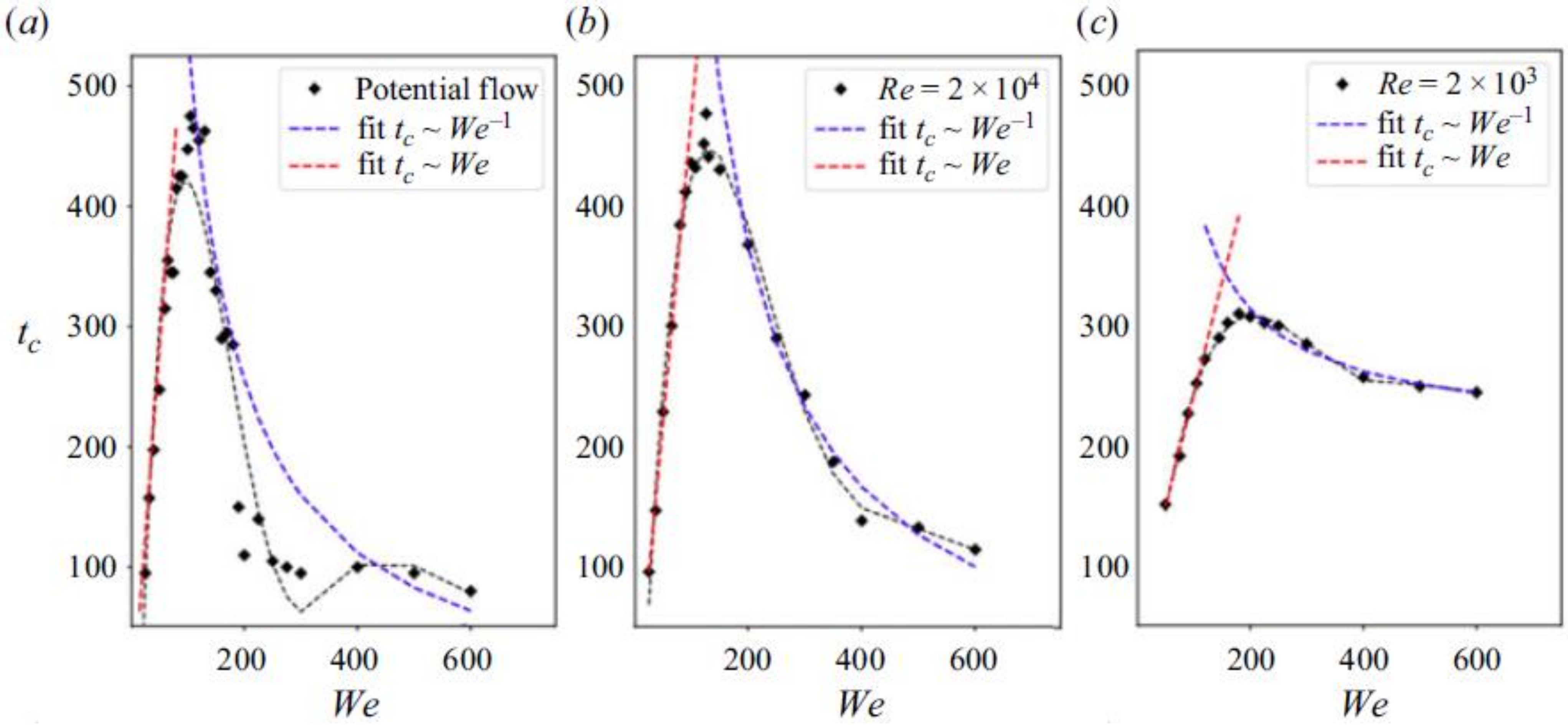
$$\ddot{r} = -\frac{2\Delta P}{\rho_g \pi a} = -\frac{u_g^2}{\pi a} = -c_1$$

$$r(t = t_c) = -\frac{1}{2} c_1 t_c^2 + \dot{r}_0 t_c + r_0 = 0$$

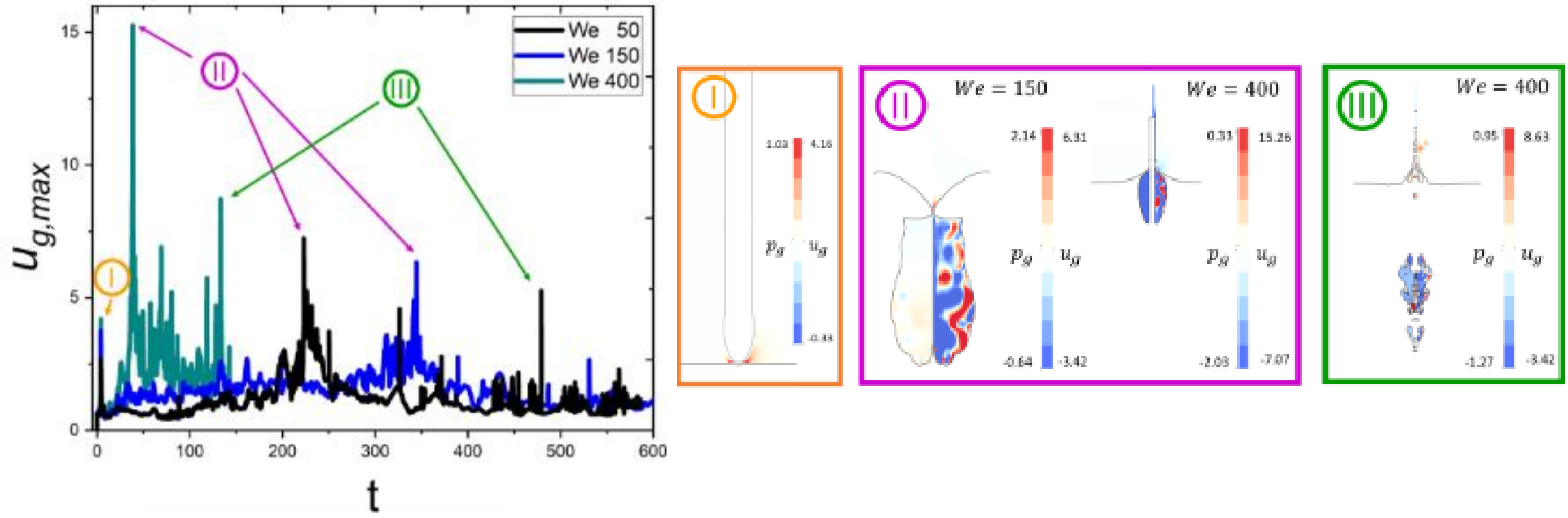
$$t_c = \frac{\dot{r}_0 \pm \sqrt{\dot{r}_0^2 + 2c_1 r_0}}{c_1} \sim \frac{\dot{r}_0 a}{u_g^2}$$

$$t_c \sim We^{-1}$$

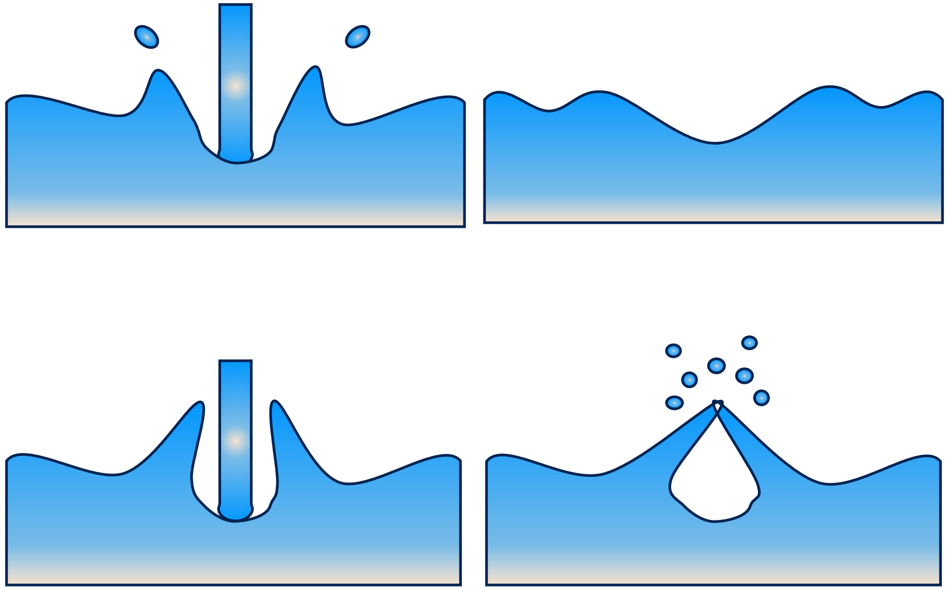
Comparison between simulations and model



Gas pressure and velocity distributions



Conclusions



- Two regimes of collapse depending on the Weber number.
- Capillary regime: $We < 150$
  $$t_c \sim r_{max} \sim We$$
- Bernoulli regime: $We > 180$
  $$t_c \sim We^{-1}$$

Aknolwedgements

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*Devaraj van der Meer
*Thijmen Kroeze

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THANK YOU!

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Microfluidic jet impacts on deep pools: transition from capillary-dominated cavity closure to gas-pressure-dominated closure at higher Weber numbers

Thijmen B. Kroeze[1], David Fernandez Rivas[1] and Miguel A. Quetzeri-Santiago[2,†]