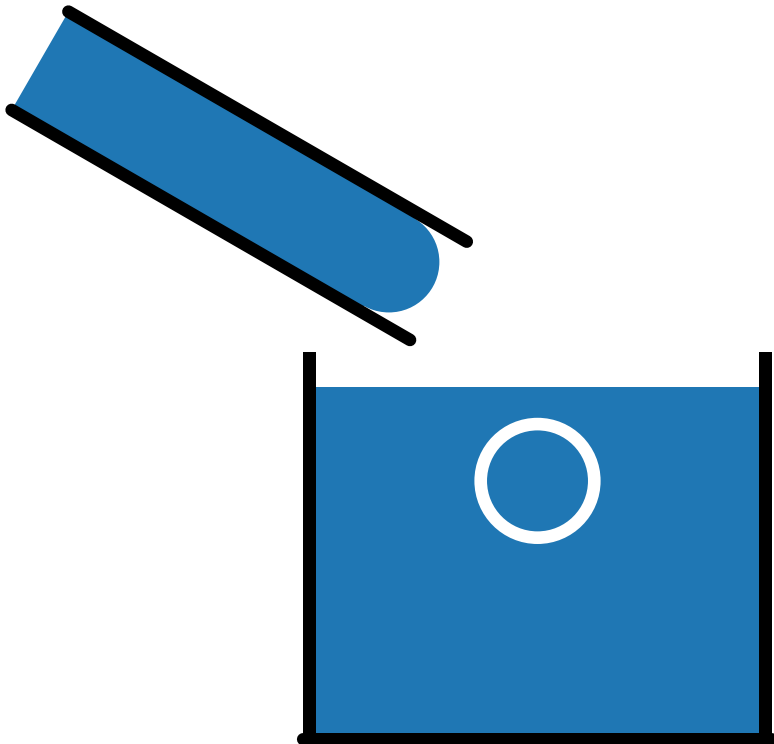


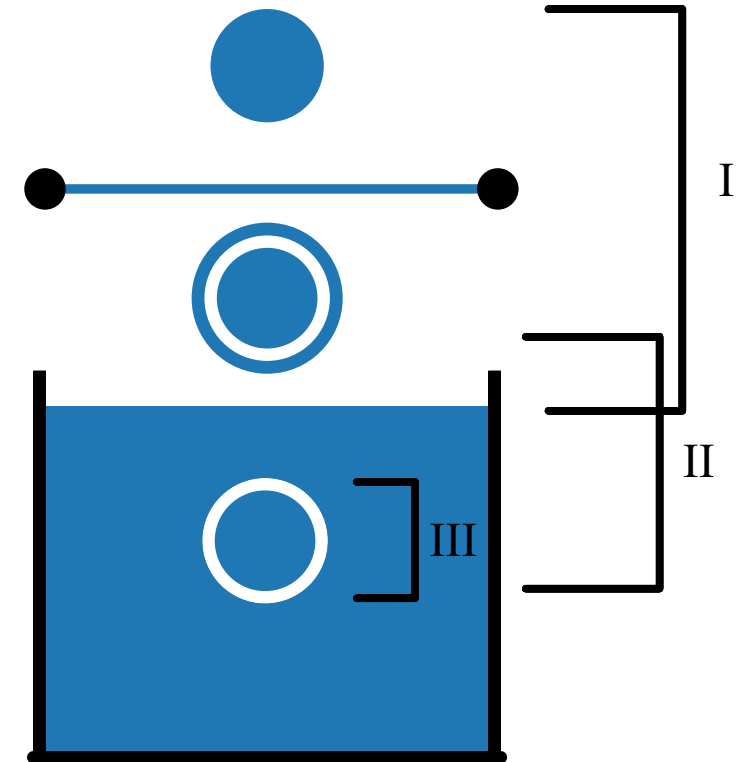
From droplets to multilayer antibubbles: formation and stability

C. André, C. Amerein, J. Miguet, B. Scheid, S. Dorbolo

Pouring method



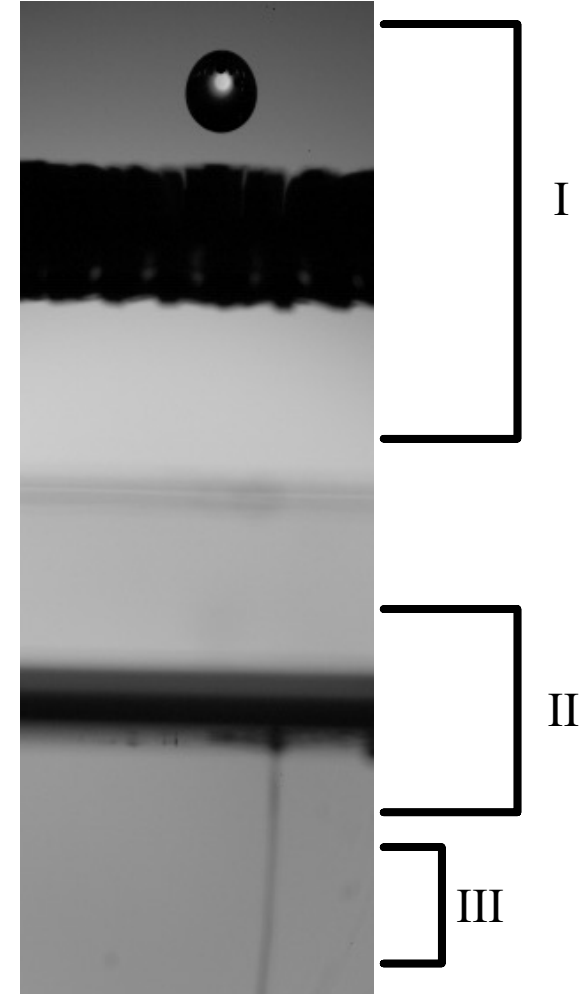
Soap film method



Pouring method

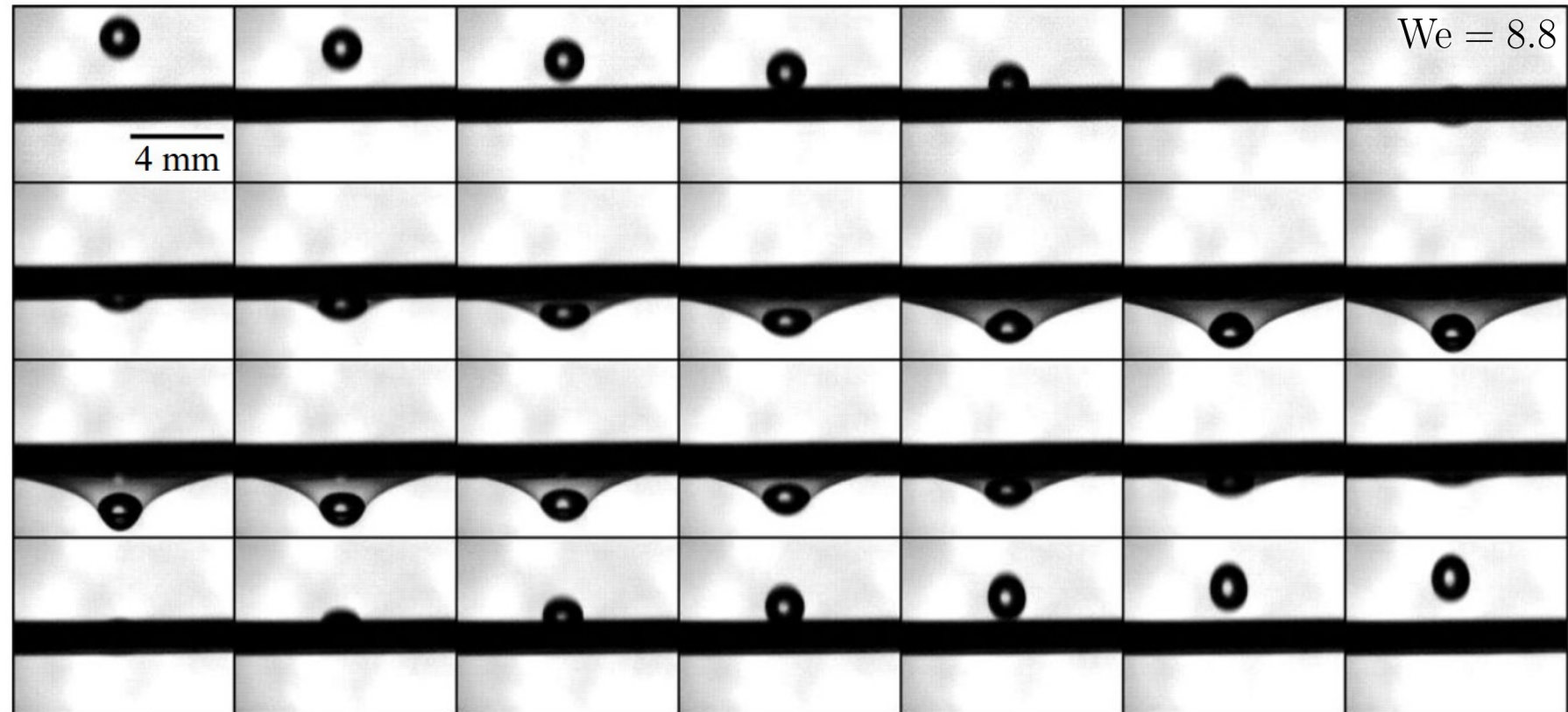
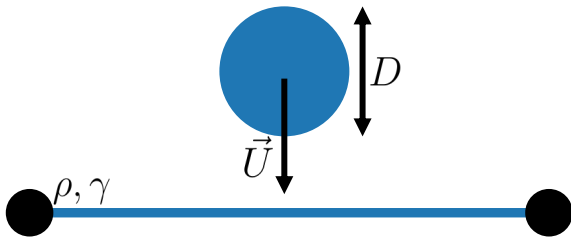


Soap film method



I. Droplet-film interaction

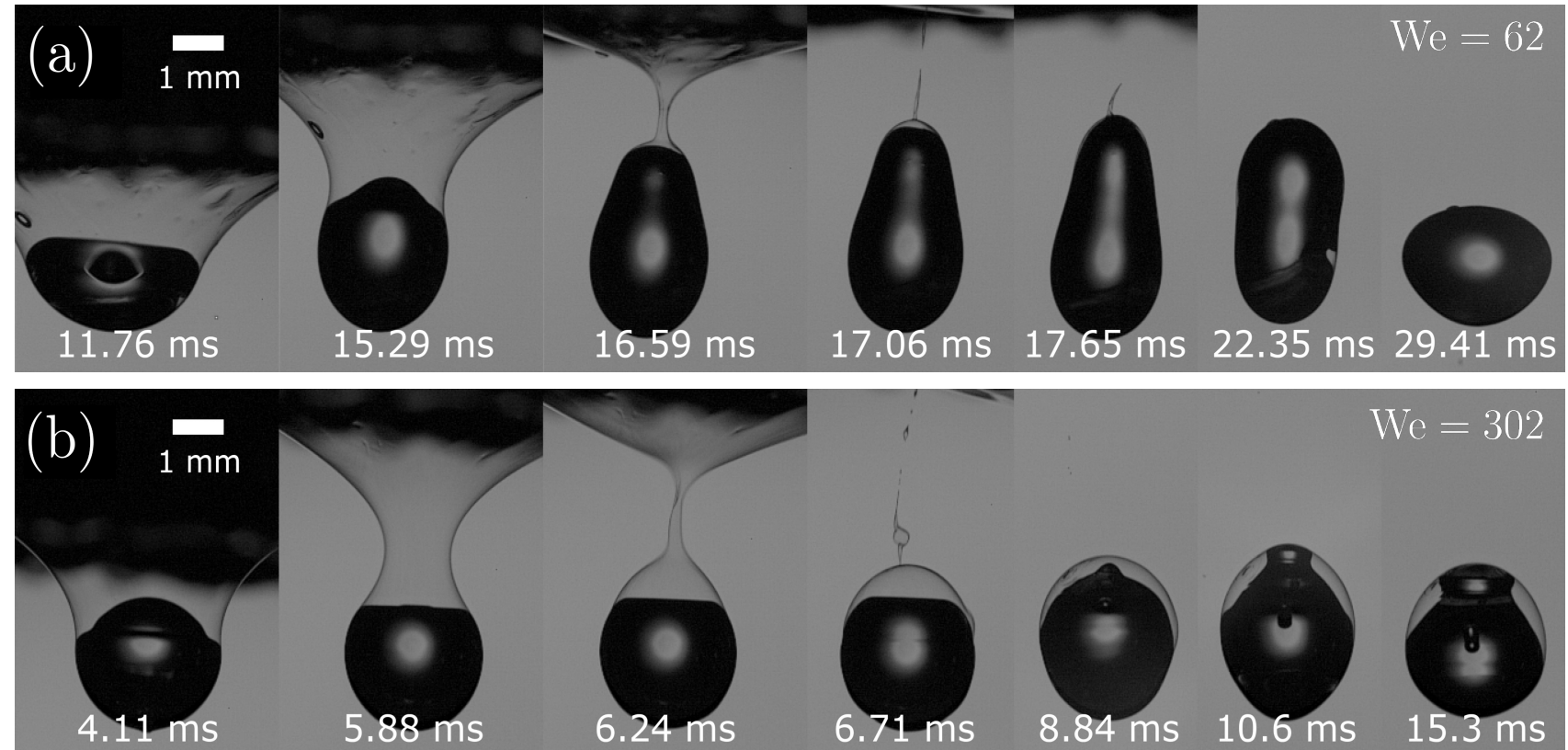
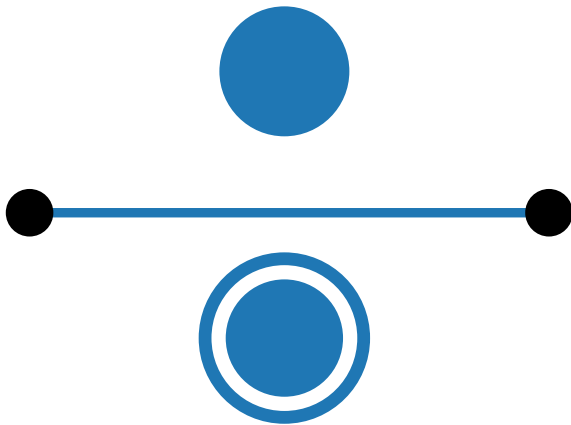
- $We = \frac{\rho U^2 D}{\gamma}$
- For small Weber:
 - Partial coalescence
 - **Bouncing**



T. Gilet and J. W.M. Bush, *The fluid trampoline: droplets bouncing on a soap film*, JFM **625**, 2009

I. Droplet-film interaction

- $We = \frac{\rho U^2 D}{\gamma}$
- For higher Weber:
 - Passing
 - **Packing** / encapsulation

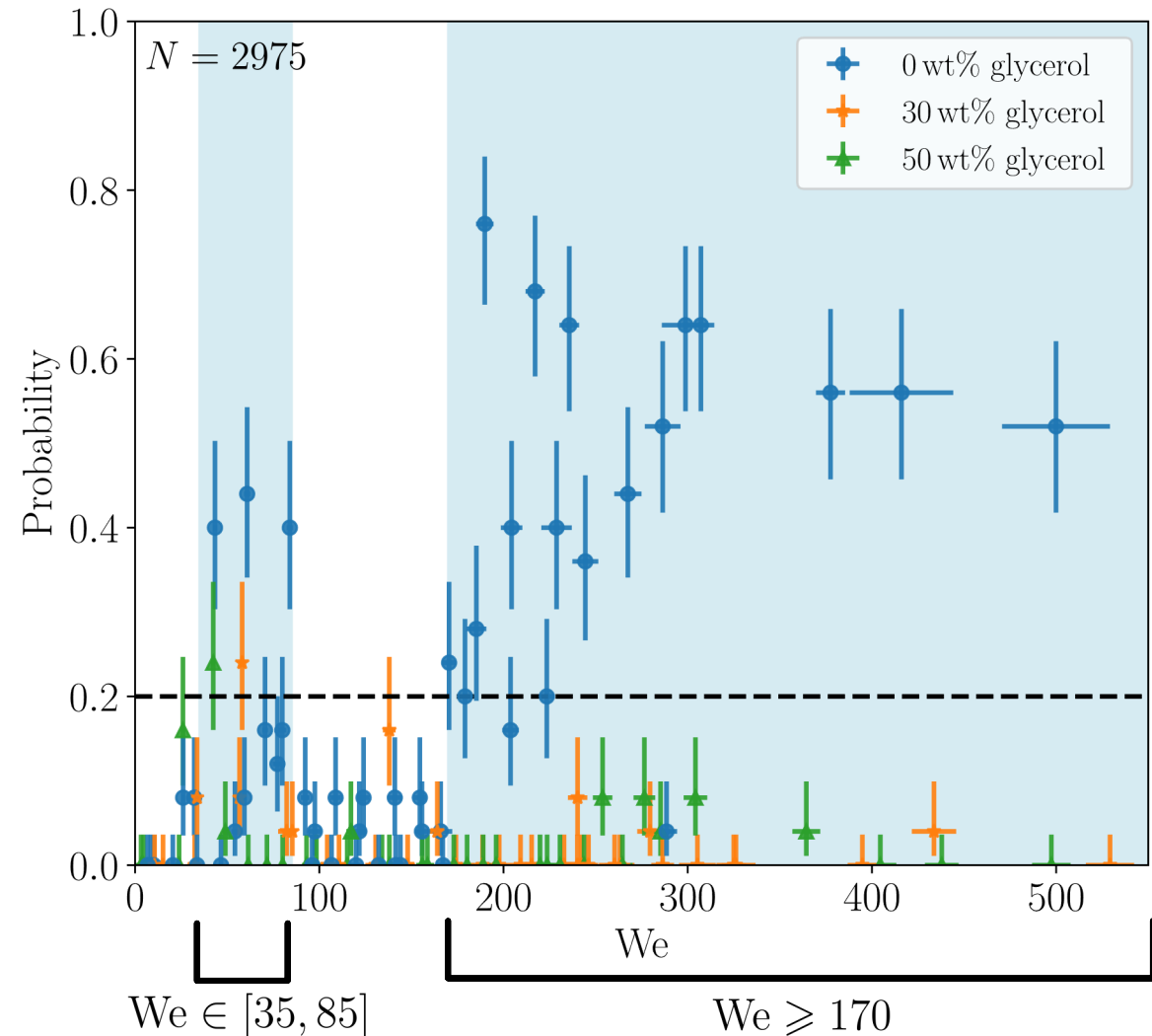


I. Droplet-film interaction

- $We = \frac{\rho U^2 D}{\gamma}$
- Probability of packing:
 - Different diameters
 - Different viscosities

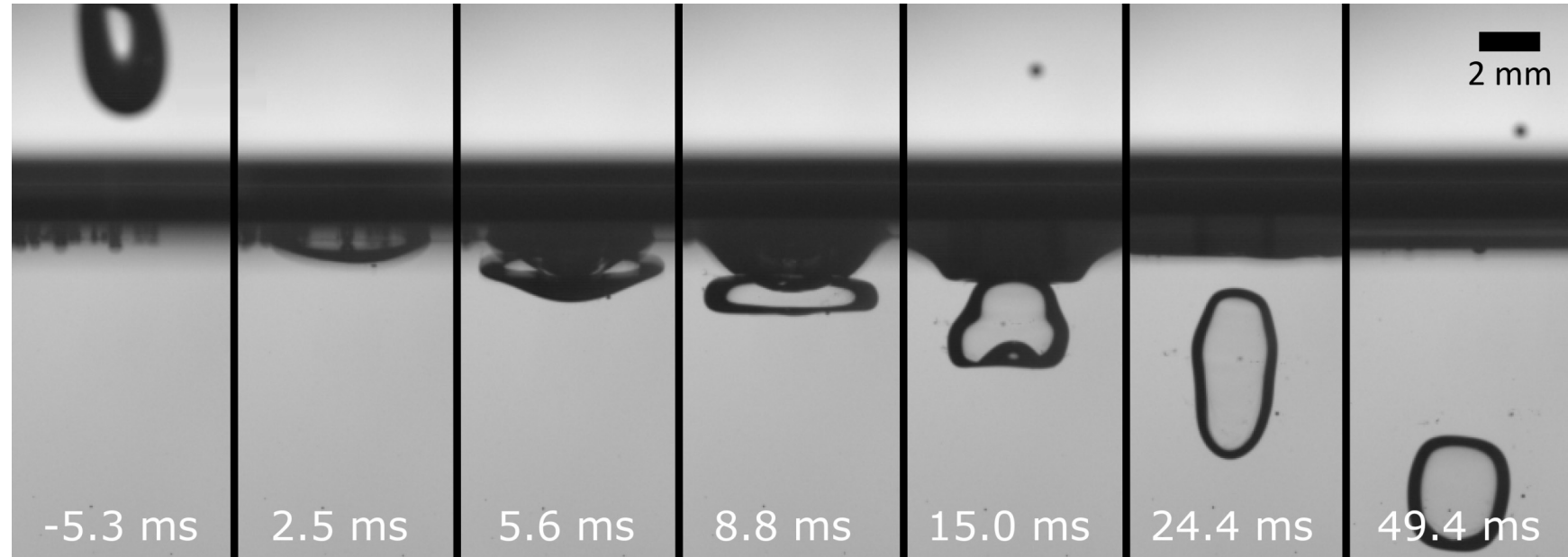
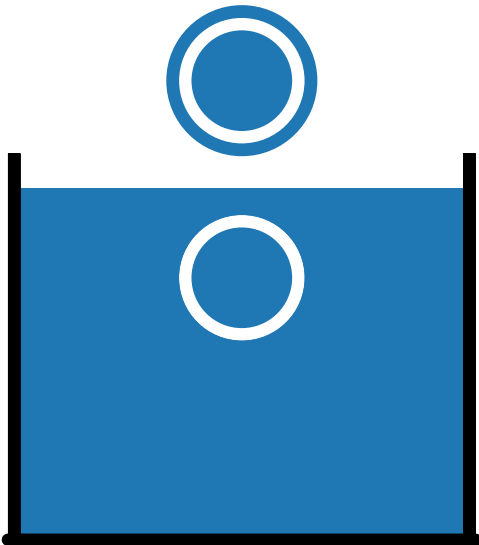
Glycerol (wt%)	γ (mN/m)	μ (mPa.s)	ρ (kg/m ³)
0	25.8	1.0	998
30	25.6	2.5	1075
50	24.4	6.0	1123

Two packing ranges
Viscosity reduces the probability



II. Antibubble formation

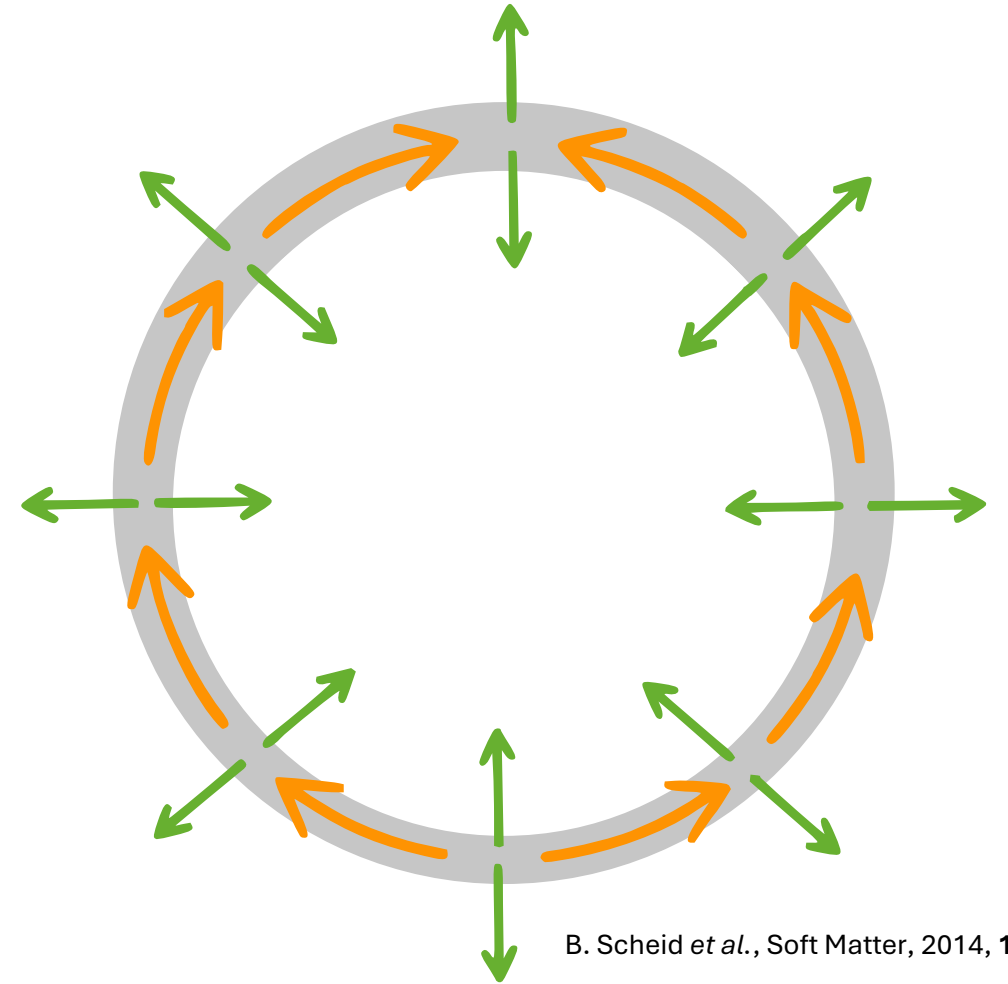
- Impact with the bath:
 - Coalescence of the outer film
 - Antibubble generation



III. Antibubble stability

- Destabilization:

- Dissolution
- Drainage: $\Delta p = \rho g(2R)$



B. Scheid *et al.*, *Soft Matter*, 2014, **10**, 7096

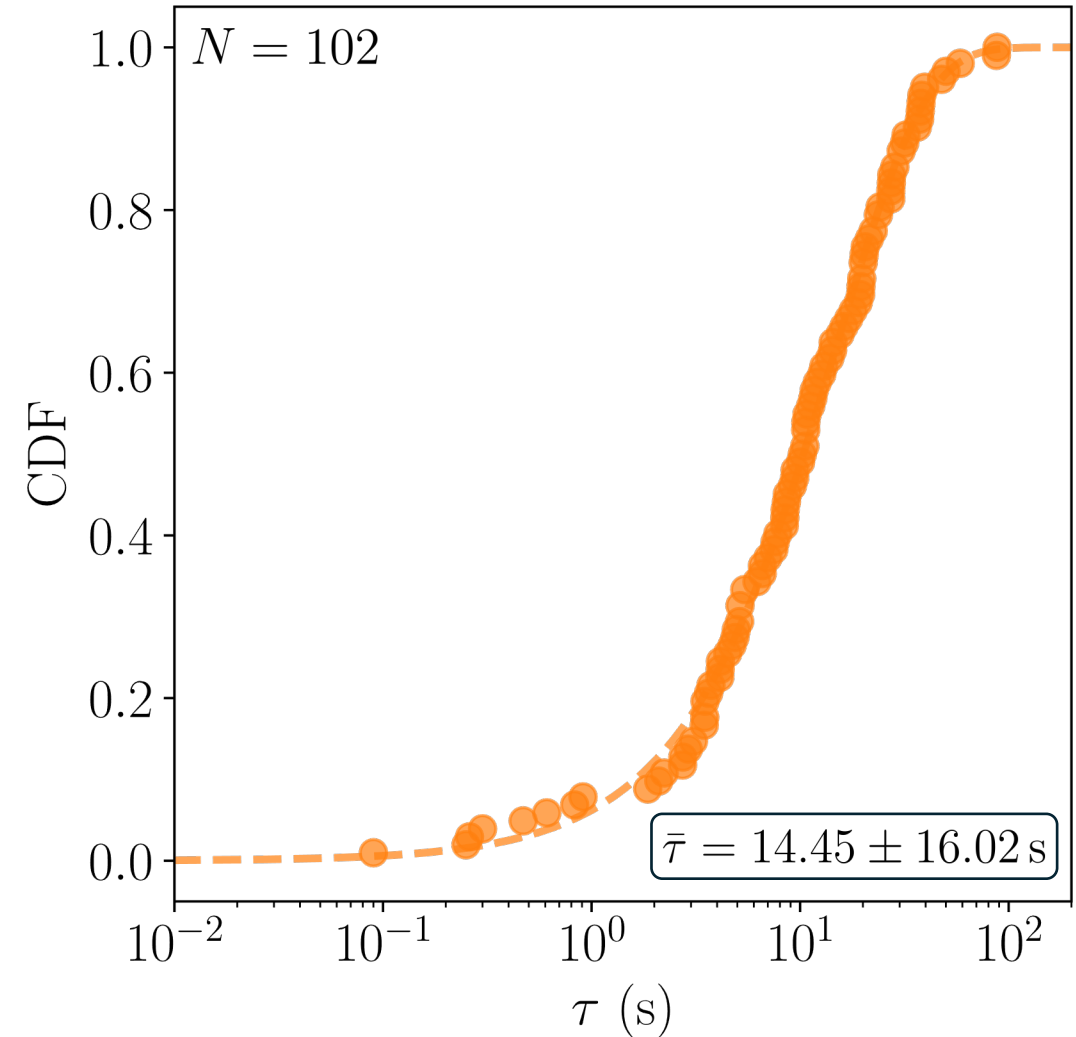
III. Antibubble stability

- Destabilization:
 - Dissolution
 - Drainage: $\Delta p = \rho g(2R)$

- Weibull distribution:

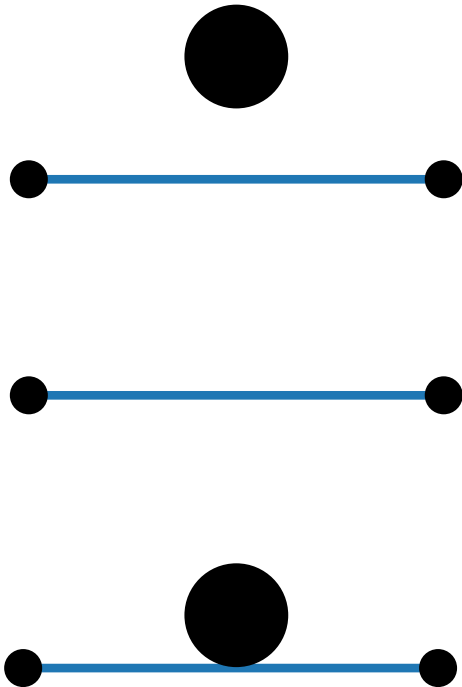
$$F(\tau) = \begin{cases} 1 - e^{-(\tau/\lambda)^k} & , \quad \tau \geq 0 \\ 0 & , \quad \tau < 0 \end{cases}$$

Markovian behavior: constant collapse rate ($k = 1$)



I'. Multilayer packings

Hard spheres



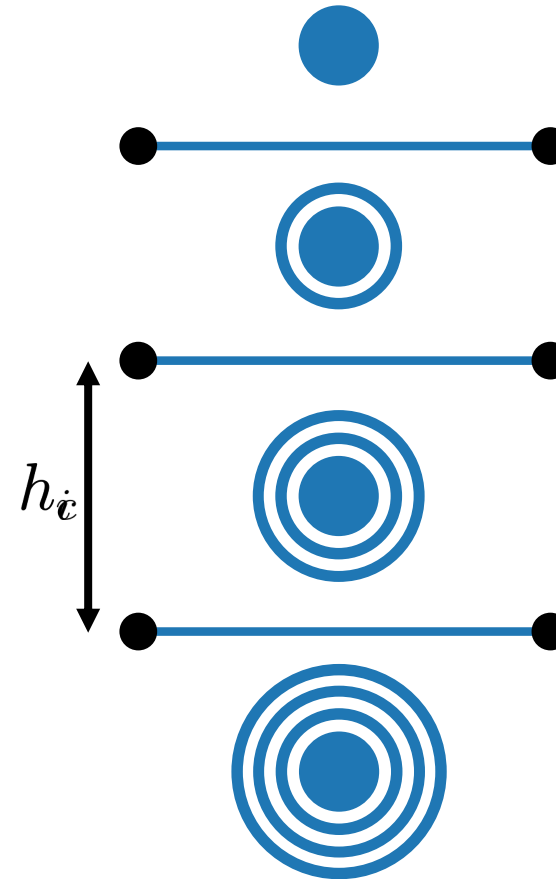
- Energy balance:

$$12\gamma R^2 \approx mgh$$

- Passing a film:

$$\Delta z \approx \frac{9\gamma}{\rho g R}$$

Droplets



- Energy balance:

$$24\gamma R^2 \approx mgh$$

- Passing a film:

- $h_c \approx \frac{18\gamma}{\rho g R}$

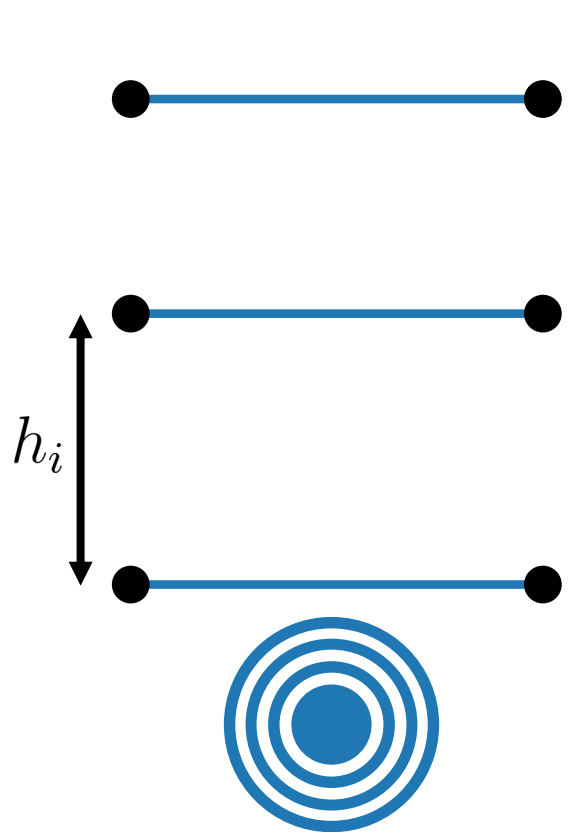
- $\Delta We \in [40, 70]$

- Condition for packing:

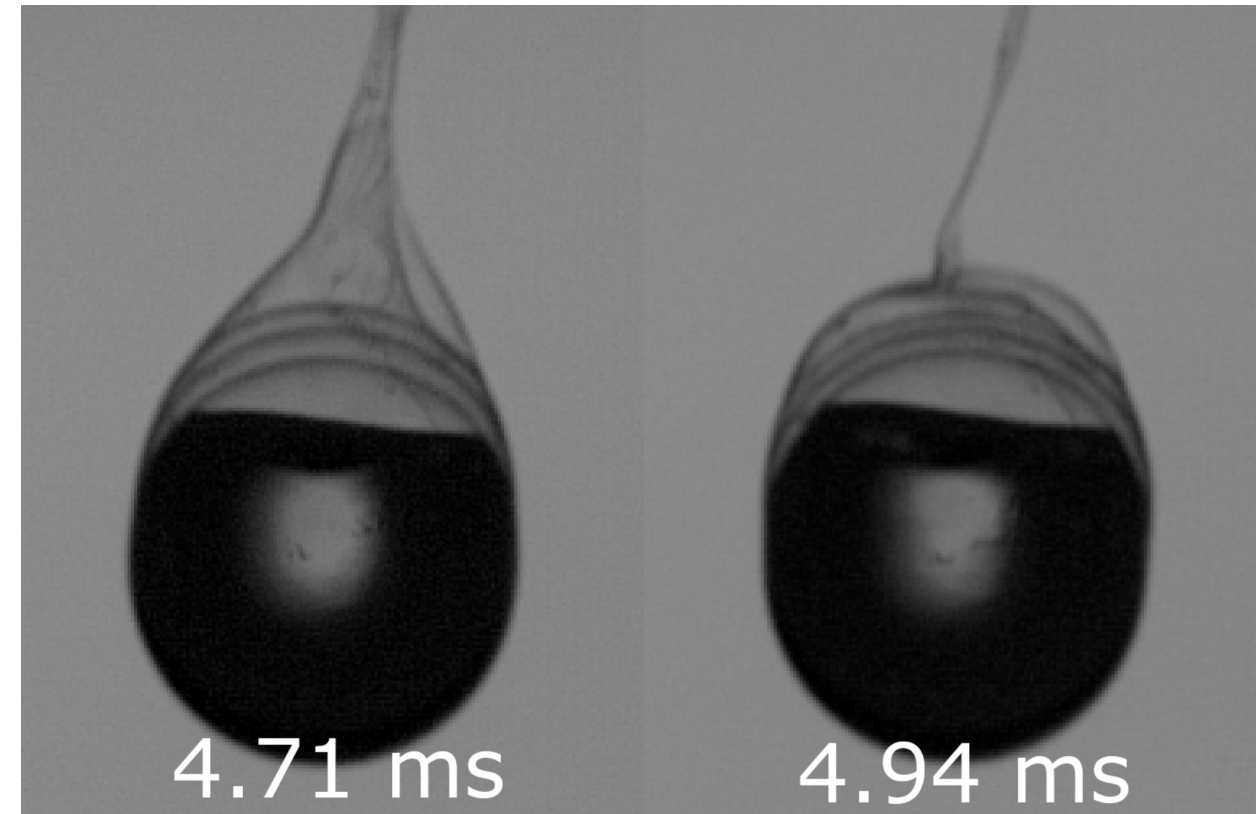
$$h_i = \Delta We \frac{\gamma}{2\rho g D}$$

I'. Multilayer packings

Droplets

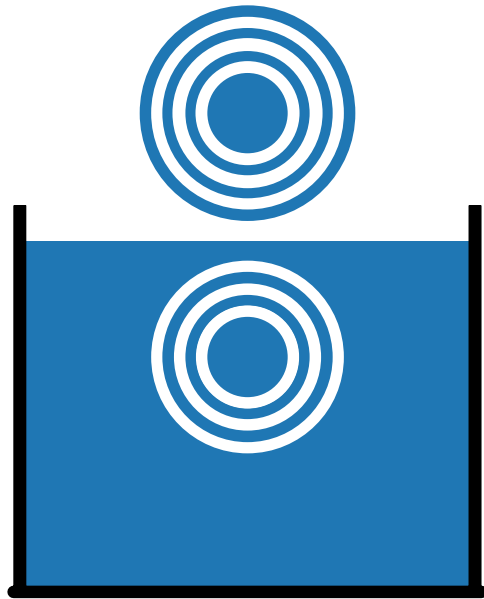


- Energy balance:
$$24\gamma R^2 \approx mgh$$
- Passing a film:
 - $h_c \approx \frac{18\gamma}{\rho g R}$
 - $\Delta We \in [40, 70]$
- Condition for packing:
$$h_i = \Delta We \frac{\gamma}{2\rho g D}$$

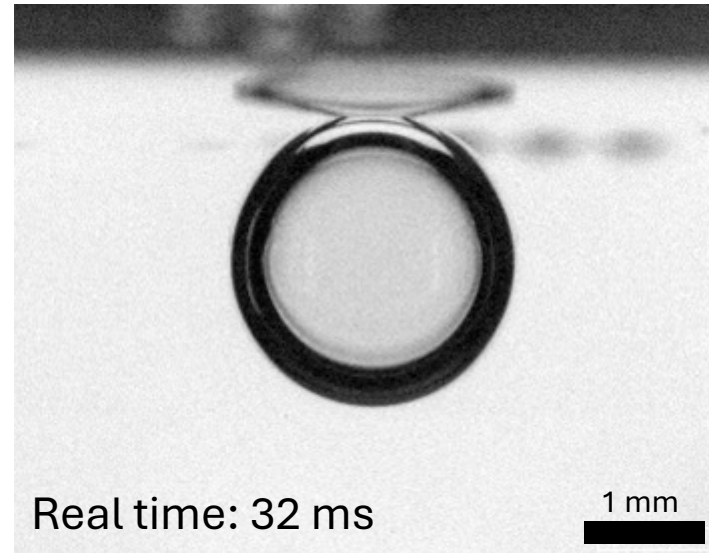


II'. Multilayer antibubbles

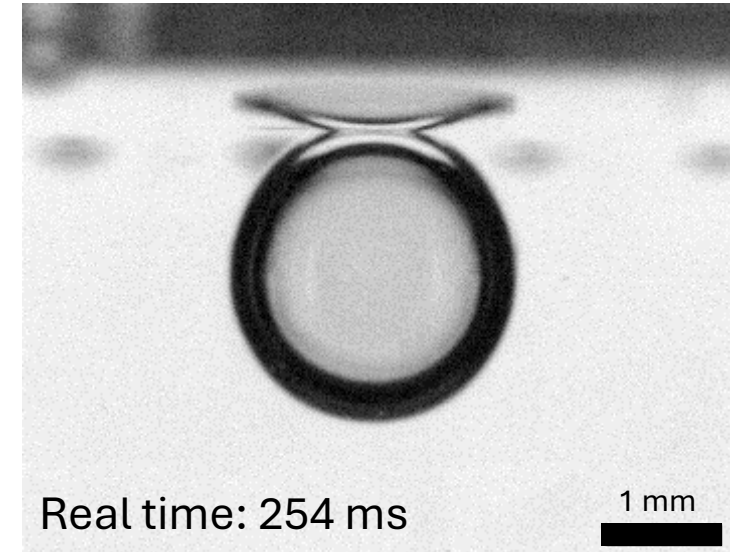
- Impact with the bath:
 - Outer film coalescence
 - Multilayer antibubble



One-layer

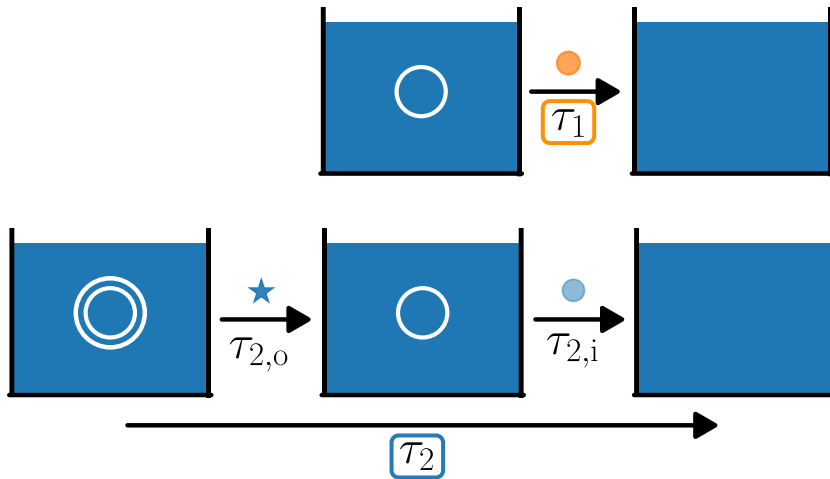


Two-layers



III'. Stability

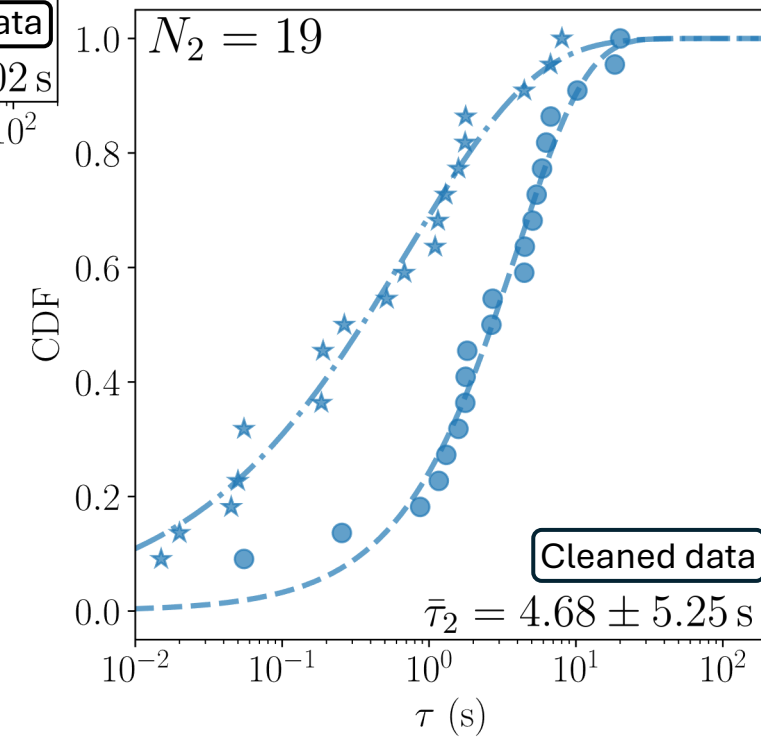
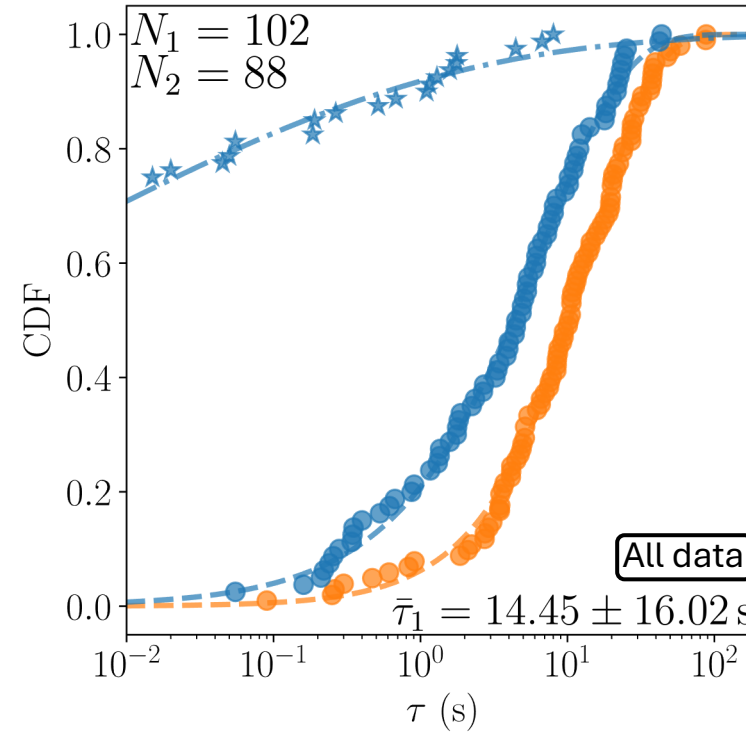
- Summary



- Multilayers antibubbles have a shorter lifetime

Outer layer: decreasing collapse rate ($k_{2,o} = 0.5$)

Inner layer: constant collapse rate ($k_{2,i} = 0.9$)

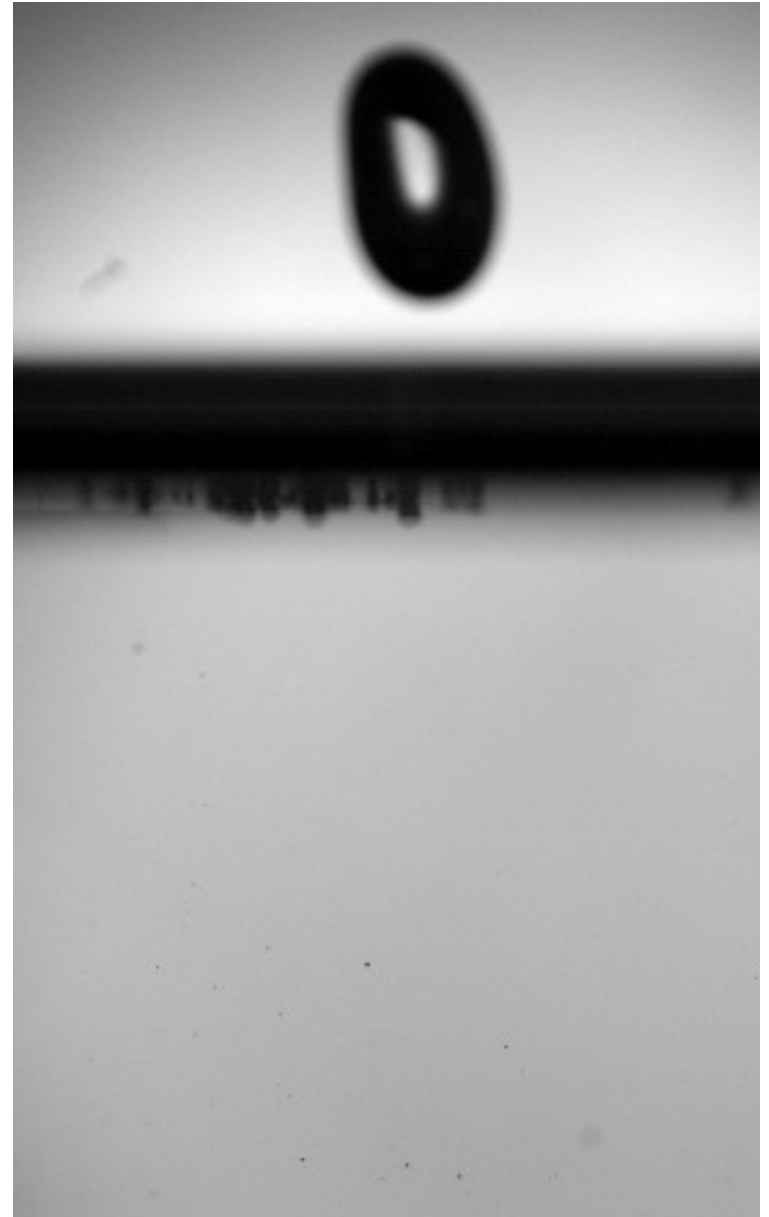


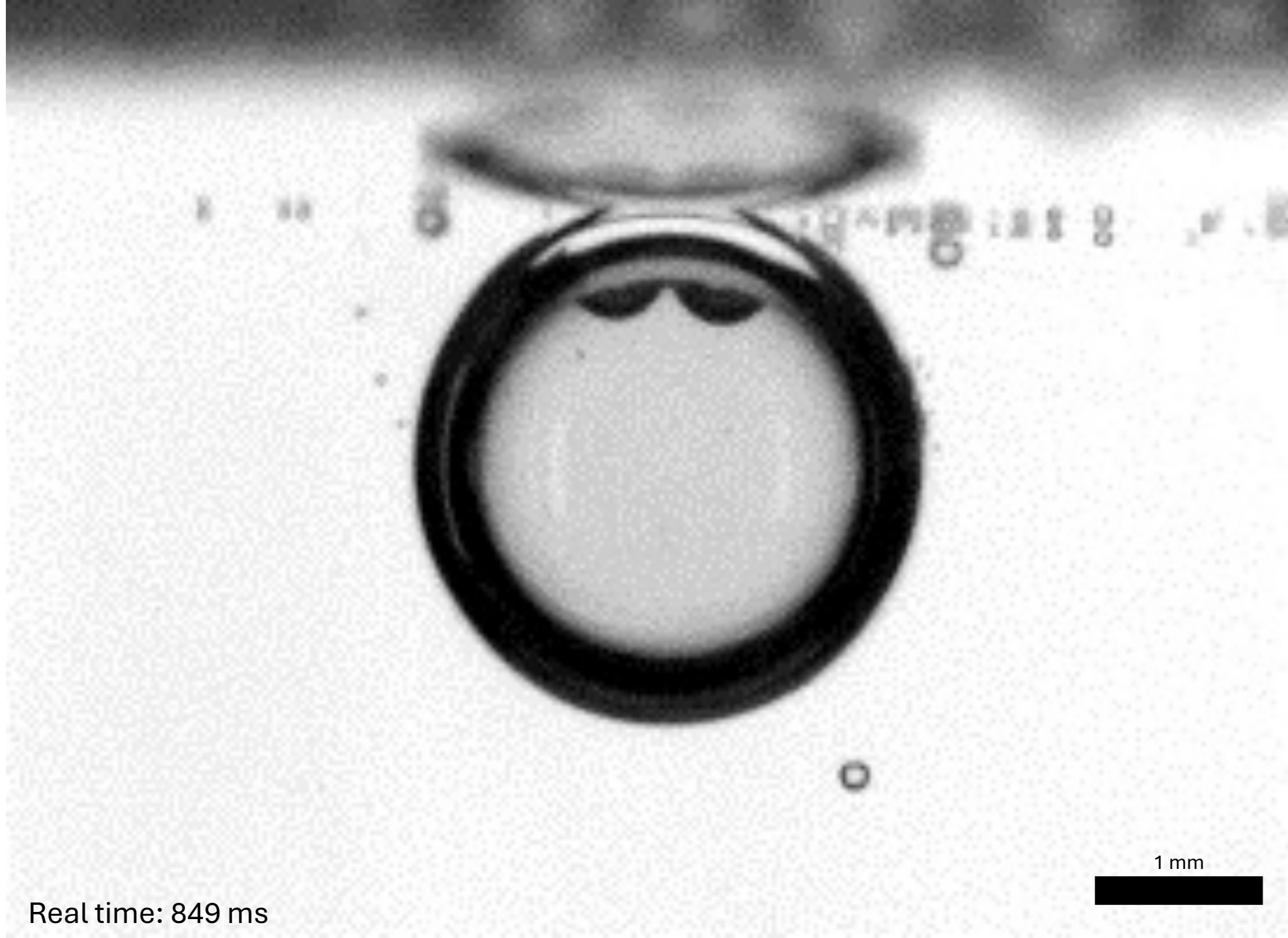


- Unstable multilayer antibubbles
- Interactions between layers
- Drainage in the layers

More information coming soon!

C. André, C. Amerein, J. Miguët, B. Scheid and S. Dorbolo,
From droplets to multilayer antibubbles: formation and stability, submitted.





Real time: 849 ms

1 mm