



Foam drainage:

Drop coalescence with a single Plateau border

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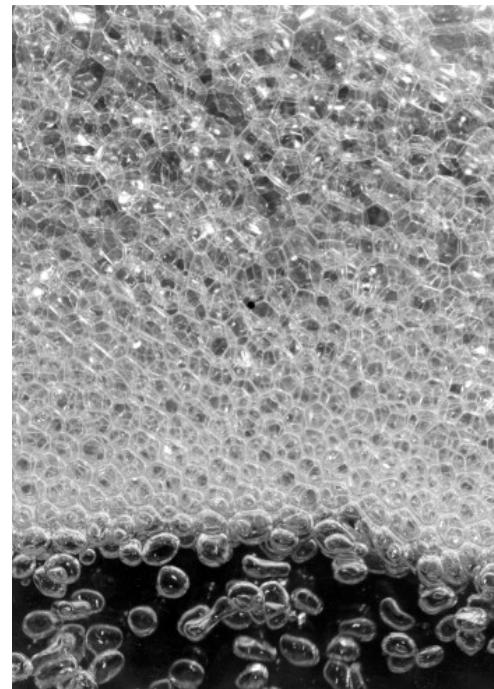
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Context:

Flows in PBs and vertices induced by gravity: **drainage**

→ Inhomogeneity of liquid fraction:

Stability problems & foam studies problems
(mechanics, acoustics, thermodynamics...)



J.J. Cilliers

$$\phi_l = \frac{V_l}{V_{tot}}$$

↓ →
g

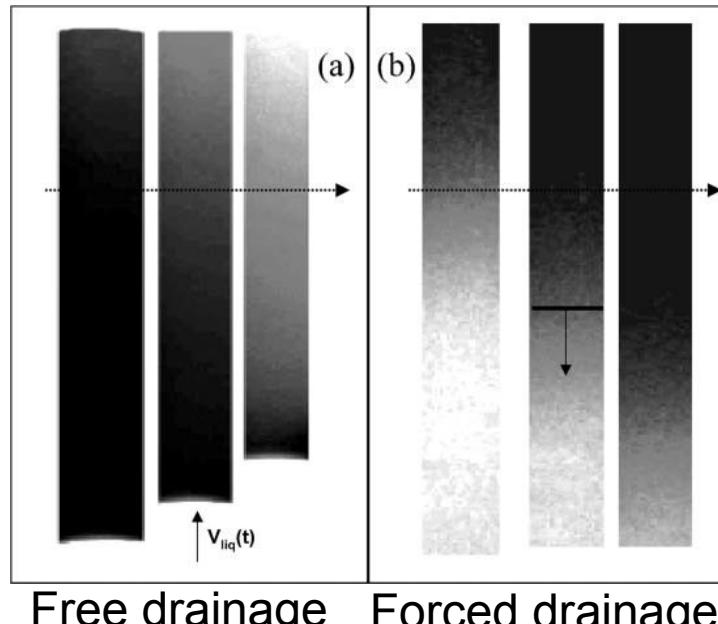
Studies of foam drainage

Porous media models:

$$\bar{u} = \frac{\alpha}{\mu} \nabla (\text{Pressure})$$

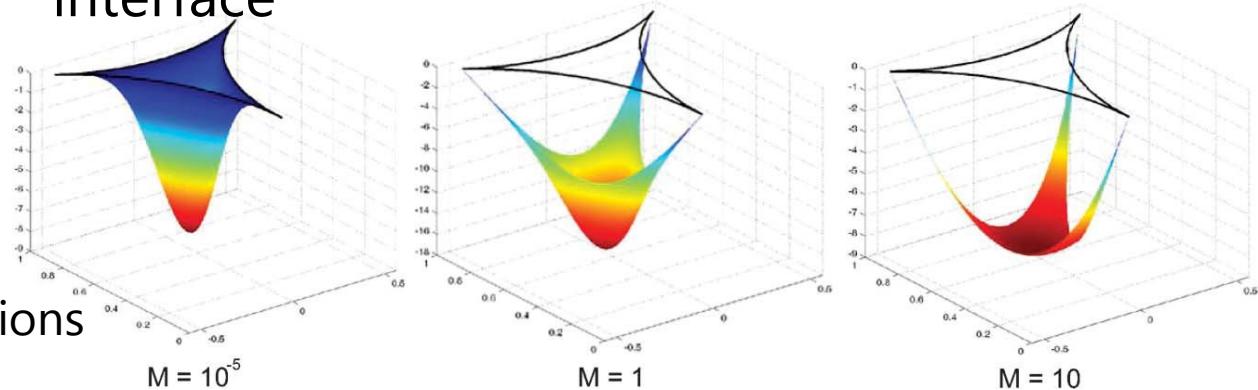
$$\alpha = f(\text{Geometry}, \phi_l)$$

Flows without rigid boundaries conditions
Flows depend on surfactants

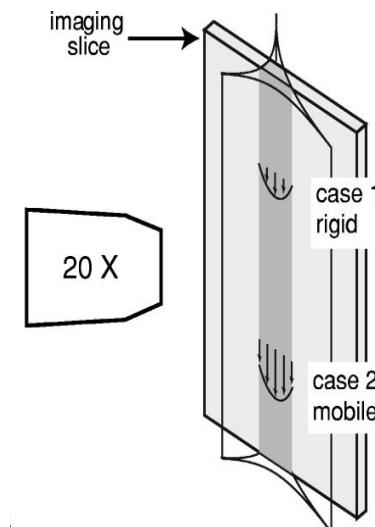


Saint Jalme, Soft Matter, 2, 836–849, 2006

Rigid interface

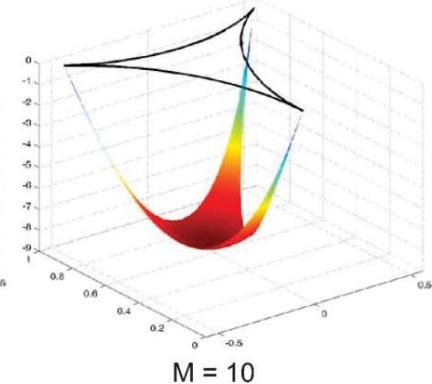


Main dissipation
in PBs



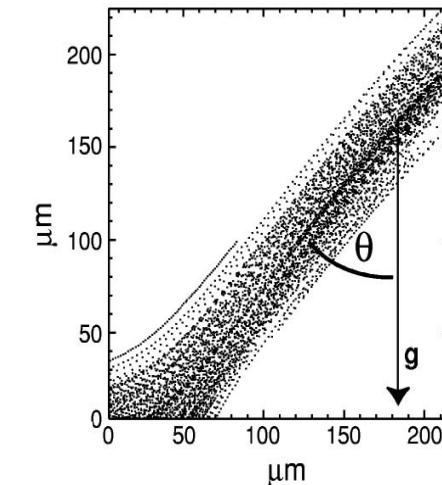
Khoelher et al. Phys. Rev. E 6, 04060 (2002)

Mobile interface



Main dissipation
in vertices

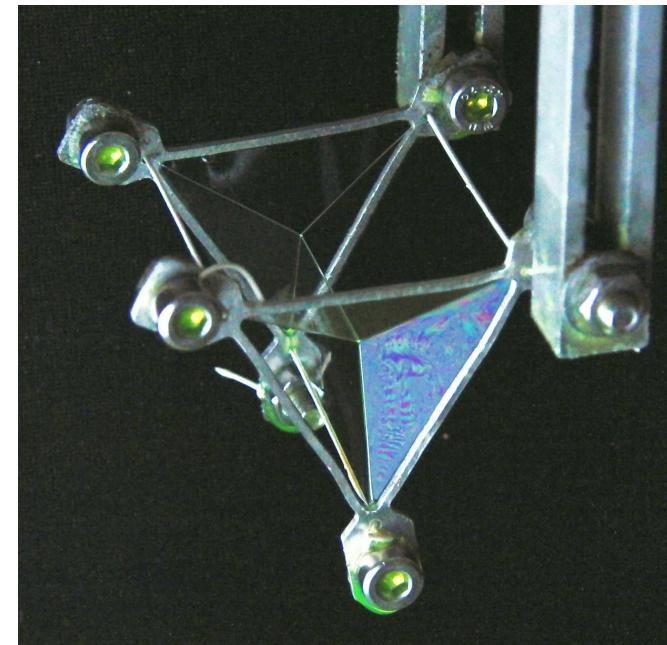
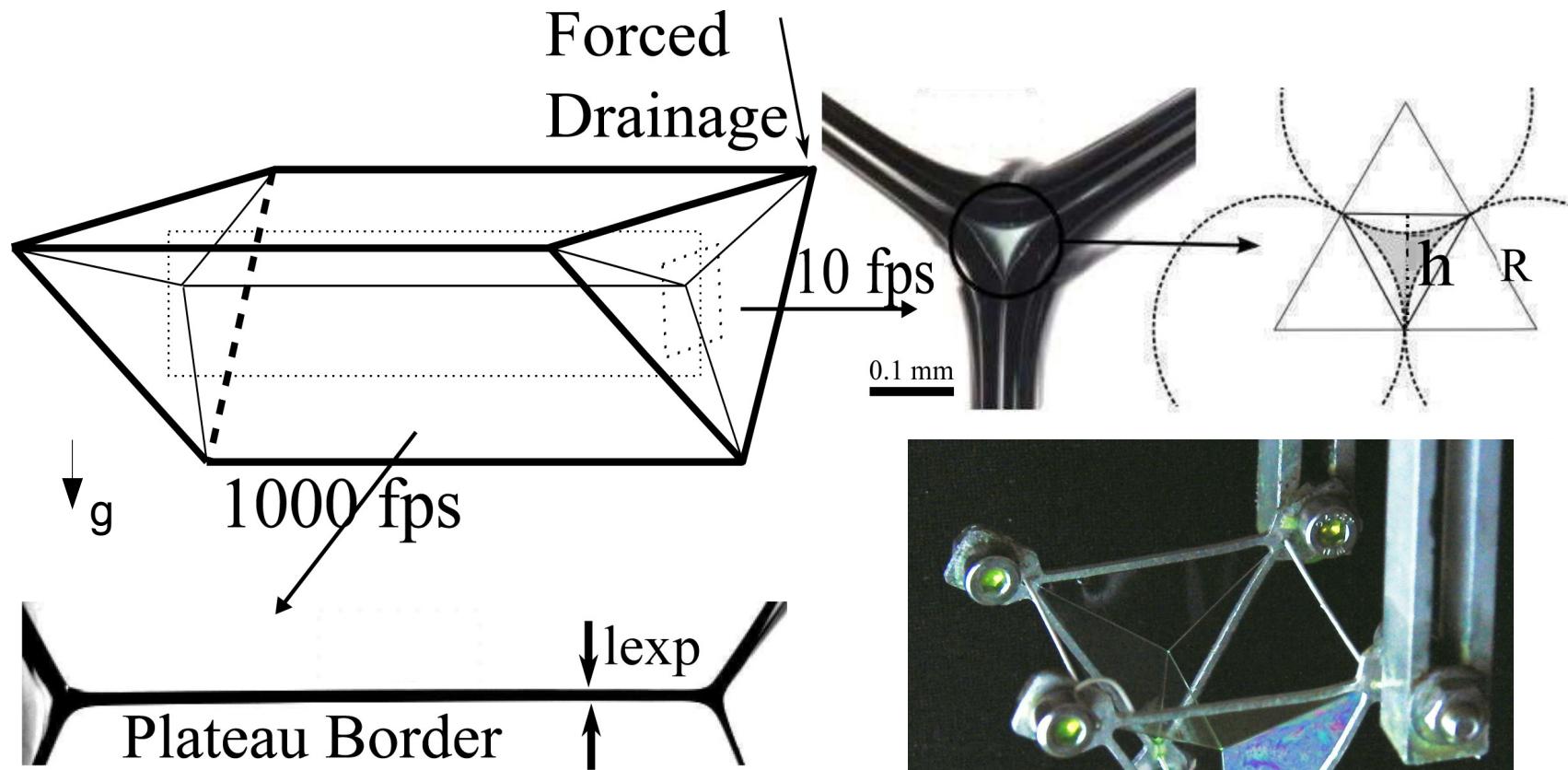
Simulation by W. Drenckhan



Our experiment

- Observation at the bubble scale
- Liquid flows in a single Plateau border:
 - Transient flows
 - Dissipation sources: Vertices Vs PBs

Elementary cell of foam



Simplified geometry :

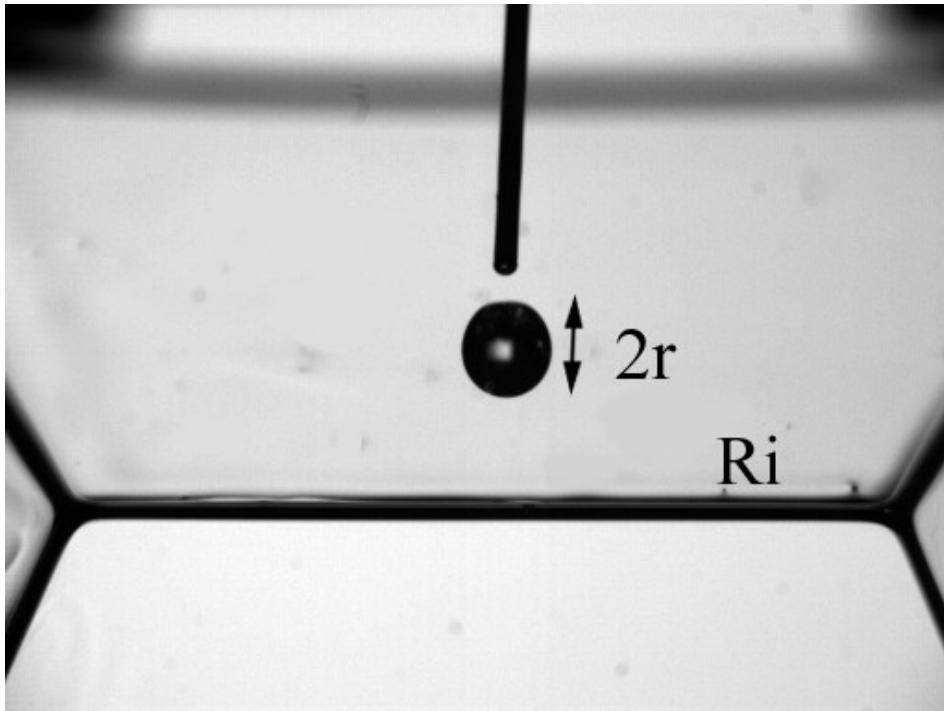
9 films

2 vertices

6 Plateau Borders +1 **central Plateau Border**

Homogeneous and controlled liquid fraction

Method : drop coalescence



Drop Radius :

$$r = 0,2 - 1,8 \text{ mm}$$

Plateau border radius of curvature :

$$Ri = 0,1 - 1,3 \text{ mm}$$

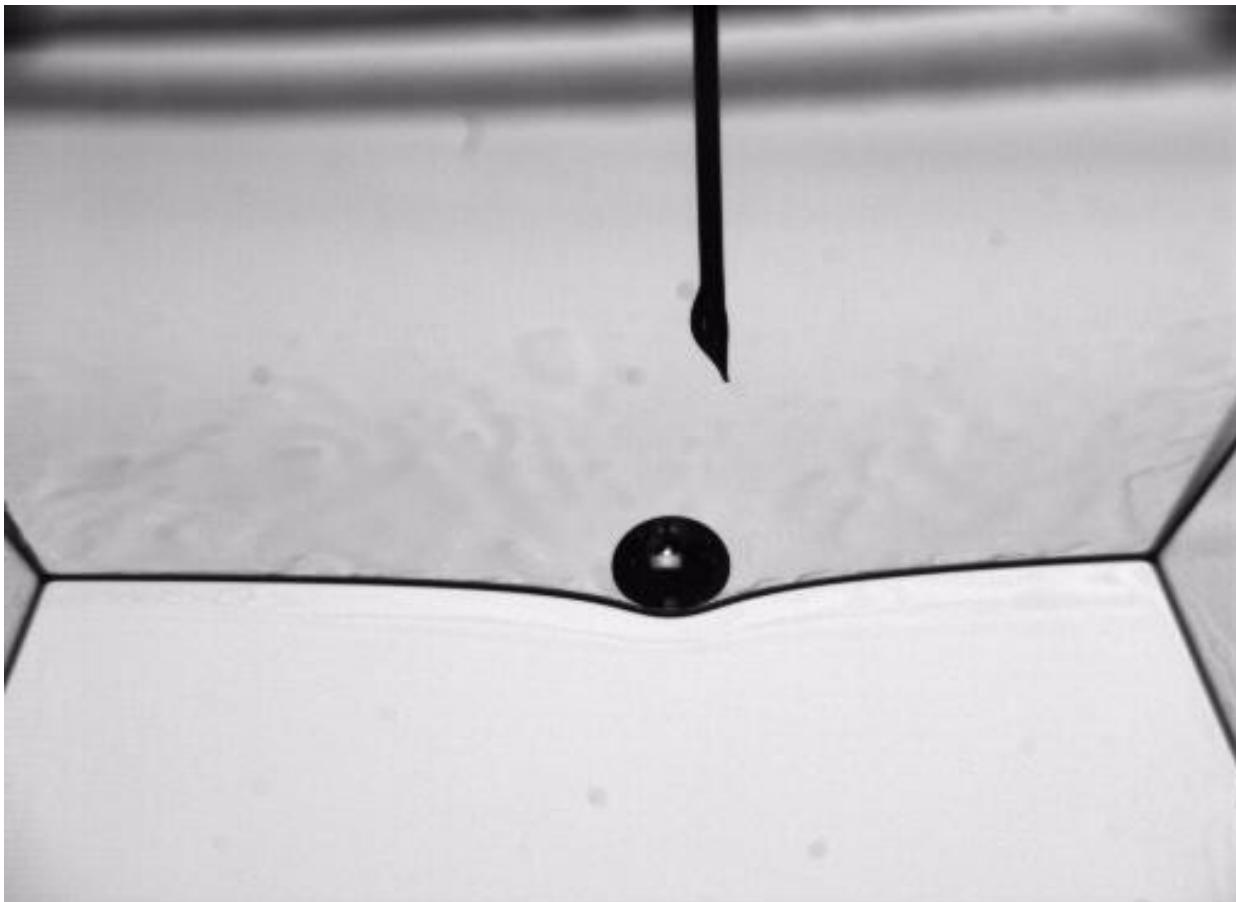
Liquids : Dreft solution & TTAB+Glycerol solutions

Viscosity : $\mu = 0,9 - 28 \text{ mPa.s} \rightarrow \text{x 30}$

Volumic mass : $\rho = 1000 - 1190 \text{ kg/m}^3 \rightarrow \text{x 1,5}$

Surface tension : $\sigma = 26-38 \text{ mN/m} \rightarrow \text{x 1,2}$

Slow flow



TTAB + 85 %w glycerol

Drop bounces

Drop coalescence

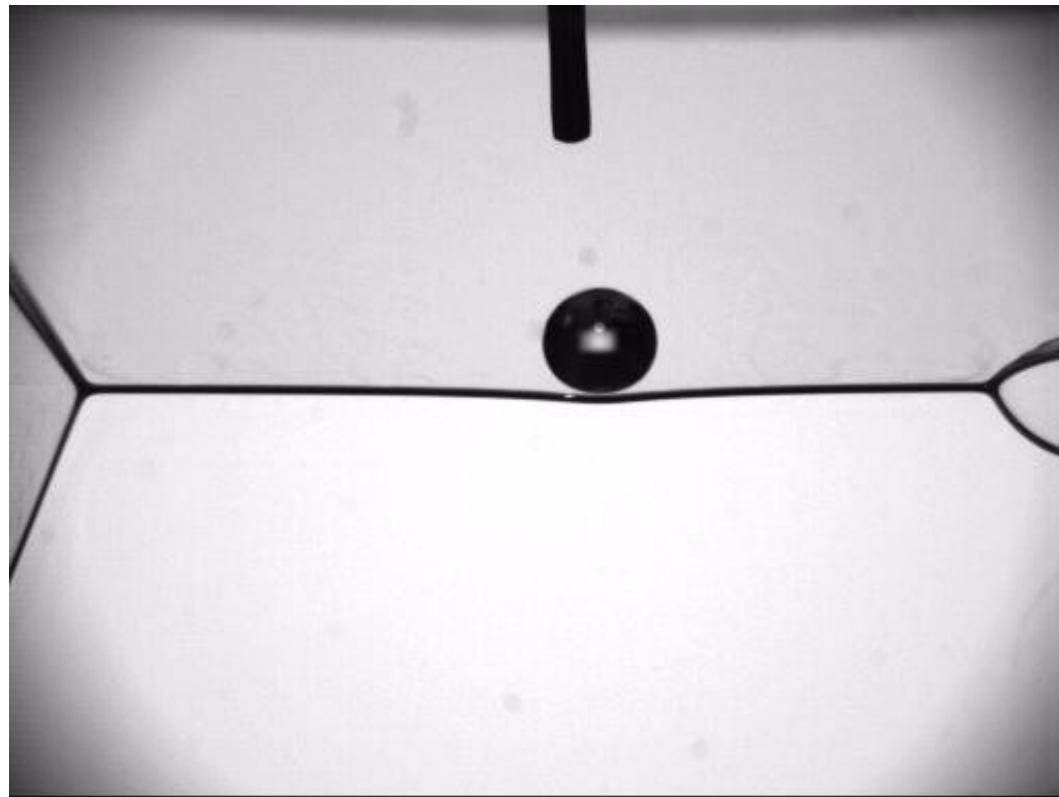
Lateral redistribution
of liquid

— 1 mm

Filmed at : 2000 fps

$\mu = 28 \text{ mPa.s}$ $\rho = 1190 \text{ kg/m}^3$ $\sigma = 32 \text{ mN/m}$

Propagative drainage



■ 1 mm

Filmed at 2000 fps

$\mu = 1 \text{ mPa.s}$ $\rho = 1032 \text{ kg/m}^3$ $\sigma = 38 \text{ mN/m}$

Drop bounces

Drop coalescence

Fast liquid redistribution

Thickening propagation :

- **Uniform and constant thickness**

- **Constant velocity** ~ 0,5 m/s

Regime transition

- Parameters :
- Dimensionless numbers :

driving force : σ

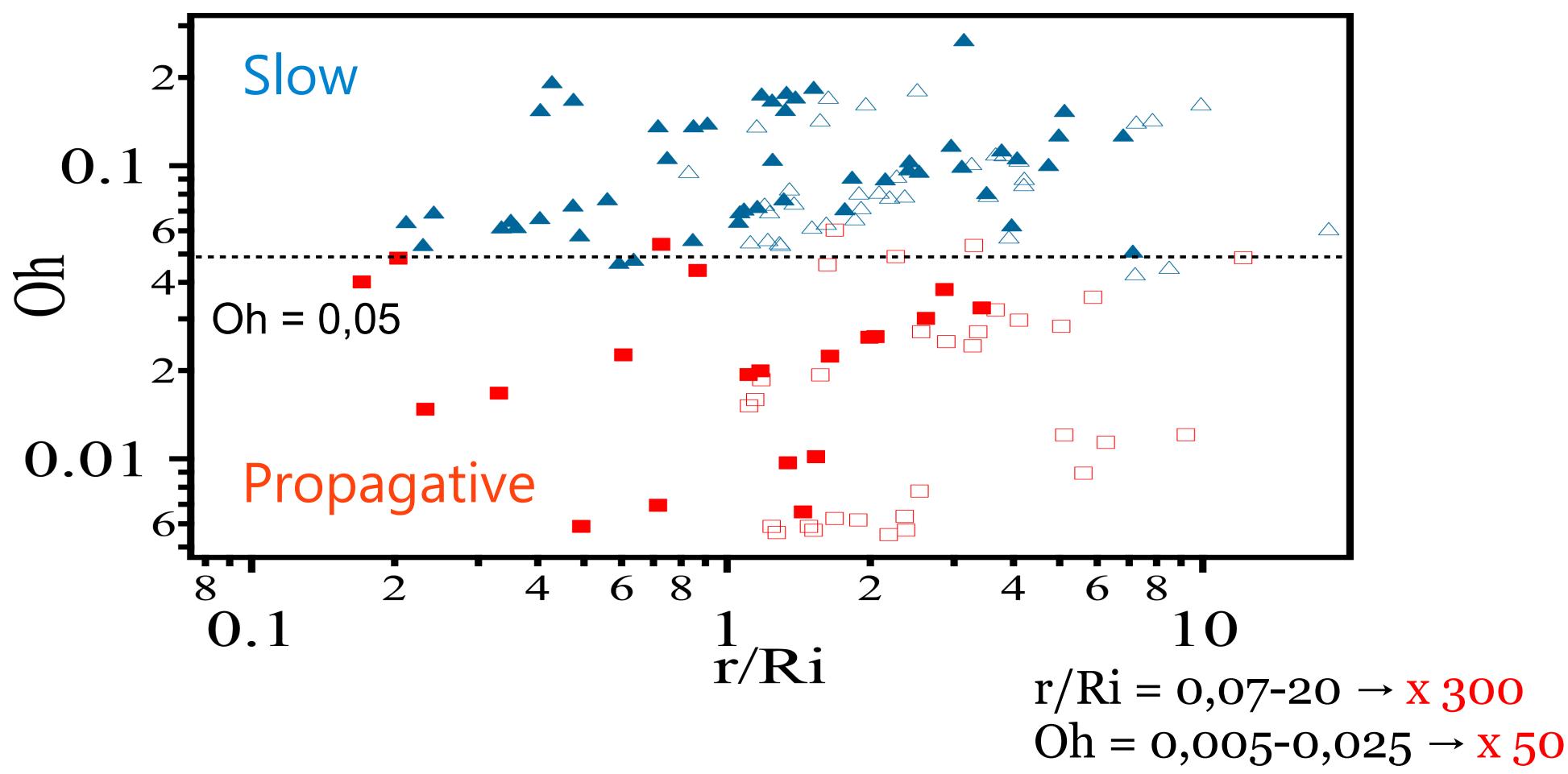
Length ratio : r/R_i

fluid properties : ρ, μ

ratio of viscous forces to

geometry parameters : r, R_i

capillaro-inertials forces : $Oh = \frac{\mu}{\sqrt{\rho \sigma R_i}}$



$t = 0\text{ms}$

initial Plateau Border

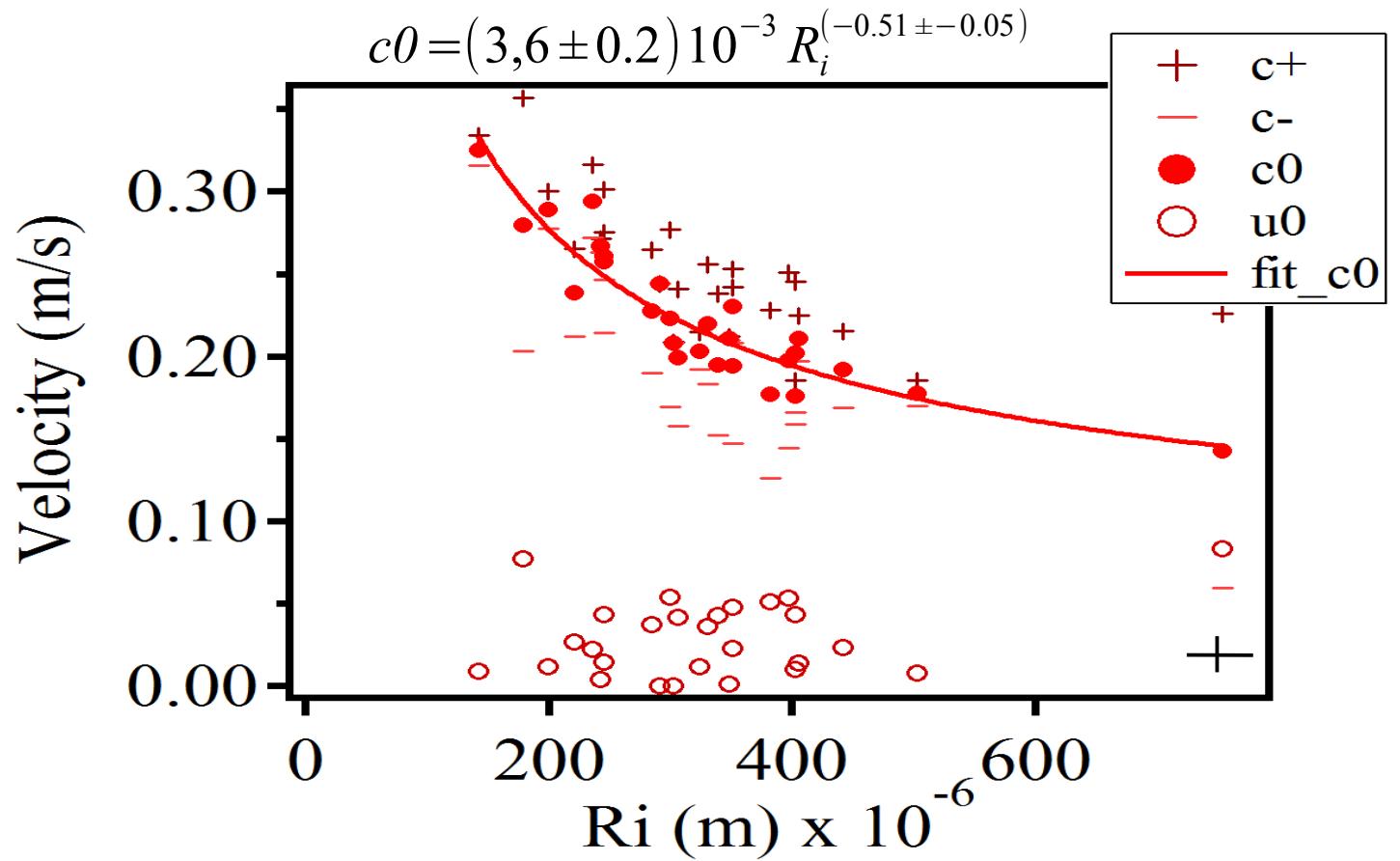
Forced drainage

Propagatif regime: velocity

Experimentally:

$u_0 = (c_+ - c_-)/2$: initial drainage velocity

$c_0 = (c_+ + c_-)/2$: front velocity (fluid reference frame)



Dimensional analysis : $c_0 = \sqrt{\frac{\sigma}{\rho R_i}} f\left(\frac{r}{R_i}, Oh\right)$

Perturbed Plateau Border

$t = 64 \text{ ms}$ 1 mm

$t = 0\text{ms}$

initial Plateau Border

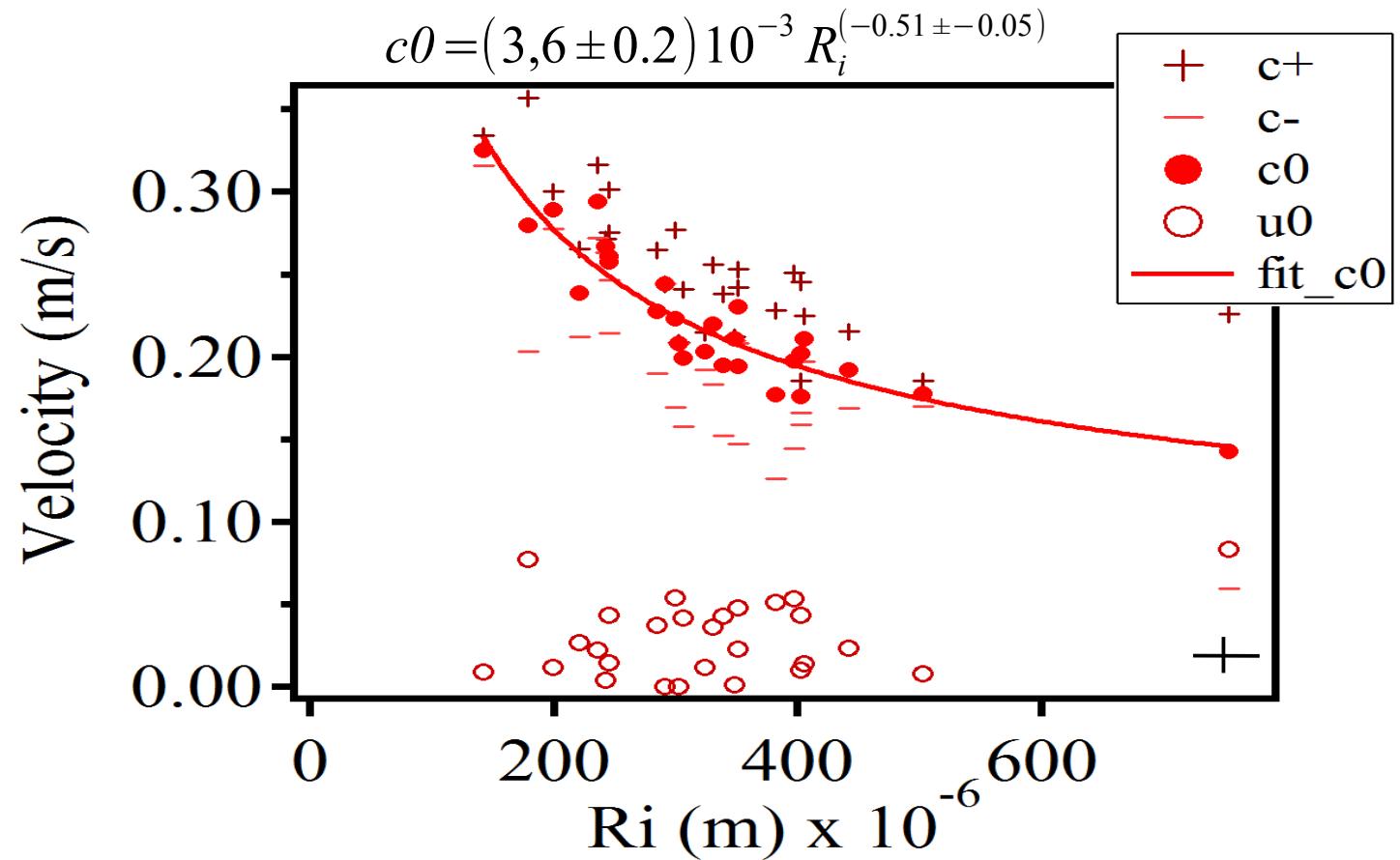
Forced drainage

Propagatif regime : velocity

Experimentalement :

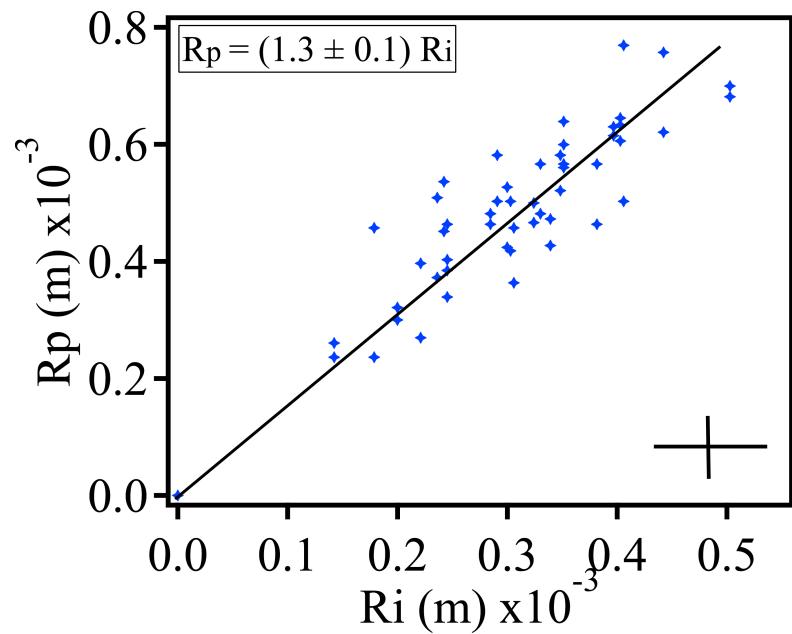
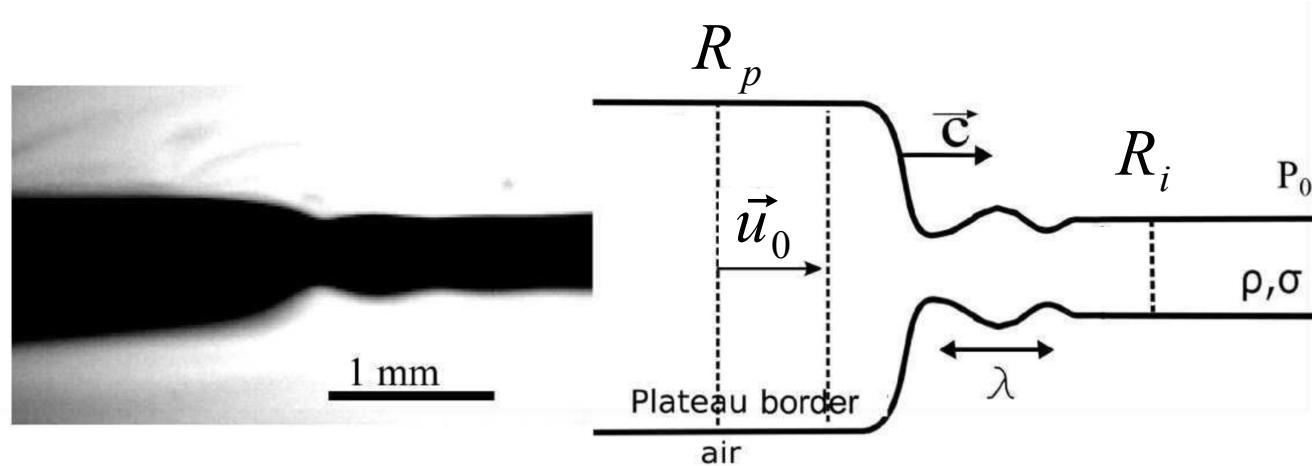
$u_0 = (c_+ - c_-)/2$: initial drainage velocity

$c_0 = (c_+ + c_-)/2$: front velocity (fluid reference frame)



Dimensional analysis : $c_0 = \sqrt{\frac{\sigma}{\rho R_i}} f\left(\frac{r}{R_i}, Oh\right)$ $f = \text{constant} \sim 1$

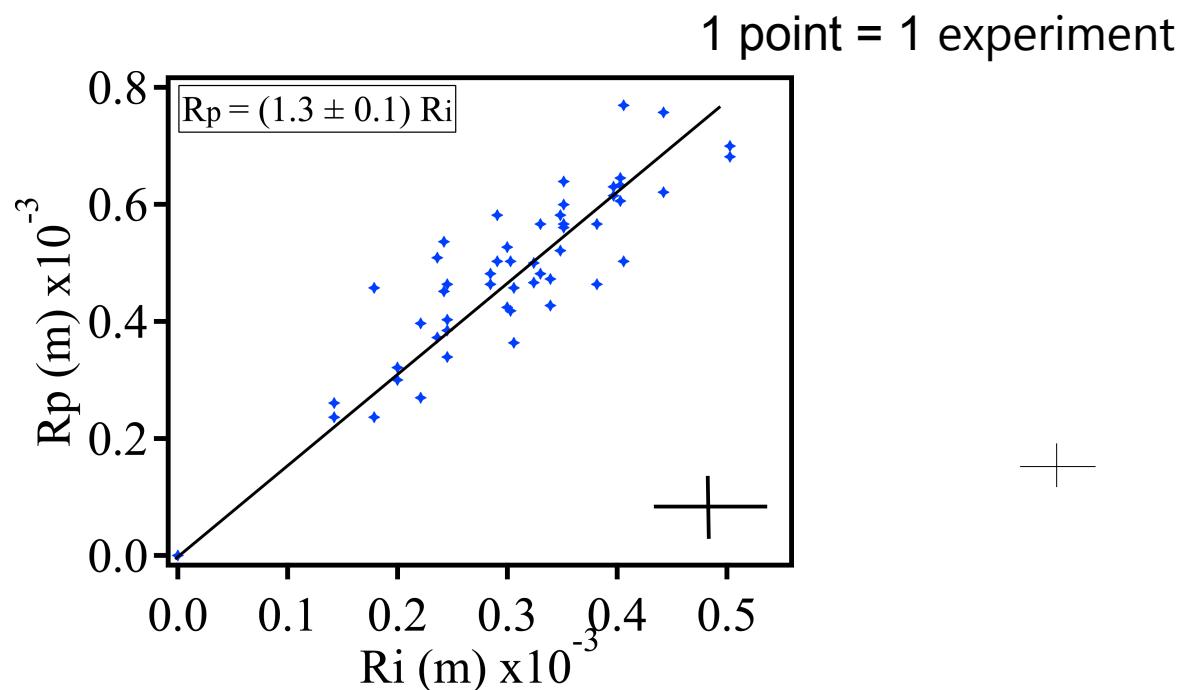
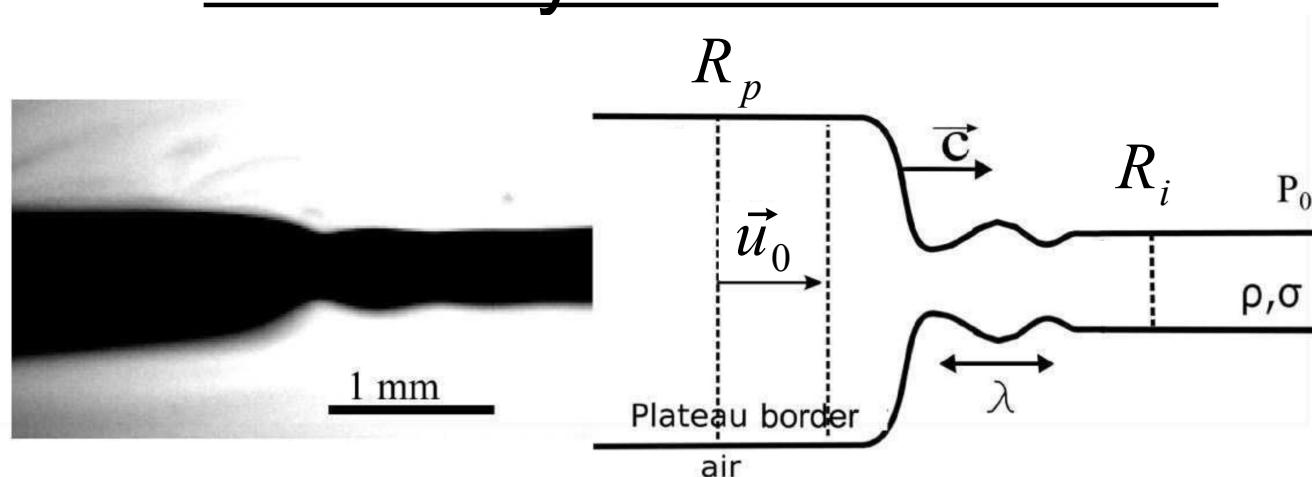
Geometry of the front zone



$$R_p = R_i f_R \left(\frac{r}{R_i}, Oh \right)$$

$$\lambda = R_i f_\lambda \left(\frac{r}{R_i}, Oh \right)$$

Geometry of the front zone



$$R_p \propto R_i \cdot f_R \left(\frac{r}{R_i}, Oh \right)$$

$f = \text{constant} \sim 1$

$$\lambda \propto R_i \cdot f_\lambda \left(\frac{r}{R_i}, Oh \right)$$

$f = \text{constant} \sim 1$

Rigid interface



Drop bounces

Drop coalescence

1st order: Film drainage

2nd order: Slow lateral redistribution

SLES+Betaine+MAc (*Golemanov et al. Langmuir 2008*)

$$\mu = 1 \text{ mPa.s} \quad \rho = 1000 \text{ kg/m}^3 \quad \sigma = 28 \text{ mN/m}$$

■ 1 mm

Filmed at : 2000 fps

films drainage : gravity effect

TTAB + glycerol

TTAB

Open
symbols:
Film
drainage

Gravity effect

$$\lambda_c = \sqrt{\frac{\sigma}{\rho g}}$$

Closed
symbols:
No film
drainage

Transition : $r = 0,6\lambda_c$

Transient flows (mobile interfaces)

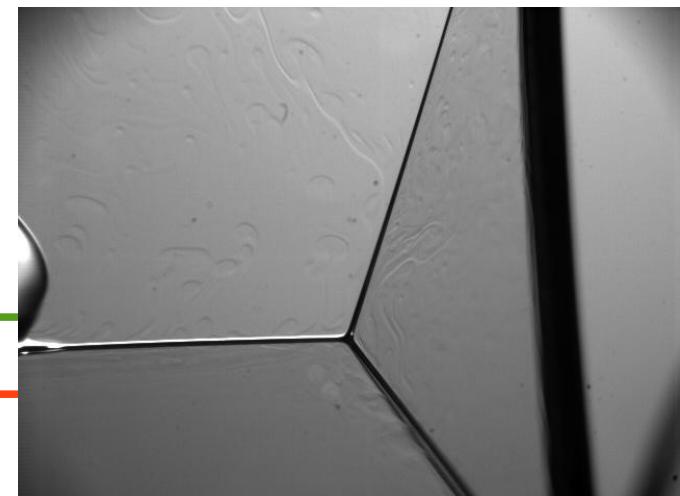
- Slow motion characterization : viscous or inertial ?
- Rapid motion: Why does Ri fix the other lengths ?
- c_0 depend on ρ , σ and Ri

Link with drainage studies at the foam scale:

Dry limite: $R_i = R_b \sqrt{\frac{\phi_l}{0,33}}$ & $R_i = \frac{\mu^2}{Oh^2 \rho \sigma}$

→ Propagative regime: $R_b \sqrt{\frac{\phi_l}{0,33}} > \frac{\mu^2}{(0,05)^2 \rho \sigma}$

With standard numerical values $\Rightarrow R_b \sim 0,1 \cdot 10^{-3} m$



Vertex effect on the flow ?

Thank you

Slow motion studies

