From two bubbles to one thousand…

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dépasser les frontières

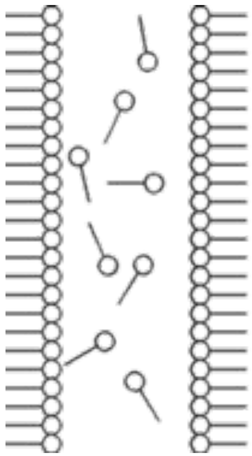
Laboratoire PMCN

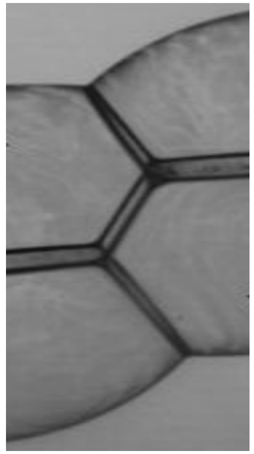
Laboratoire de physique de la matière condensée et nanostructures

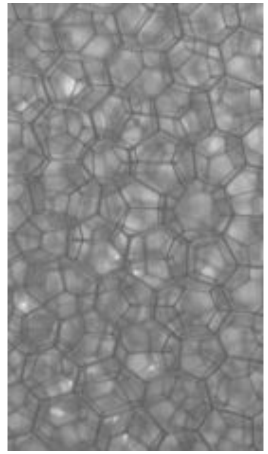
UMR 5586

Université Claude Bernard Lyon 1

How to link **microscopic** properties to **macroscopic** behavior?







Rheology

Restructuration

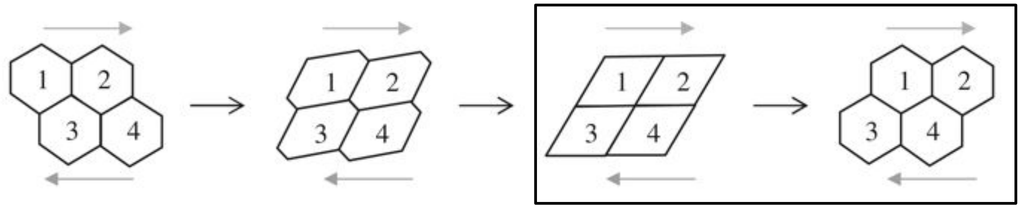
Transport (mass, charge…)

Surfactants

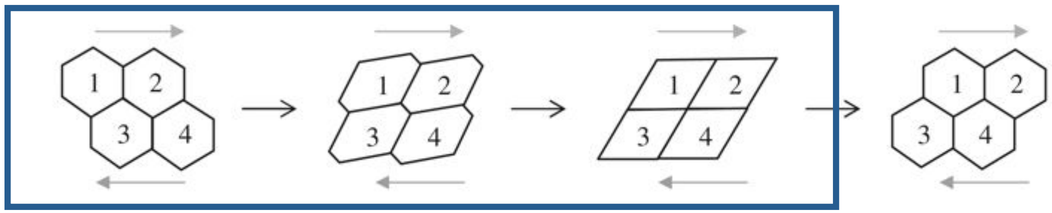
Liquid fraction

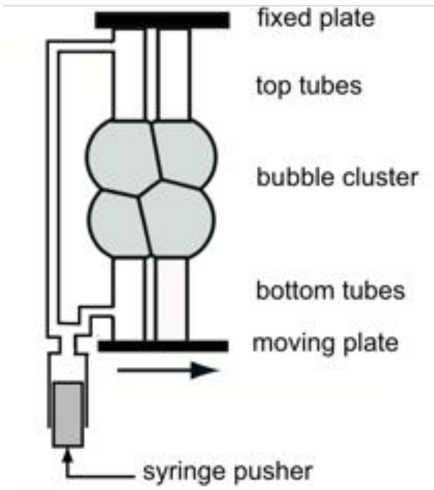
T1s

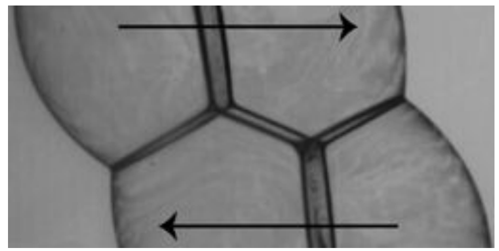
- T1 relaxation

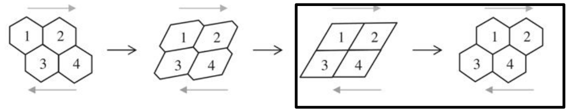


- Yielding

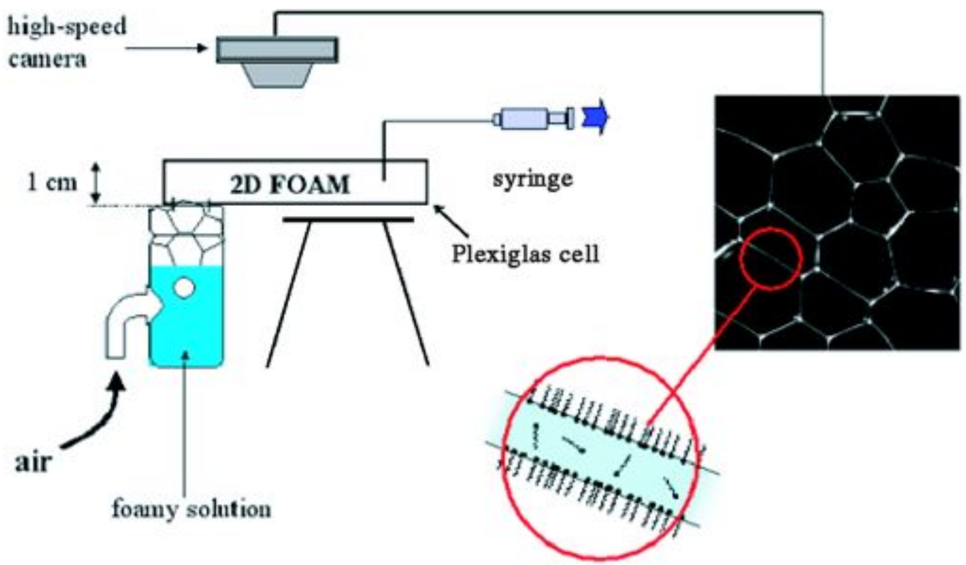


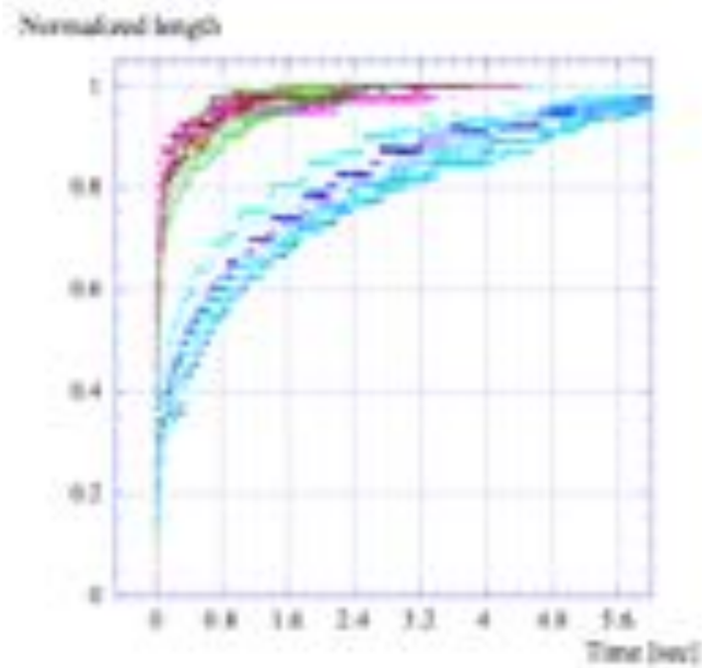






T1 relaxation time scale





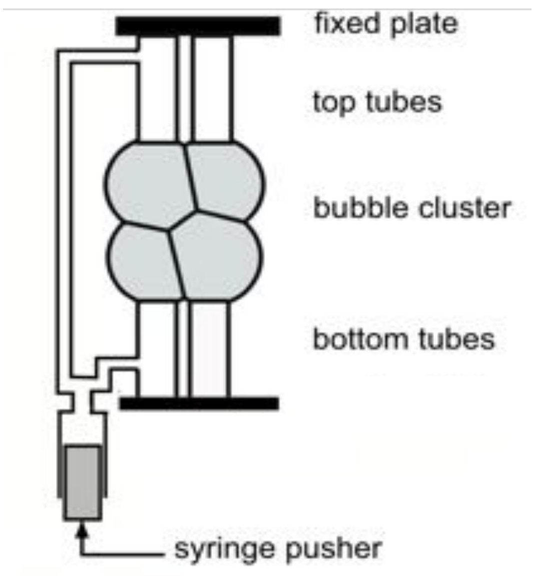
Durand, Stone, PRL 2006

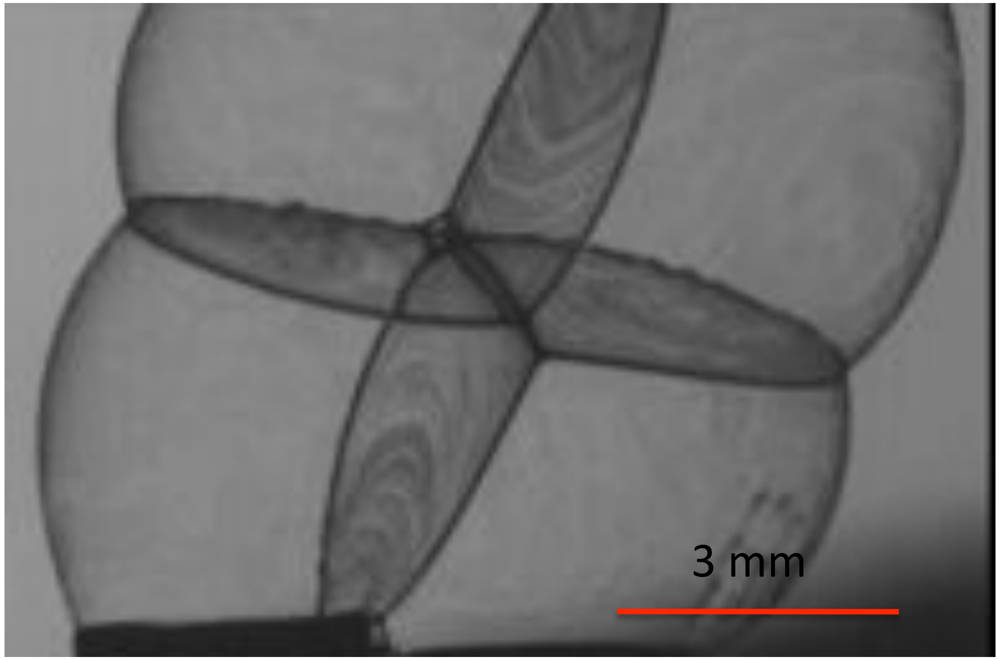
$$\tau = \frac{\kappa}{\gamma} f\left(\frac{\epsilon}{\gamma}\right)$$

Friction on the border ?
Liquid fraction ?

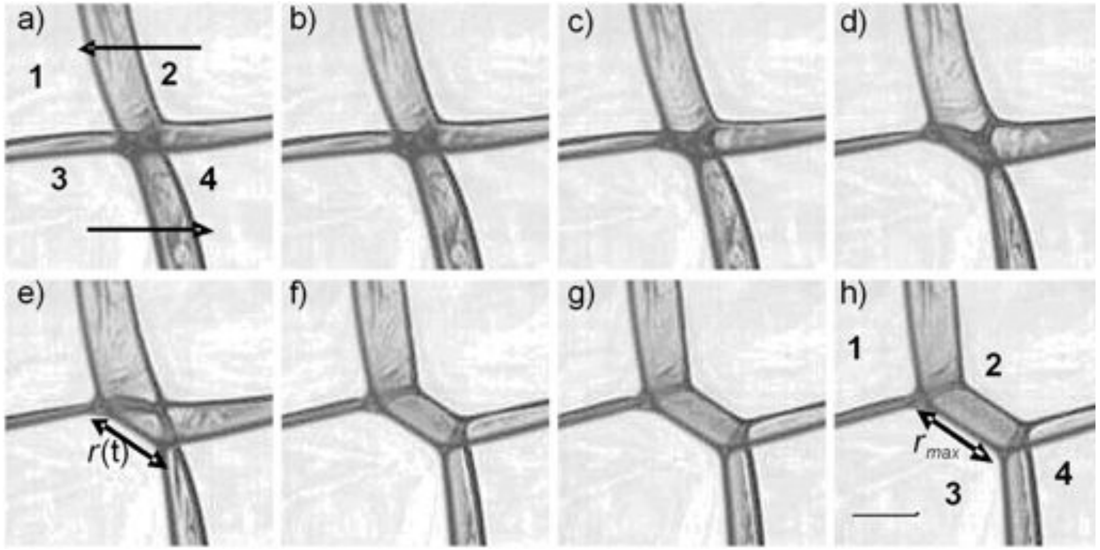
Four bubbles

T1 in 3D Foam clusters

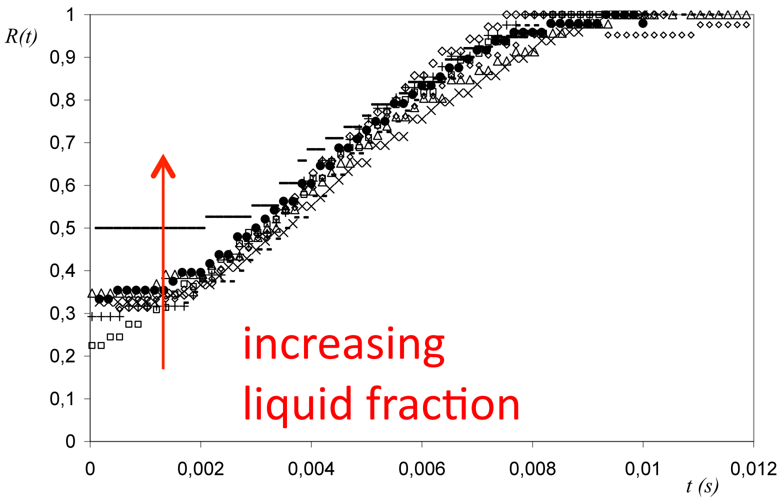




SLES+CAPB+Mac, slowed 3X

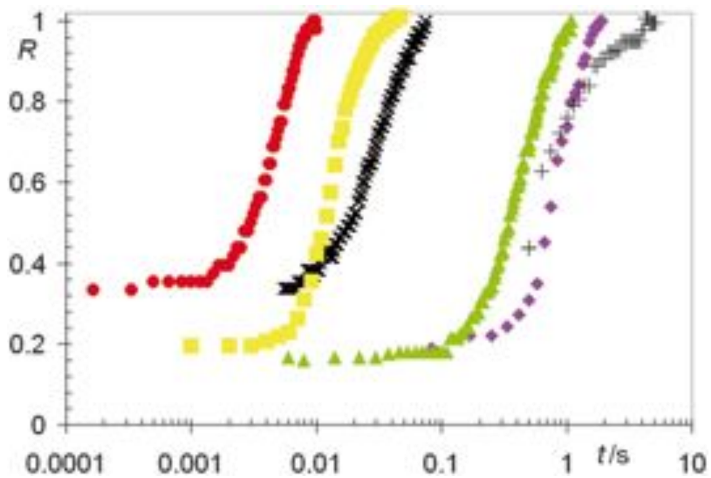


liquid fraction

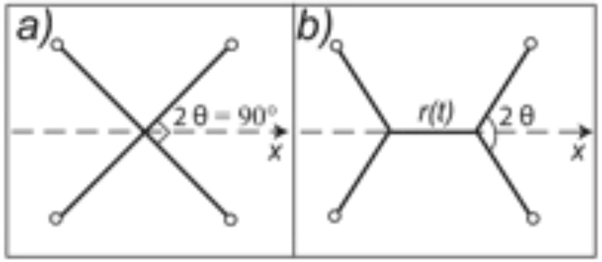


TTAB, 3g/L

surfactants



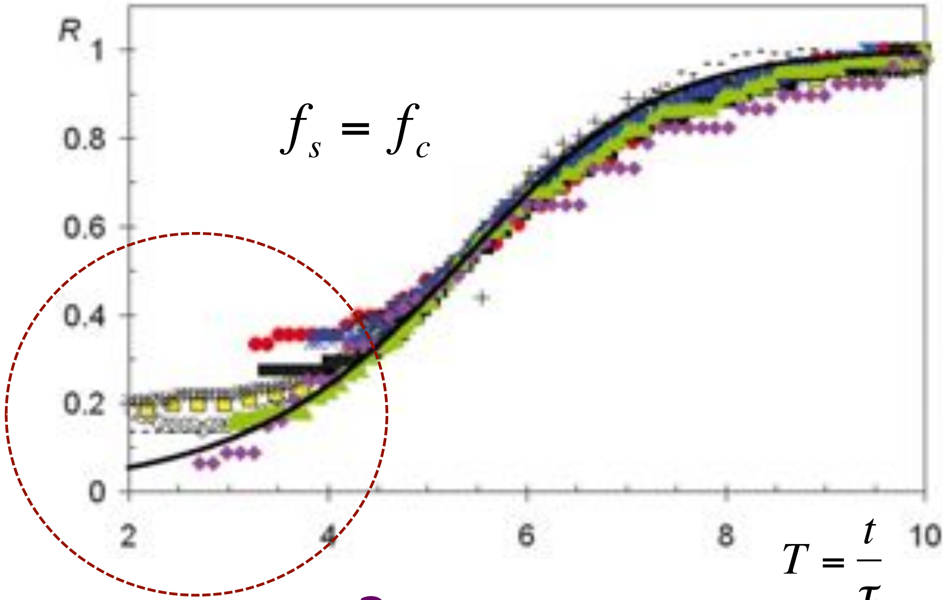
TTAB SLES+CAPB (+LOH), (+MAc)



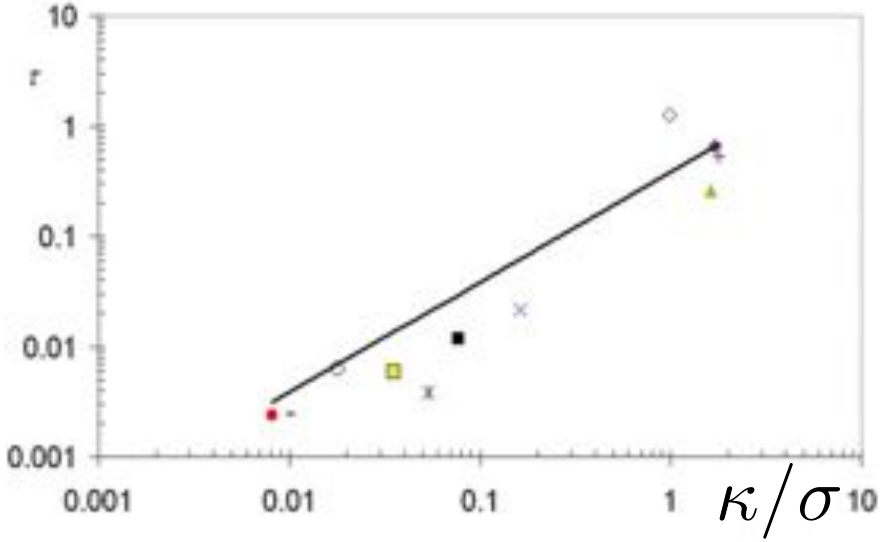
$$f_s = 2\mu^* \frac{1}{R}\frac{\partial R}{\partial t}$$

$$f_c = 2(2\sigma\cos\theta - \sigma(t))$$

$$\tau = \frac{\mu^*}{\sigma}$$



?

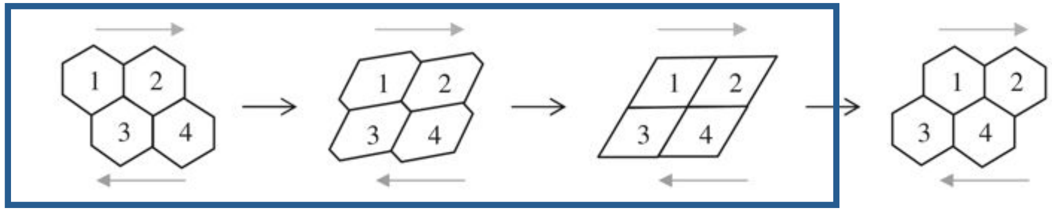


A-L Biance, S. Cohen-Addad, R. Höhler, Soft Matter 2009

Toward 3D foam: definition of a Deborah number

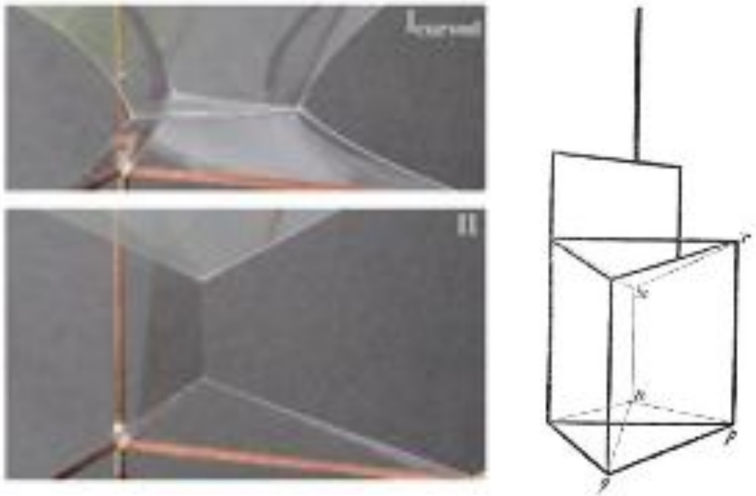
$$De = \dot{\gamma}\frac{\mu^*}{\sigma}$$

Plateau frames



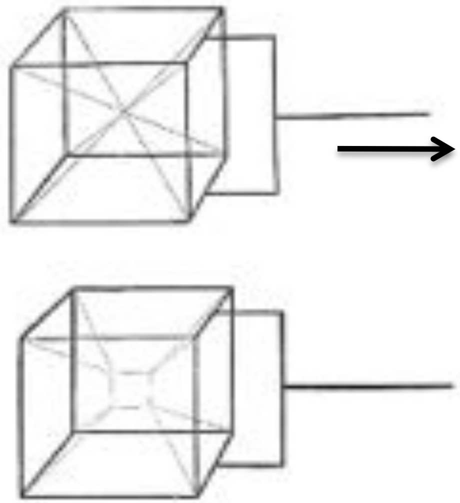
Yielding?

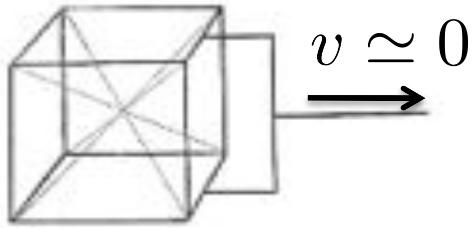
Energy considerations and phase transition

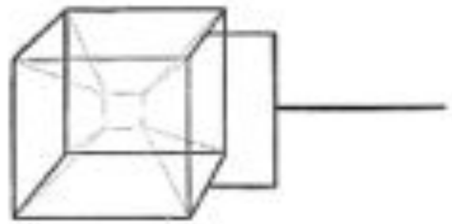


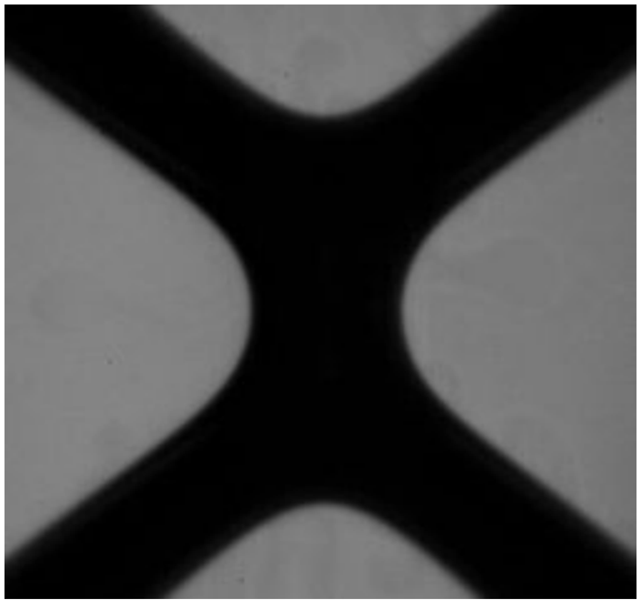
Hutzler et al., EPL 2007
Vandewalle et al., PRE 2011

Dynamics?



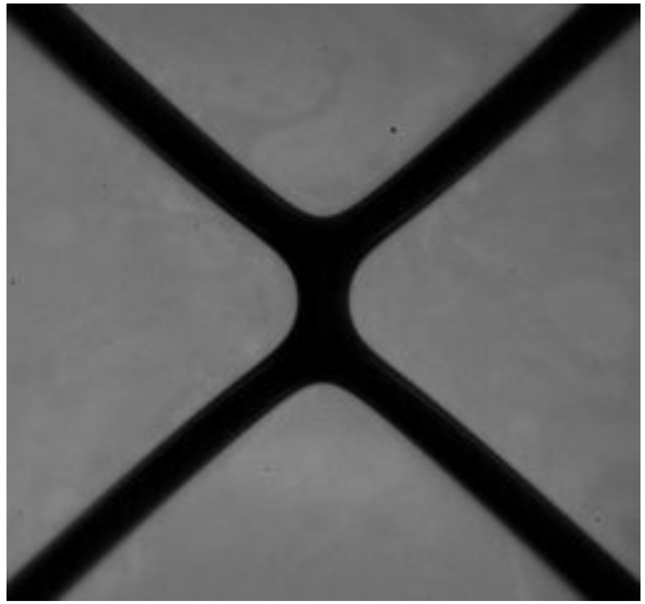






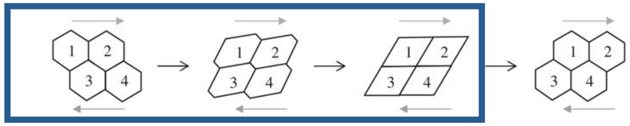
1 mm

TTAB, 3g/L, slowed 400 x

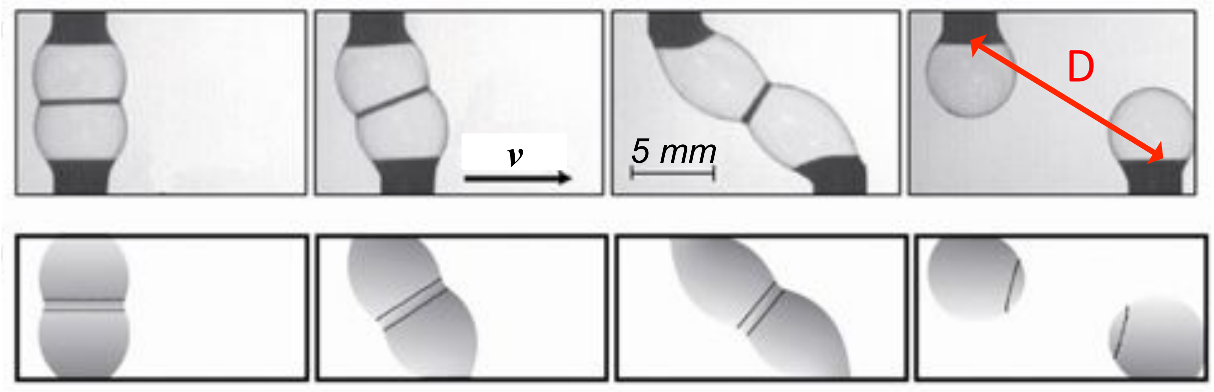


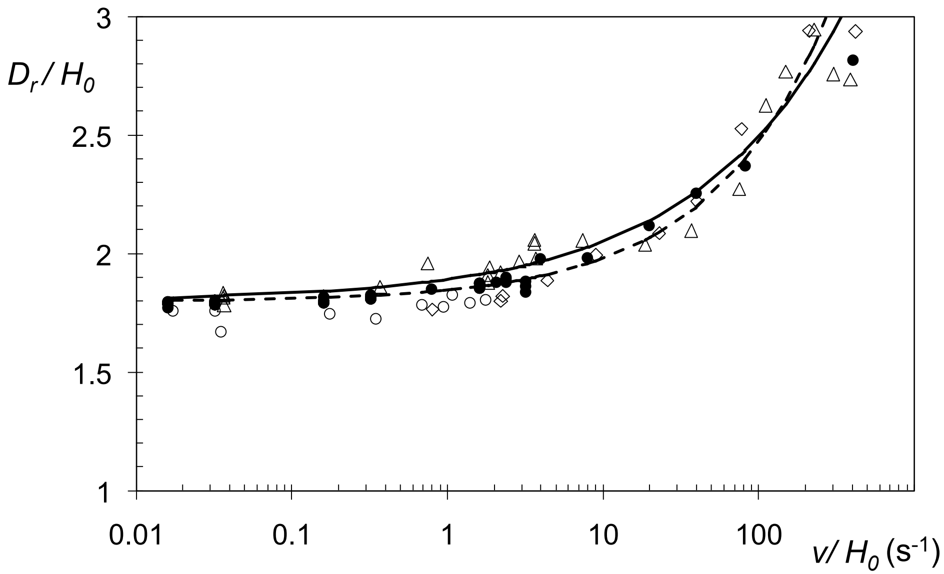
Another timescale ?
In progress

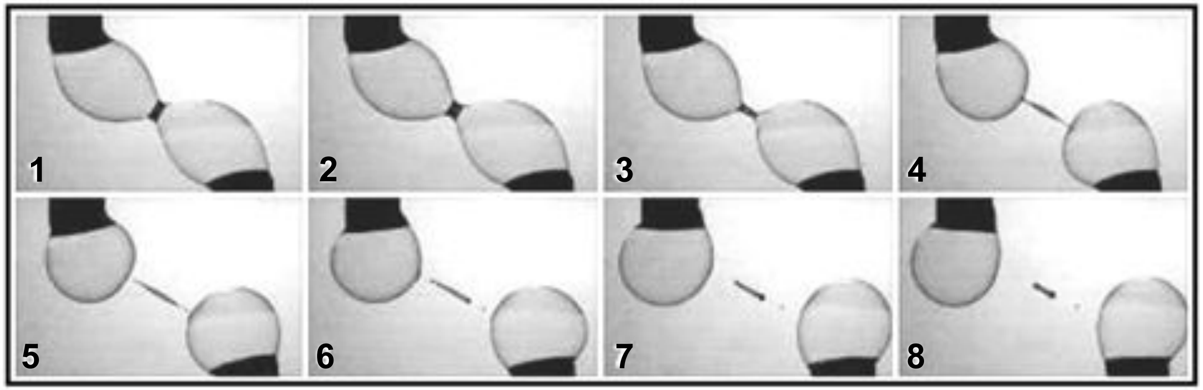
Two bubbles!

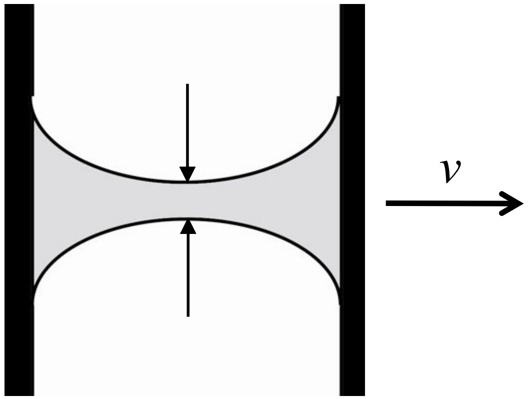


Fast yielding









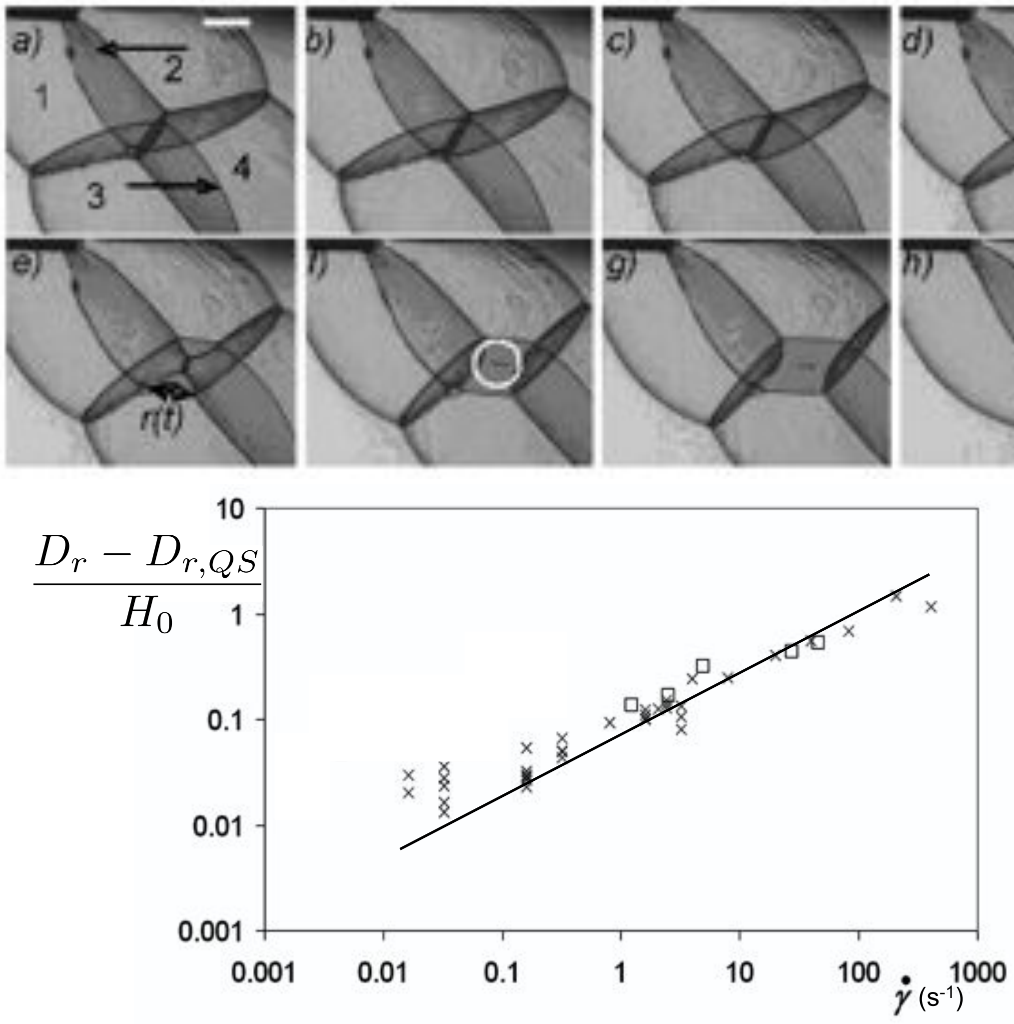
Meniscus pinch-off

Volume conservation + *inertial* Rayleigh destabilization time

$$\frac{D_r}{H_0} = \left(\frac{D_r}{H_0}\right)_{QS} + \left(\frac{vT}{H_0}\right)^{\frac{4}{7}}$$

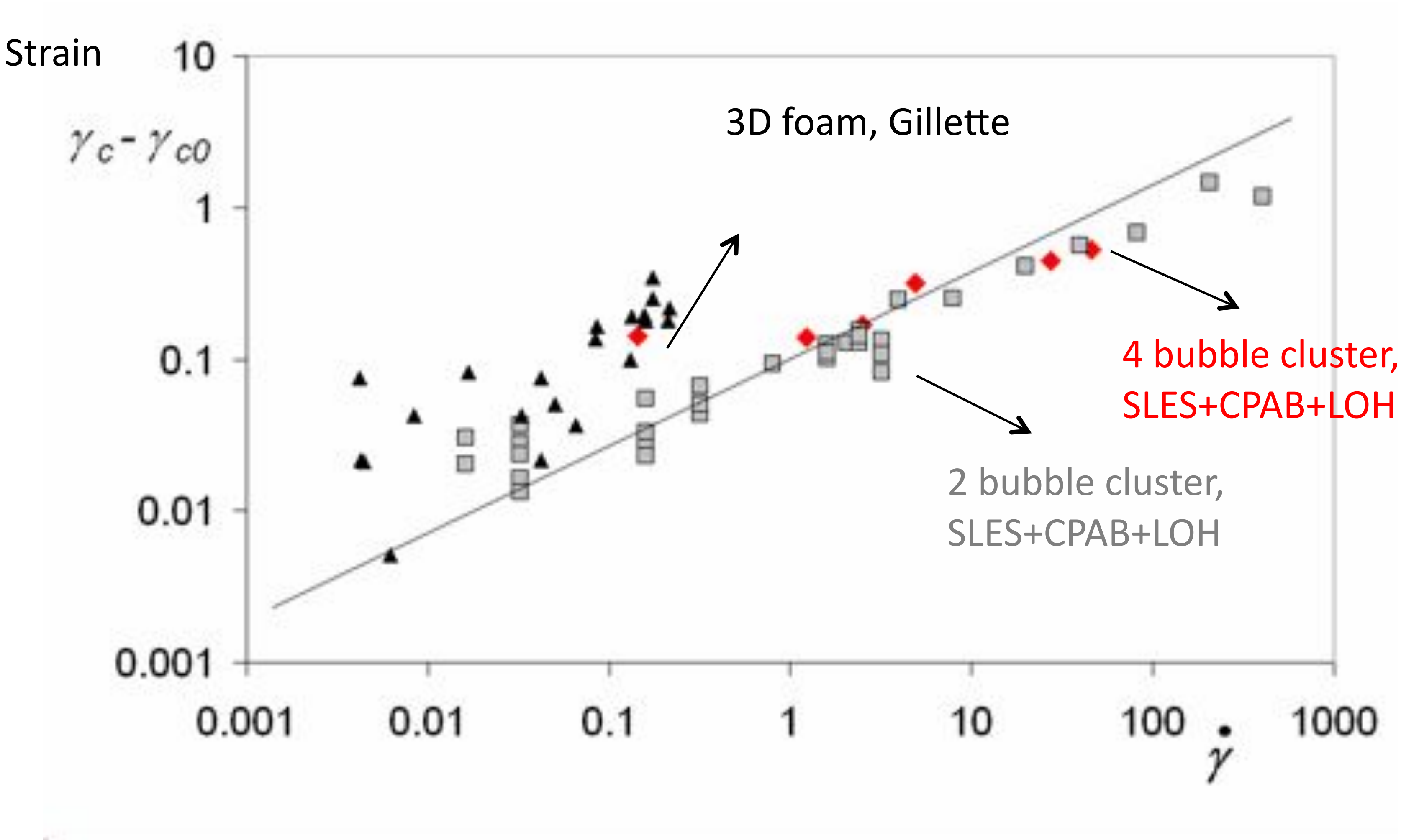
$$T \simeq \left(\frac{\Omega}{H_0}\right)^{\frac{3}{4}} \left(\frac{\rho}{\sigma}\right)^{\frac{1}{2}}$$

Four bubbles



A-L Biance, A. Calbry-Muzyka, R. Höhler, S. Cohen-Addad, Langmuir, 2012

One thousand bubbles



3D foam, F. Rouyer et al., PRE 2004

Reynolds numbers are different!

Conclusions and prospects

• T1 time scale is governed by *surface properties in dry foams* and does not depend on liquid fraction.

> ➢ Experimental investigation of flow velocity field and/or surfactant dynamics need to be performed to validate models.

• Quasistatic yielding defines a time scale depending on liquid fraction (waiting time).

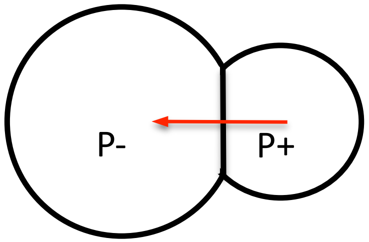
> ➢ What does it depend on?

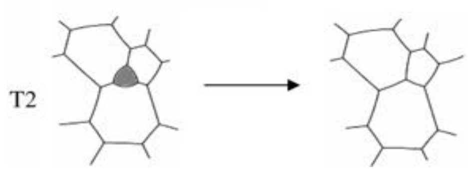
• Yielding under dynamic conditions is governed by pinch-off of a meniscus (*Non linear relationship*).

> ➢ Analysis / experiments in a viscous regime need to be performed.

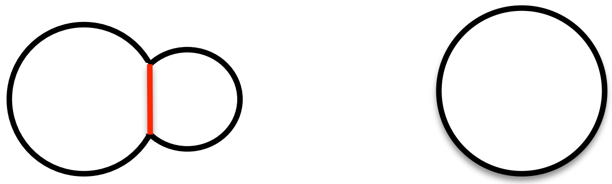
Restructuration

○Coarsening

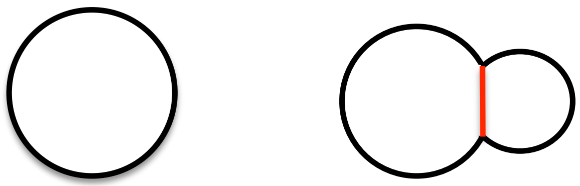




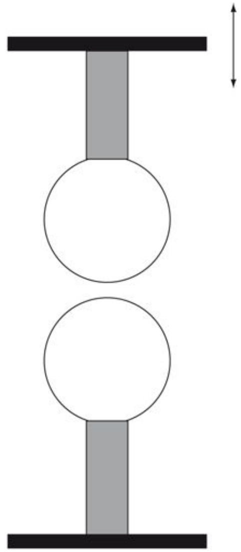
○Coalescence: film rupture



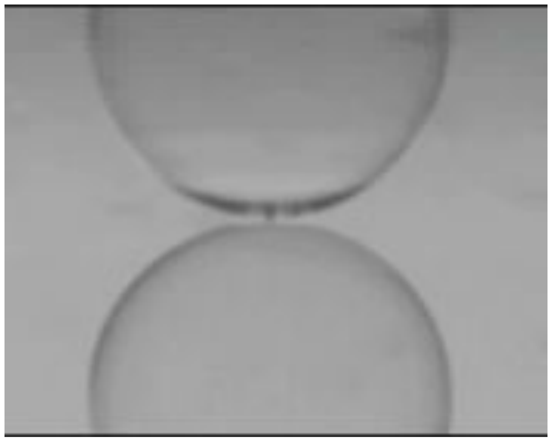
○Fragmentation

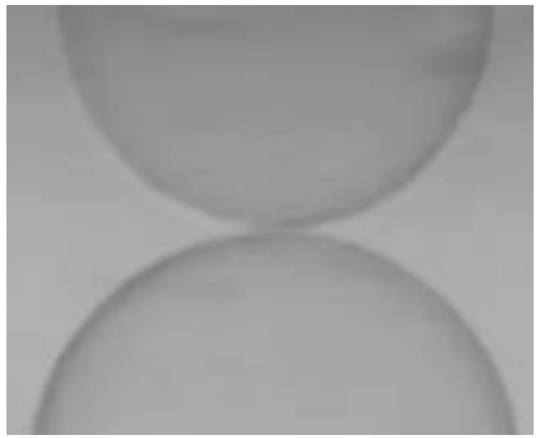


Two bubbles

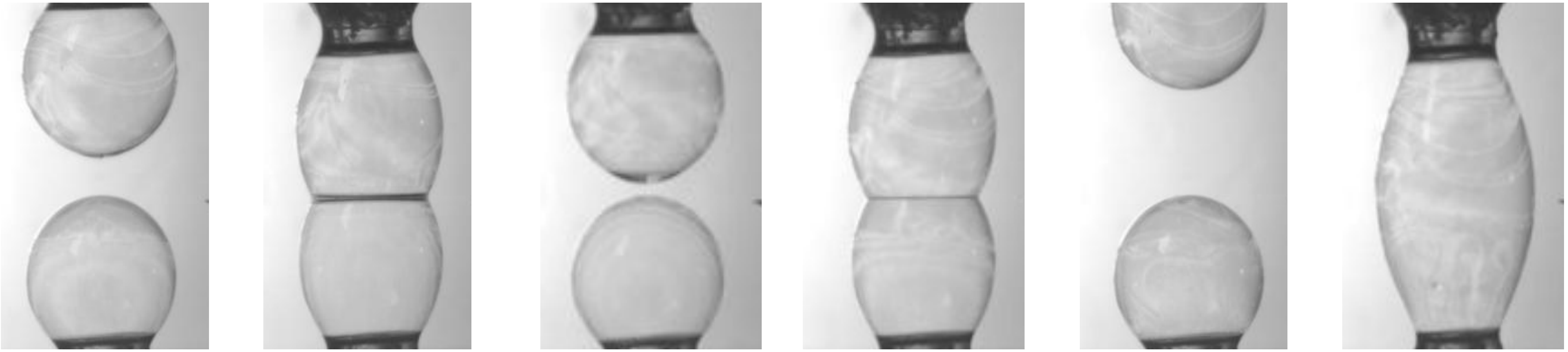


TTAB – 3 g/L

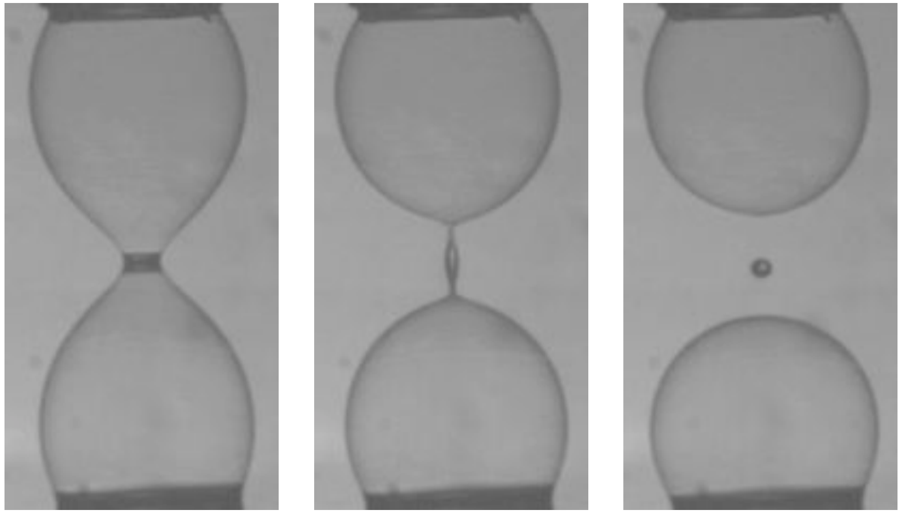


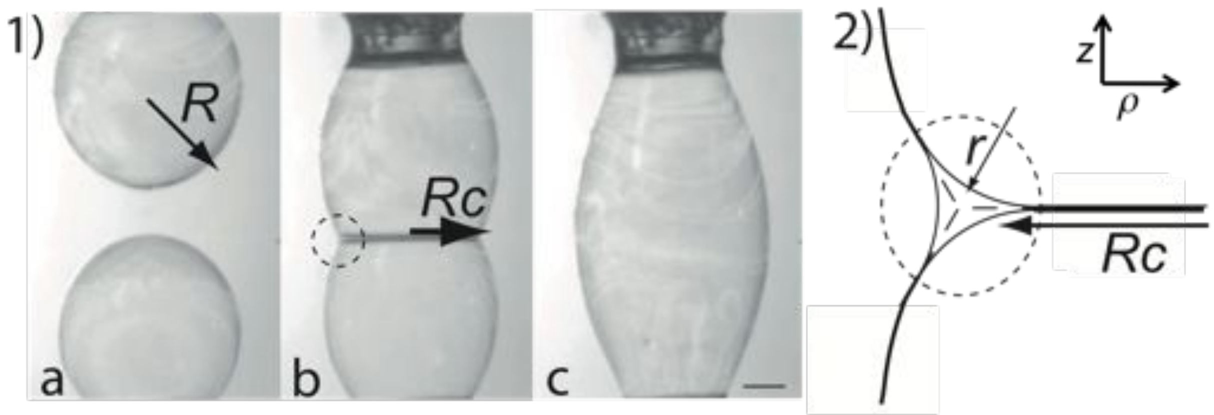


9000 frames/s
Slowed 600 X

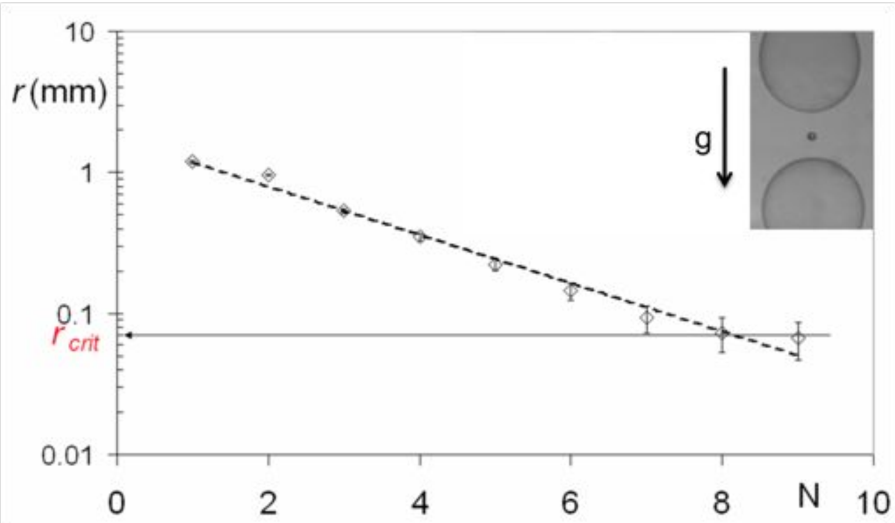


Liquid loss at each separation

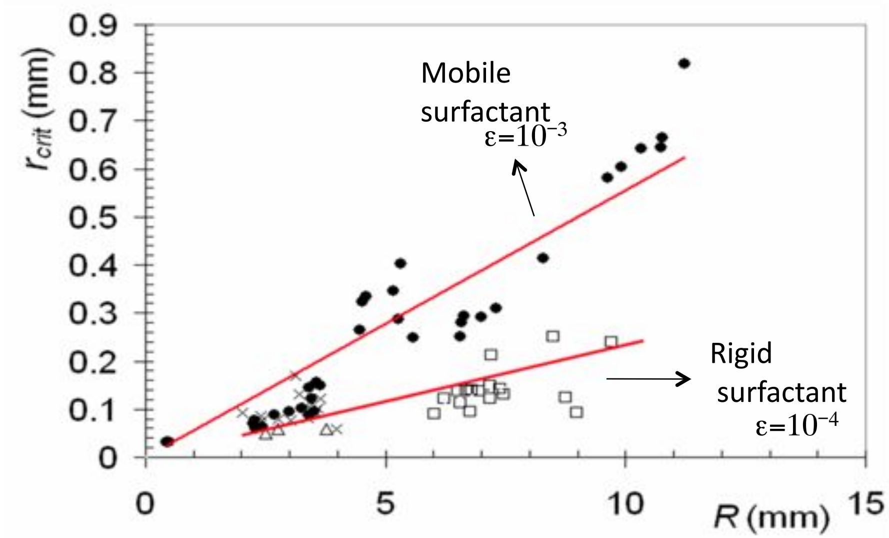




1)
R
Rc
a
b
c
2)
z
ρ
r
Rc



r (mm)
10
1
0.1
0.01
r crit
g
0
2
4
6
8
N
10

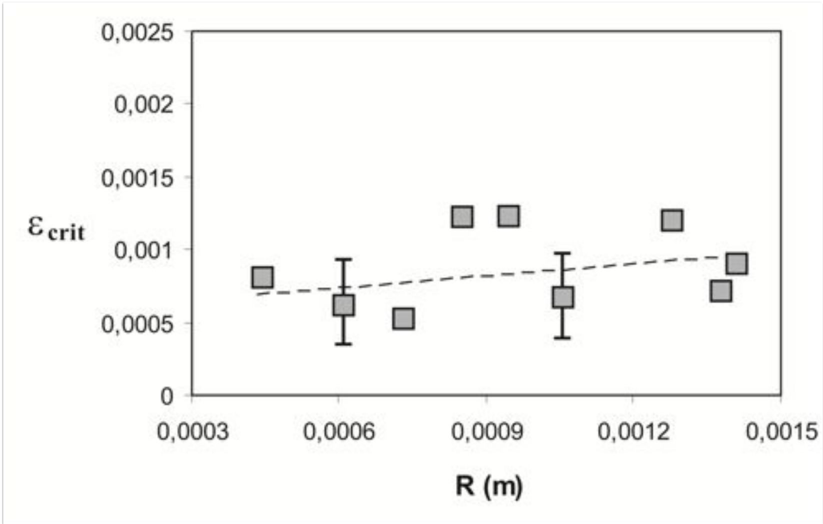


r crit (mm)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Mobile
surfactant
ε=10^-3
Rigid
surfactant
ε=10^-4
0
5
10
15
R (mm)

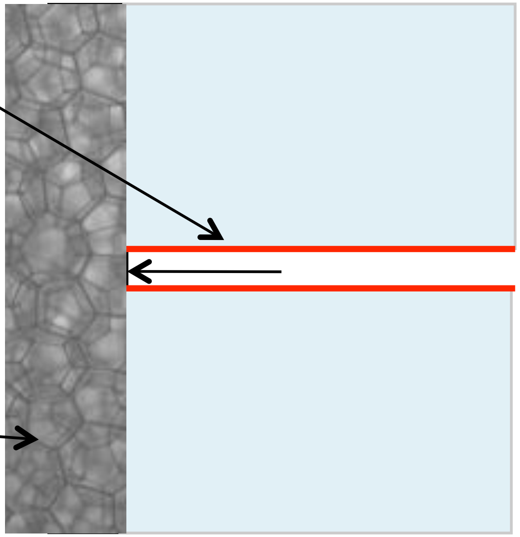
One thousand bubbles

○Static conditions : critical liquid fraction

V. Carrier, A. Colin, Langmuir 2003



○Dynamic conditions?

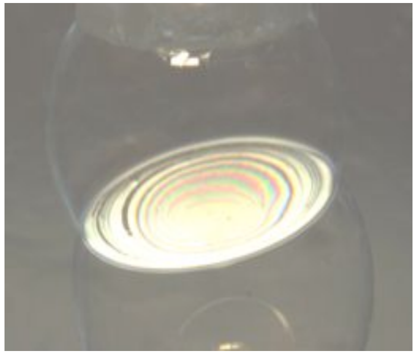


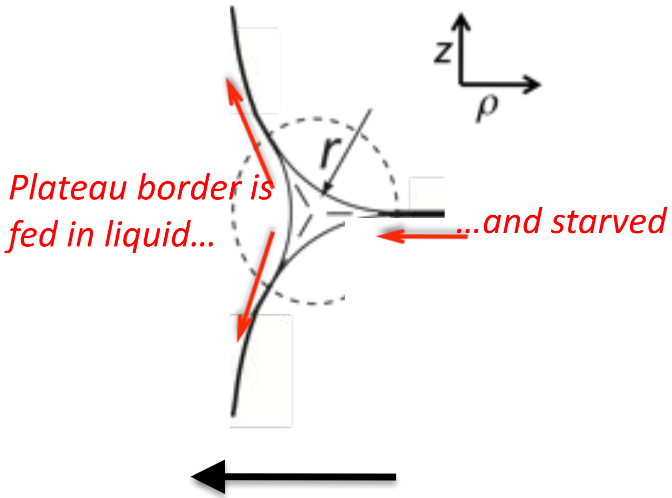
TTAB – 3 g/L

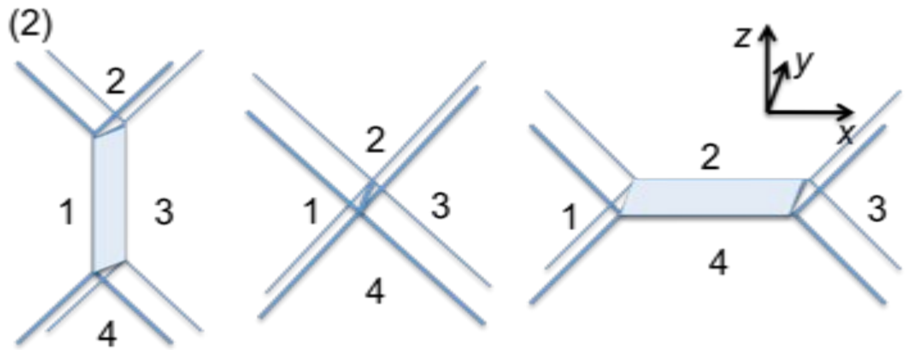
	Composition	ϵ^{*}_{crit}	ϵ^{**}_{crit}
A	TTAB	8.10^{-4}	10^{-3}
B	TTAB,LOH	$< 10^{-4}$	10^{-4}
C	SLES,CPAB	$1.3\ 10^{-4}$	$3\ 10^{-4}$
D	SLES,CPAB,MAc	$< 10^{-4}$	10^{-4}

Good agreement!

Thick films are formed during T1s



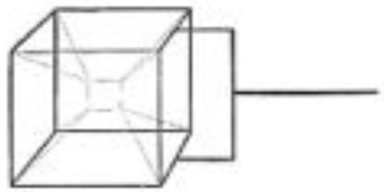


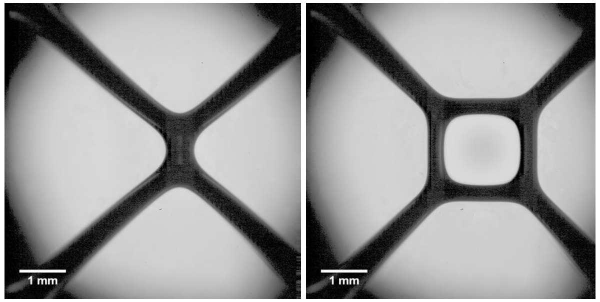


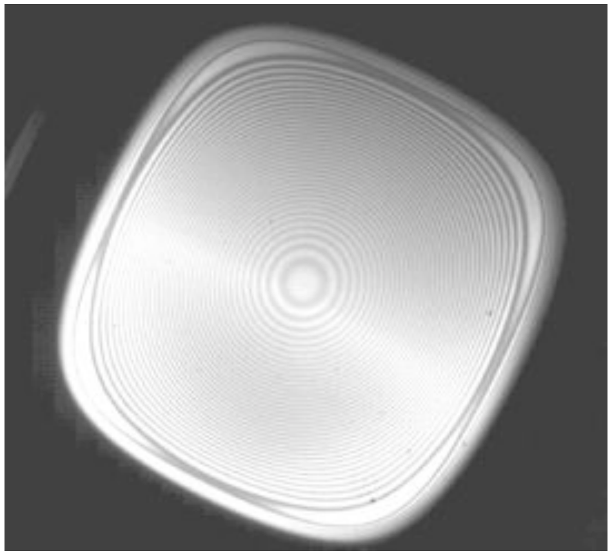
Orders of magnitude: h=5 µm – Volume$_{film}$=50 pL – Available Volume $_{\text{Plateau border}}$=50 pL…

A-L Biance, A. Delbos, O. Pitois, PRL 2011

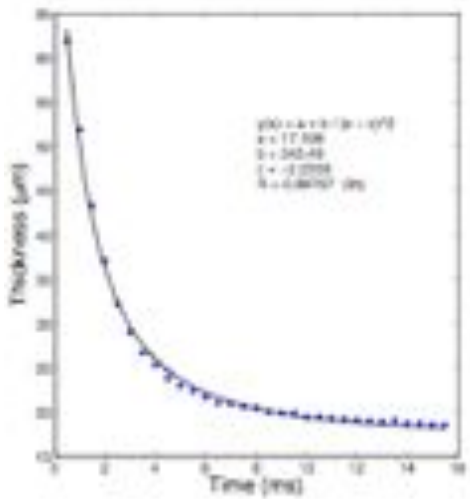
Plateau frames

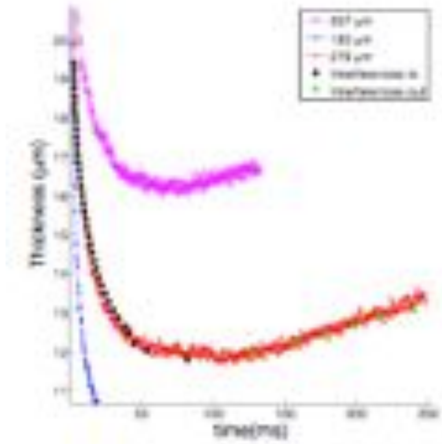


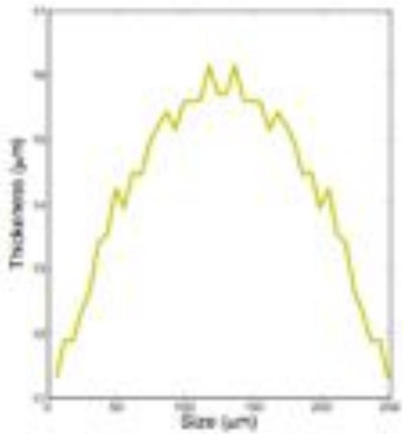




How thick?







In progress…

Conclusions and questions

- Coalescence is induced by dynamic events.

- During T1s, thick films are created.
  - ➢ How thick? When do they rupture?

- Foam collapse is induced by successions of T1s/coalescence events.
  - ➢ Avalanches have been observed.
  - ➢ Can it be connected to rheology?

- Coalescence rate in simulations, depending on shear rate?

- As films remain thick on « drainage time », does liquid fraction fluctuations have to be taken into account ?

Thanks

Adélaïde Calbry-Muzyka
Pauline Petit
Aline Delbos

Sylvie Cohen-Addad
Reinhard Höhler
Olivier Pitois