Wet foam coarsening: 3D rotating experiments

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Motivations:

Coarsening : at constant liquid fraction, bubble diameter D increases with time t : $D \sim t^{\beta}$

Coarsening exponents β versus the foam liquid fraction, ϕ_l ?

To answer, one must widely tune ϕ_l, but keep it constant during a measurement….

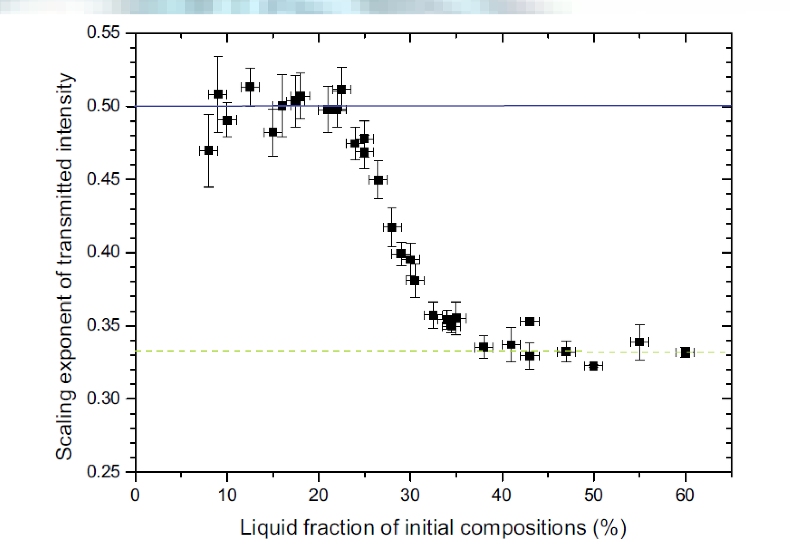


Fig. 4. The bubble growth exponent, β, determined from measurements as those shown in fig. 3 is shown as a function of liquid fraction (given in %). For comparison, the expectation of von Neumann dynamics, $\beta = 1/2$, and that of Ostwald ripening, $\beta = 1/3$ is shown by the full and dashed lines, respectively. The transition between these two regimes is rather narrow at liquid fractions between 25% and 35%.

Experiments: transition between the dry-wet regimes at high values of ϕ_l [1]

Simulations indicate a transition at very low ϕ_l [2].

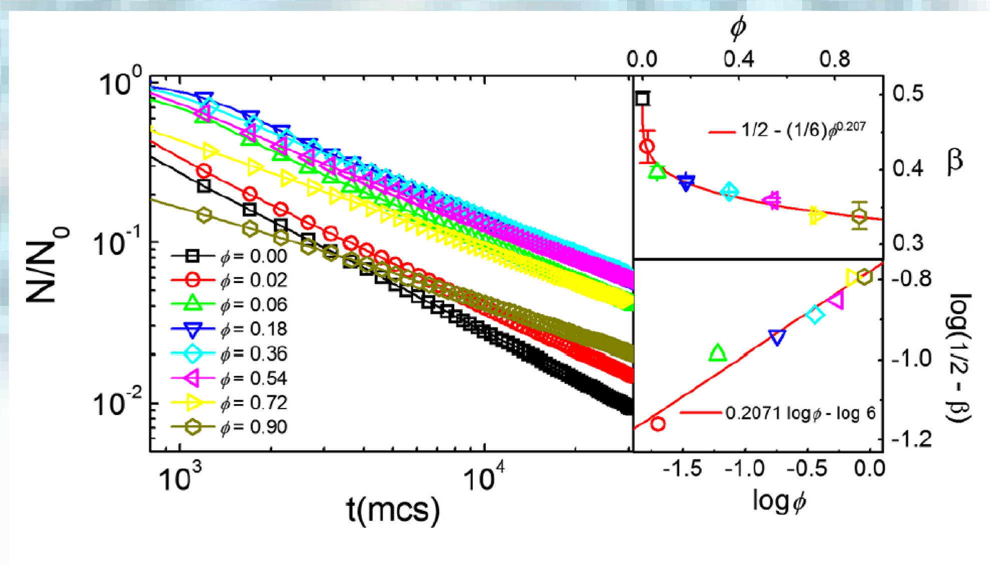


FIG. 2 (color online). (a) Evolution of the number of gas bubbles for different values of ϕ, in log-log plot. (b,c) Power law exponent β versus ϕ, in (b) linear and (c) log-log scales. The red line is $\beta = 1/2 - \phi^{0.207}/6$.

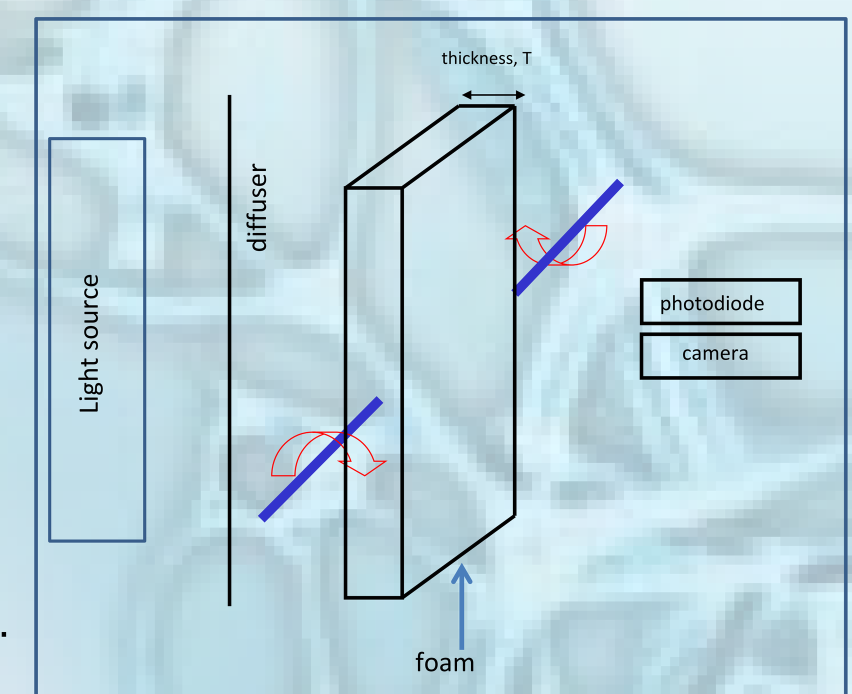
Approach / setup:

Our approach:

Removing drainage by regularly changing the direction of gravity.

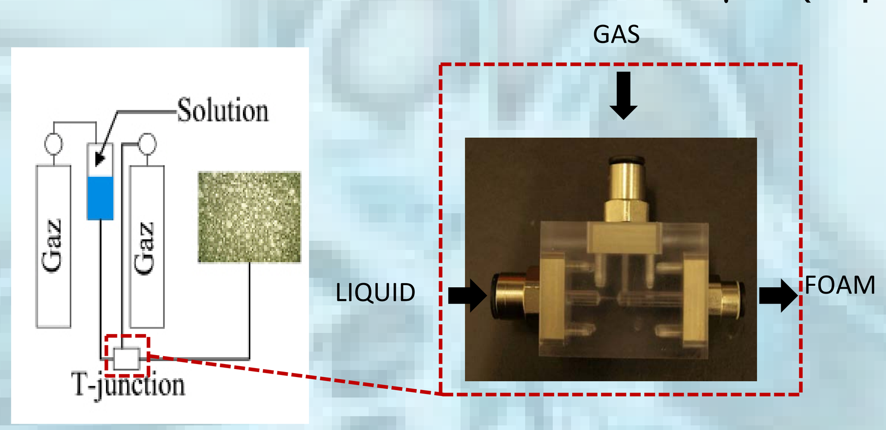
Inversion of the cell at each Δt, ranging from 10 s. to 30 s.

Another idea?
In LPS-Orsay (E. Rio, A. Salonen):
A reconstructed 3D foam, made layer by layer, with each layer being thin enough to prevent drainage in its thickness.



Rotating cell:
- Height : 30 cm, width : 12 cm ; thickness T: 3 cm.
- Foam is injected from the bottom.

Foam production:
- turbulent mixing device [3]
- liquid fraction can be varied from 0.015 to 0.5
- initial bubble radius: from 50 to 80 μm (depends on ϕ_l).



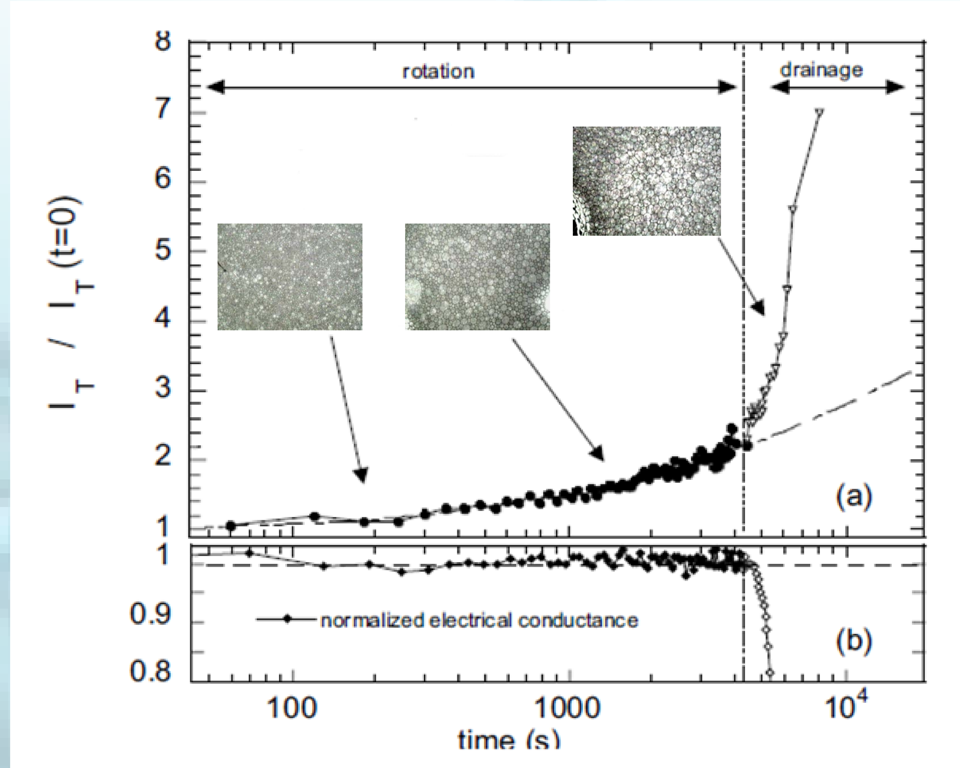
We monitor the transmitted intensity I_T

In the limit of multiple scattering:

$$I_T / I_0 \sim D / T\sqrt{\phi_l}$$

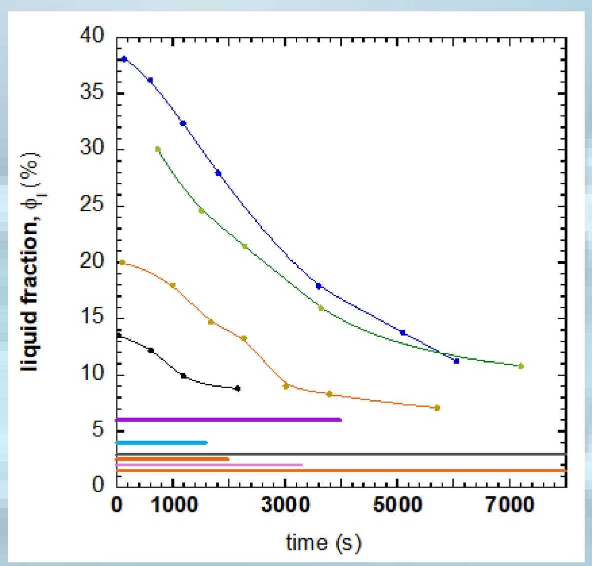
→ at constant liquid fraction, I_T scales like D

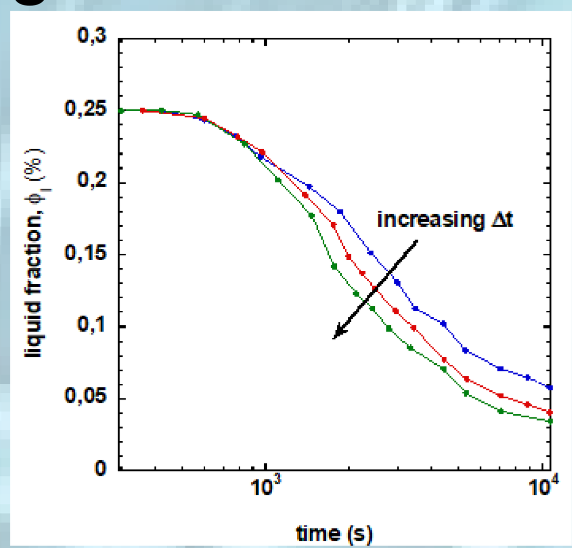
Comparing evolution with and without rotation :



Efficiency to reduce drainage?

For initial ϕ_l < 10%: a constant liquid fraction can be achieved over hours





Changing Δt also provides different drainage evolution.

For ϕ_l > 10%: decay of the liquid fraction (measured by the amount of liquid drained); BUT still very slow (500 times slower than without rotation)
→ dD/dt and $d\phi_l/dt$ are of the same order.

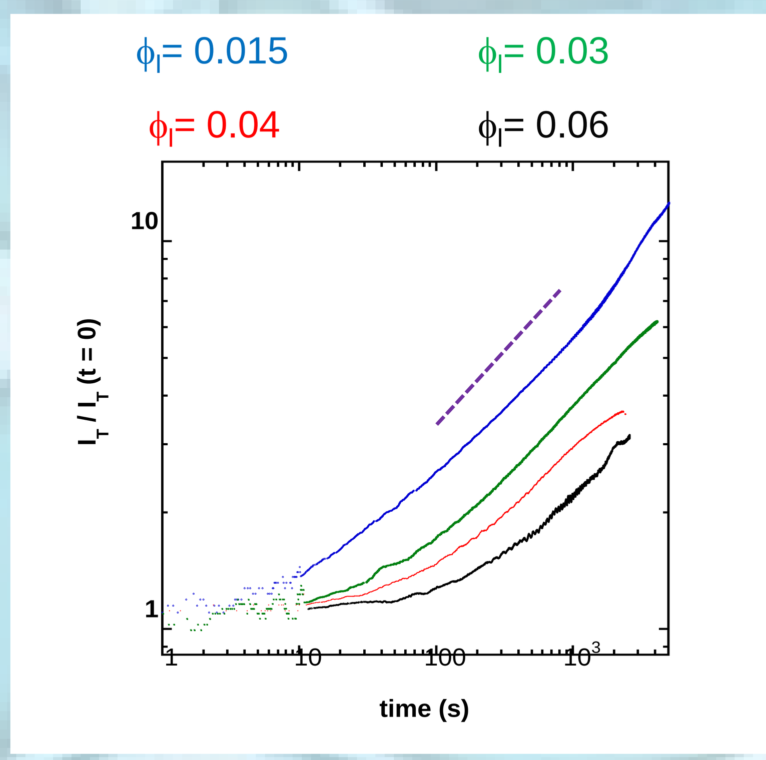
liquid fraction, ϕ_l < 10%

As ϕ_l is constant, I_T / I_T (t=0) provides the relative evolution of D(t)

Qualitatively, coarsening gets slower as ϕ_l increases.
Scaling regimes have similar exponent (except for the dryest foam at large times).

Quantitatively, scaling exponents can be extracted:

β = 0.39 +/- 0.015



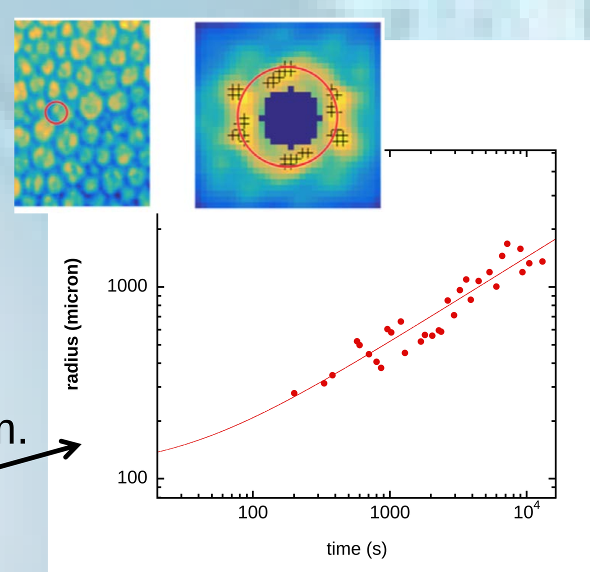
Perspectives for liquid fractions above 10%:

I_T varies because of both D(t) *and* ϕ_l(t)…

Relying on light scattering model to decouple D(t) and ϕ_l(t) ? Roughly consistent with $\beta \sim 1/3$, but not accurate enough…

An independent measurement of D(t)?
image acquisition + new treatment by Fourier Transform.

Tested on dry foams (ϕ_l = 0.03):
consistent with light scattering data !

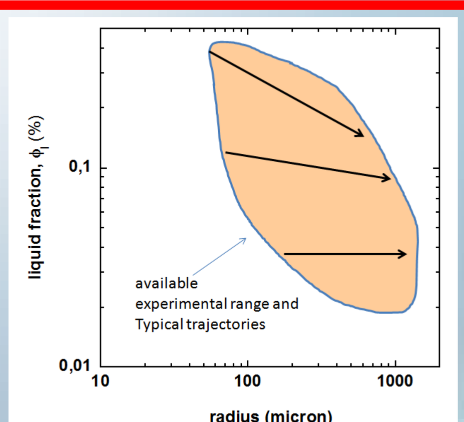


Improving data analysis:

- With independent measurements of D(t) et ϕ_l(t) + using various experiments (trajectories) where D and ϕ_l changes smoothly, it must be possible to ascribe a coarsening (and drainage) rate for each given set of D and ϕ_l.
- Compiling all these 'instantaneous' coarsening (and drainage) rate together, one can then obtain :
  - dD/dt at constant ϕ_l, versus ϕ_l and D
  - $d\phi_l$ / dt at constant D, versus ϕ_l and D

Conclusions:

a wide set of experimental parameters!



Coarsening exponents are measured well below 0.5, even for foams with liquid fractions of a few percents.

With this setup, drainage still occurs for wet foams…, but slowly enough so that there are ways to decouple the evolution of ϕ_l(t) and of D(t).

REFERENCES
1 – N. Isert *et al.*, *Eur.Phys.J.*E 36, 116 (2013).
2 – I. Fortuna *et al.*, *Phys. Rev. Lett.* 108, 248301 (2012).
3 – A. Saint-Jalmes, EPJ B, 12, 67 (1999).

ACKNOWLEDGEMENTS
Thanks for stimulating discussions :
E. Rio, E. Forel, C. Guidolin, A. Salonen