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Coarsening in complex wet foams

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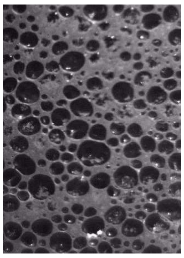
Context

Yield stress fluids, like emulsions, cement and molten metal, can be foamed: doing so they can loose weight and gain insulating properties, while keeping their elastoplastic properties, even if solidified.

In such a complex foam the yield stress can be tuned to counteract drainage and oppose bubble deformations, slowing or stopping the natural foam coarsening due to the inter-bubble gas exchange.[1]

My research focuses on the coarsening of wet foams, and how it changes with yield stress.



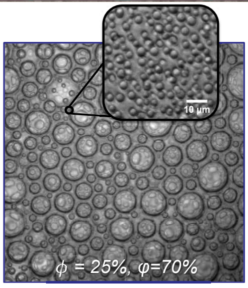
Samples

Materials:

- *Emulsion*: Silicone oil droplets inside a Gly/H_2O solution, index matched to ensure transparency.
- *Surfactant*: TTAB, both for droplets and bubbles.

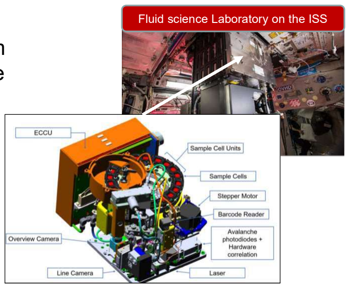
Parameters:

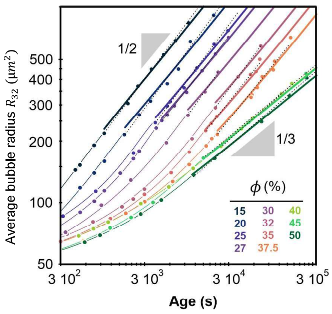
- Air bubble average radius: $30\mu m \leq \langle R \rangle \leq 600\mu m$
- Oil droplet Sauter radius: $r_{32} \approx 3\mu m$
- Liquid volume fraction: $8\% < \phi < 50\%$
- Oil volume fraction: $0\% < \varphi < 80\%$



Experimental setup and techniques

- **Microgravity experiments**: in the International Space Station the foam is produced in situ inside the sample holder[2], which is equipped with multiple optical instruments.

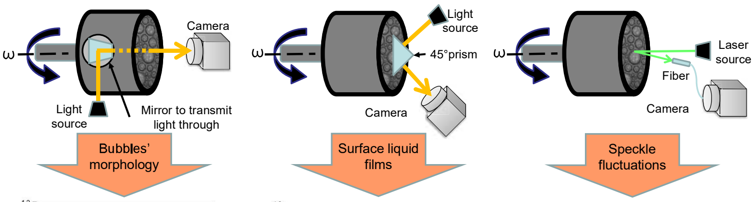


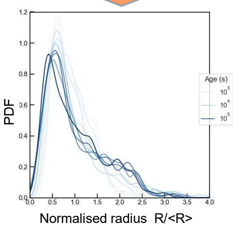


In this setup we studied the *coarsening of simple foams*[3,4]. This research works here as the reference in the comparison with complex foams.

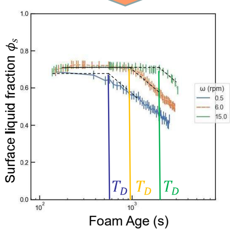
- **Ground Experiments**: the sample foam is injected in a cylindrical cell, kept under a rotation ω to prevent drainage. Like in microgravity experiments, the setup is equipped to perform multiple optical measurements in parallel:

Videomicroscopy in transmission	Videomicroscopy in total reflection	Multispeckle DWS in backscattering

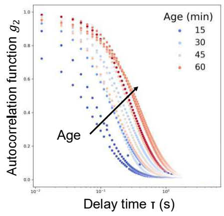




Bubble size distribution converges to a scaling state



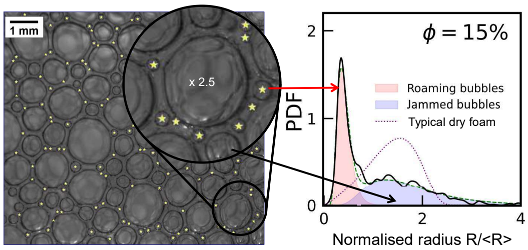
Drainage prevented by rotation ω until time T_D

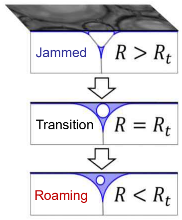


The duration of bubble rearrangements evolves in time

Hierarchical structure in wet foams: roaming bubbles

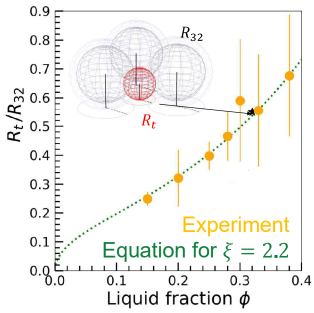
Our experiments[5] in simple coarsening foams reveal the presence of a bubble population *roaming* inside the interstices between *jammed* bubbles.





Bubbles start roaming when their size is smaller than a radius $R_t \propto R_{32}$; their unjammed state increases their lifetime and induces a *hierarchical structure*.

We find a scaling law between R_t and the *effective liquid channel radius*[6]:



$$\frac{R_t}{R_{32}} = \xi \sqrt{\frac{8\tilde{K}(\phi)}{\tilde{\sigma}(\phi)}}$$

ξ nondimensional factor

$\tilde{K}(\phi)$ dimensionless flow permeability

$\tilde{\sigma}(\phi)$ relative electrical conductivity

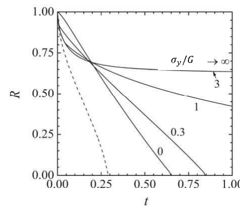
We find that roaming bubbles appear in foams regardless of the choice of gas, surfactant, and also in complex foams.

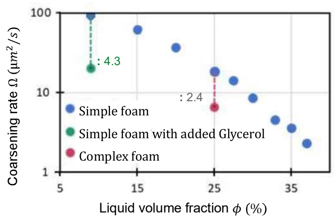
Hierarchical porosity can enhance *energy absorption* in solid materials[7]: controlling roaming bubbles could help to *design* solid foams properties.

Fine tuning in complex foams

Simulations show[8] that the combination of yield stress σ_y and elastic modulus G can increase the lifetime of isolated bubble loosing gas.
⟶ In principle in a complex foam you can:

- Slow down coarsening in the overall foam
- Stabilise roaming bubbles in the elastic matrix





In **experiments** with *small* σ_y, we observe instead a larger coarsening rate than what we expect for a simple foam with the same liquid fraction and the same glycerol amount: this hints an additional mechanism, due to the oil fraction φ but opposed to yield stress.

Objectives:

- Highlight the nature of the unkown mechanism opposing yield stress
- Determine the different coarsening regimes as a function of σ_y, φ
- Characterise the foam dynamic in the coarsening regimes

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