Elastocapillary effects in double dynamics networks

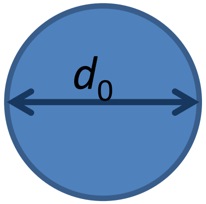
Carole-Ann Charles

My background

Bachelor degree in engineering science
Major in applied chemistry and physics, minor in mechanics,
Université Catholique de Louvain

Master degree in chemical and material science engineering, specialization in polymers and macro-molecules,
Université Catholique de Louvain

Elastocapillarity



- What is it ?

Ability of capillary forces to deform a material

Bulk elasticity ⬌ Surface energy

$$\epsilon_{bulk} \sim d_0^3 E \qquad \epsilon_{surface} \sim d_0^2 \gamma$$

Elasto-capillary length :

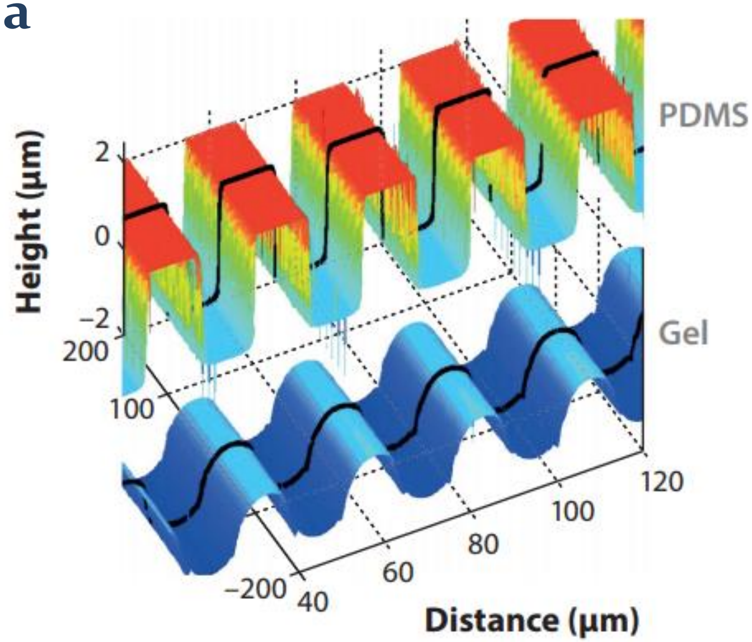
$$\boxed{l_{ec} = \frac{\gamma}{E}}$$

$d_0 < l_{ec}$ Surface energy prevails

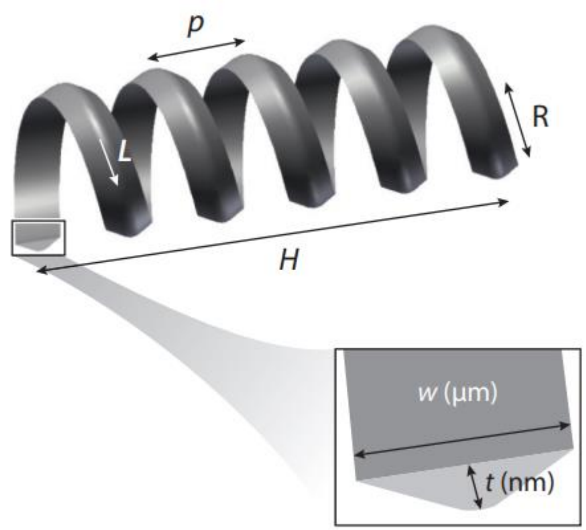
$d_0 > l_{ec}$ Bulk elasticity prevails

Elastocapillarity

a



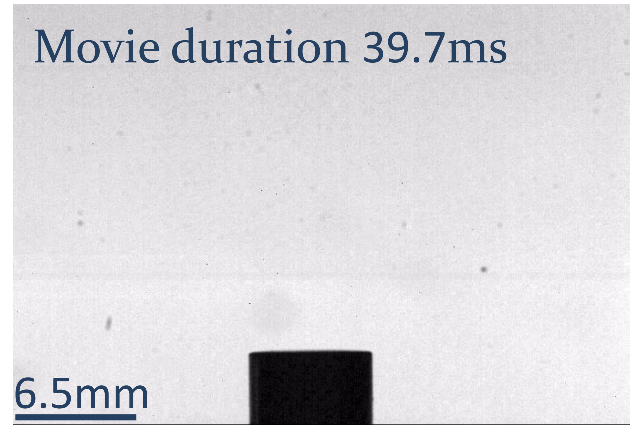
b



Paretkar et al., Soft Matter, 2014, 10, 4084-4090

Pham et al., Adv. Mater. , 2013, 25, 6703-6708

Drop impact



Impact of a water droplet on a small target

Upon impact :

Inertial forces → radial expansion of the sheet

Stored surface energy → retraction after maximal expansion

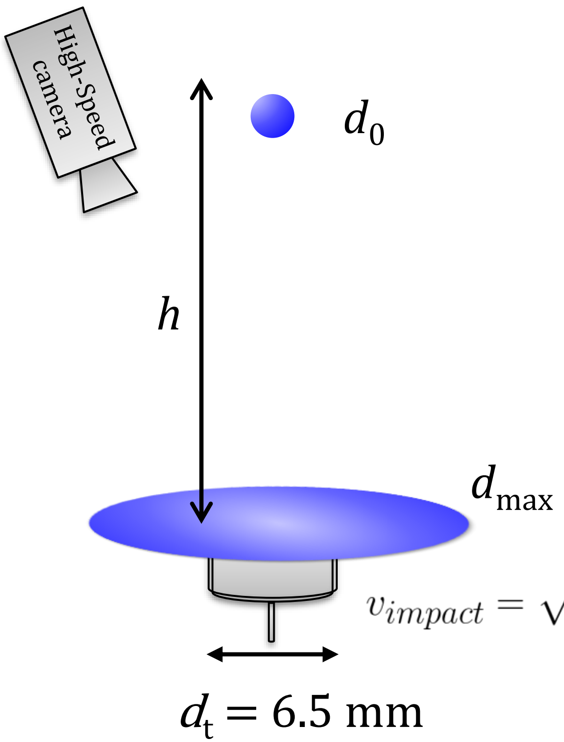
Goal:

Rationalize the respective role of

- Inertia
- Elasticity
- Capillarity
- Dissipation

Drop impact

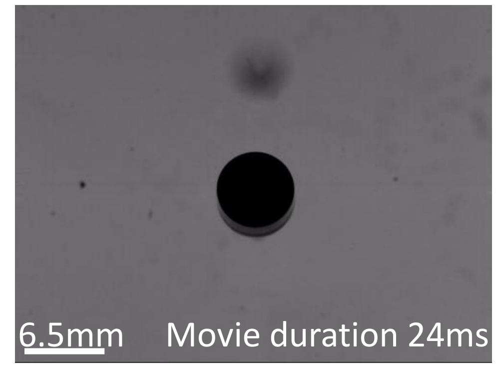
- On a small target



$$v_{impact} = \sqrt{2gh} = 4.22\ m/s$$

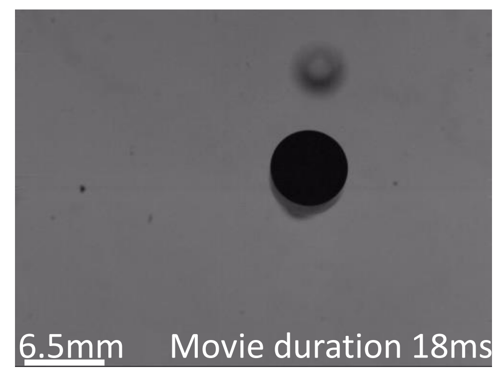
S. Arora et al, 2017

Silicone oil 5 mPas



$d_{max}/d_0 = 6.17$

Silicone oil 350 mPas



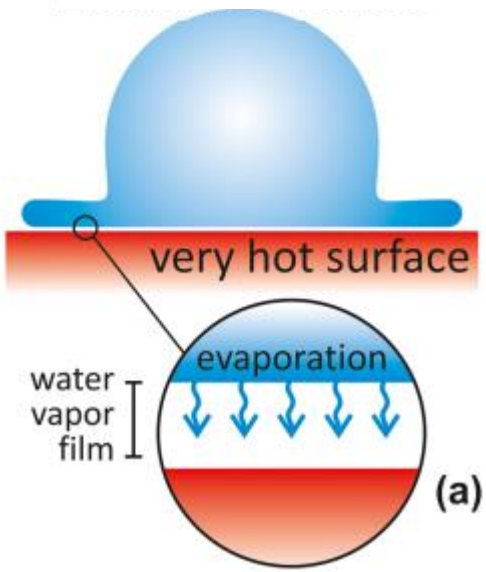
$d_{max}/d_0 = 1.78$

Dissipation effect due to target

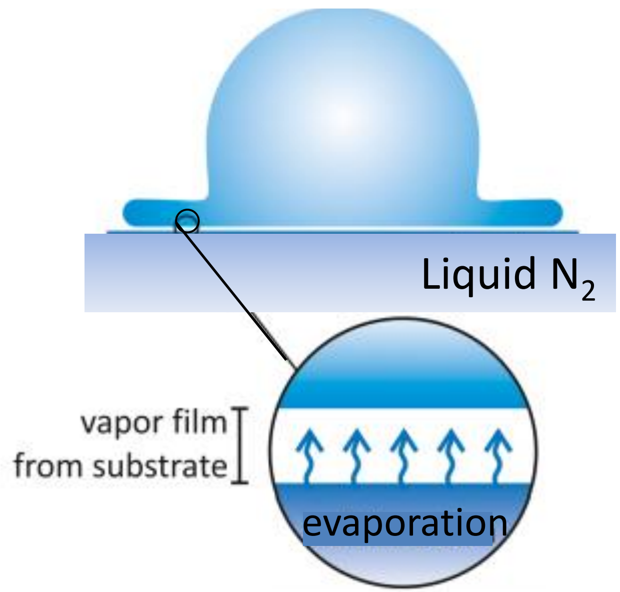
Drop impact

- Leidenfrost effect

Leidenfrost effect



Inverse Leidenfrost effect



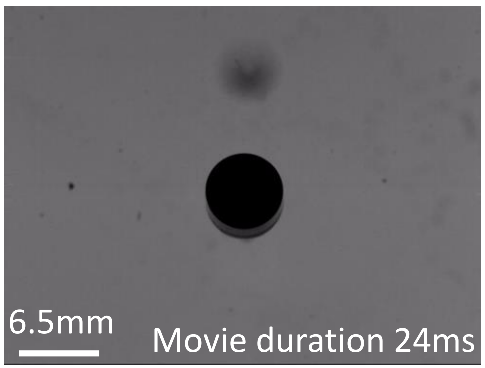
C. Antonini et al., Phys. Rev. Lett., 2013

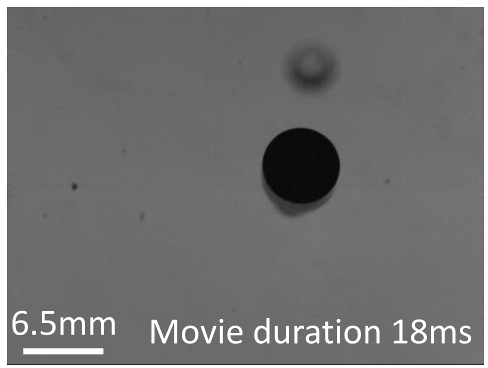
Drop impact

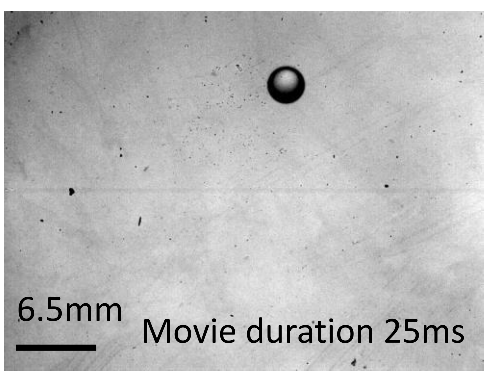
- Inverse Leidenfrost effect

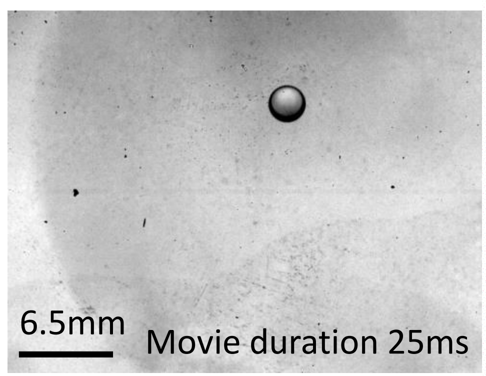
Silicone oil 5 mPas

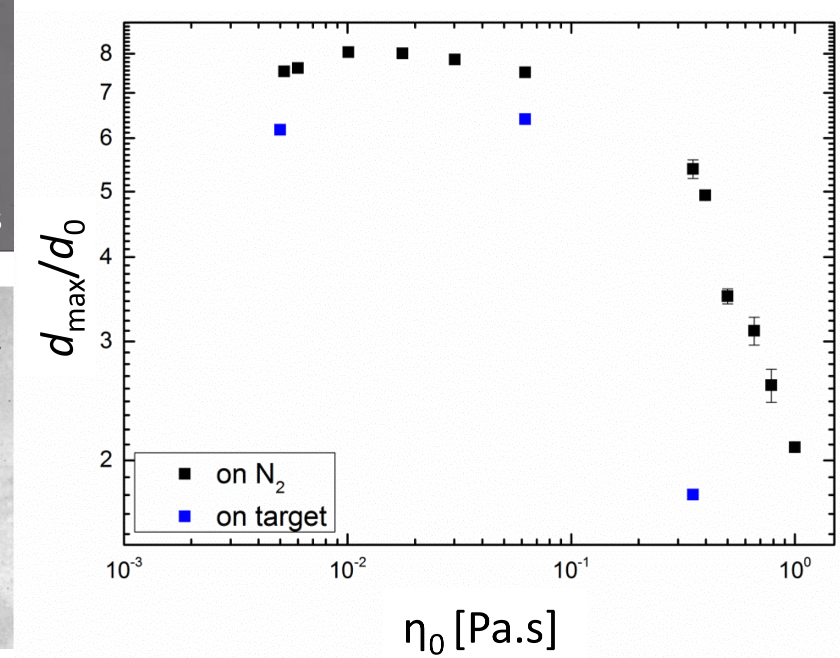
Silicone oil 350 mPas





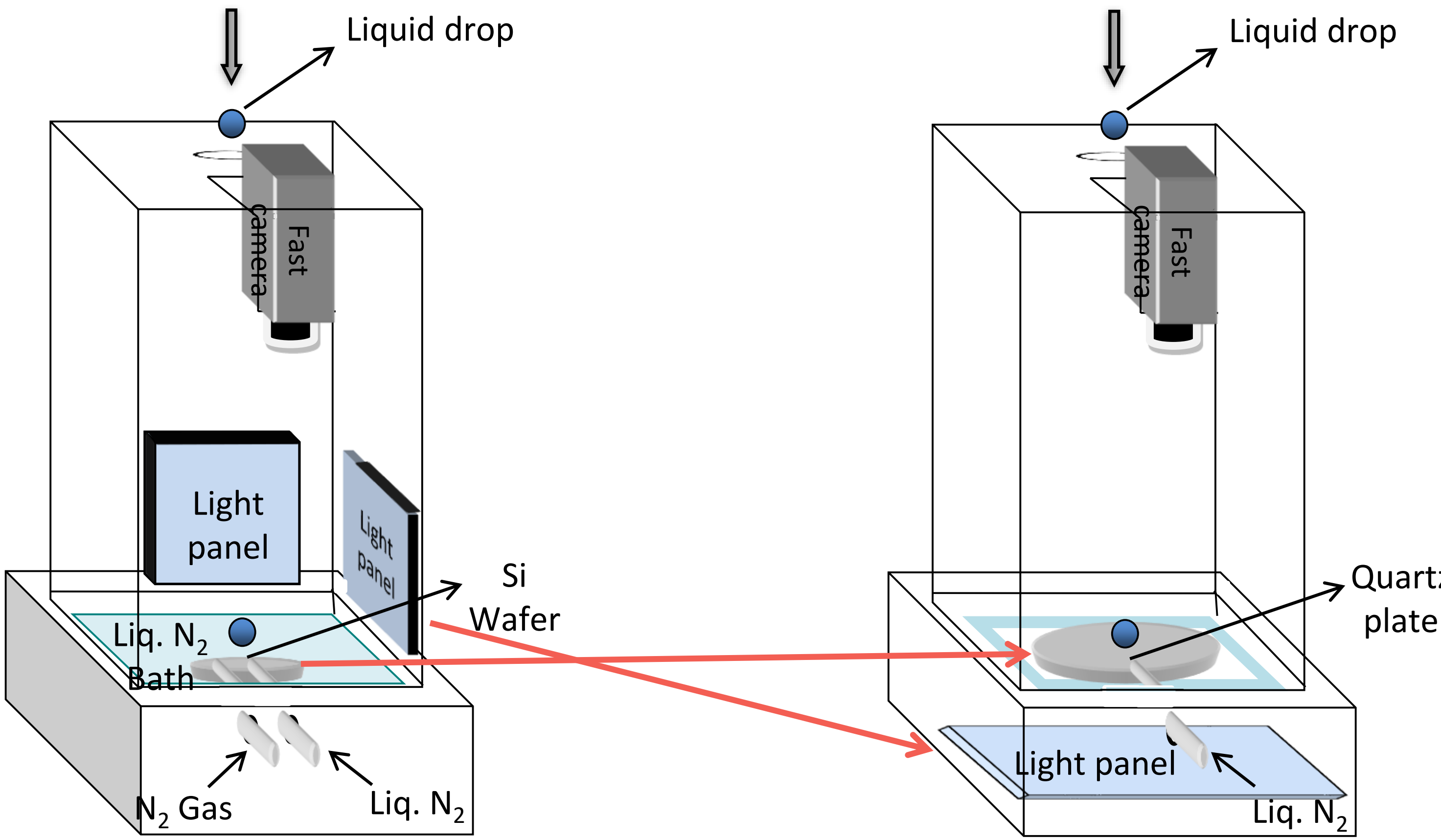






Drop impact

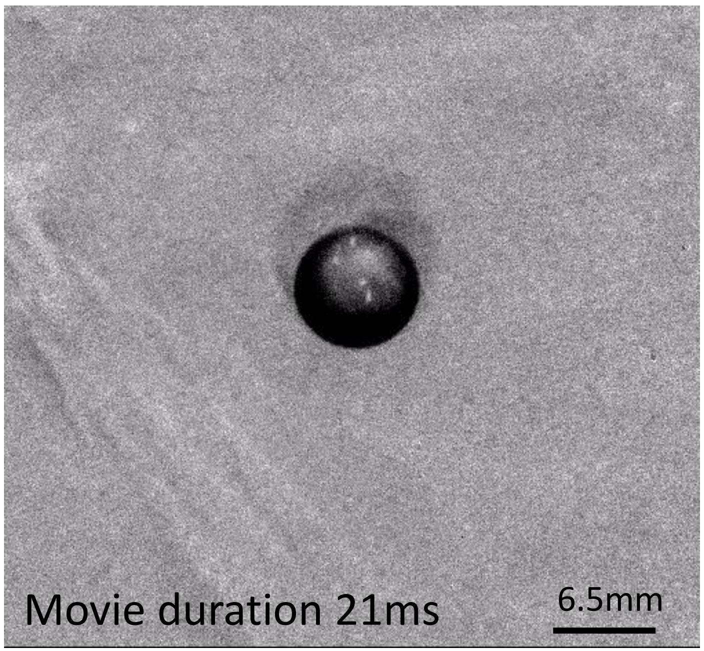
- Inverse Leidenfrost effect : Set up improvement



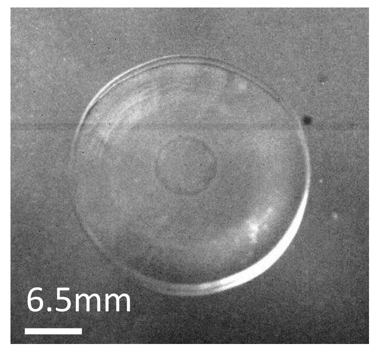
S. Arora et al, 2017

Drop impact

- Inverse Leidenfrost effect : Set up improvement

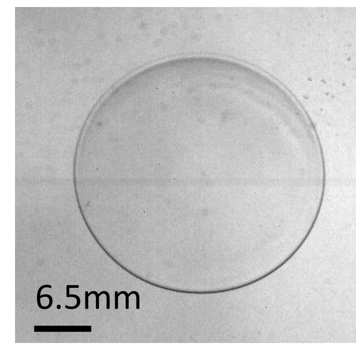


Before



S. Arora et al., 2017

After



➡ Enables semi-automatic analysis

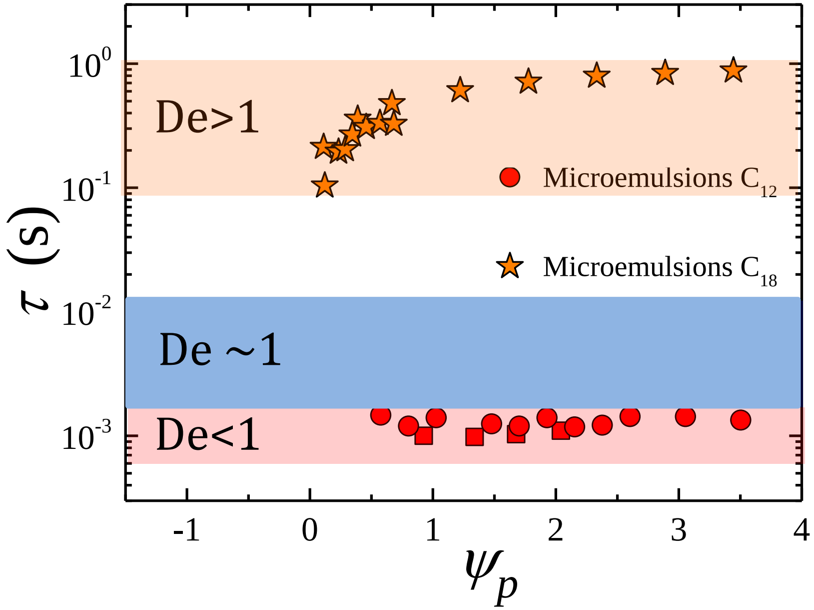
➡ Enables the analysis of the sheet thickness field

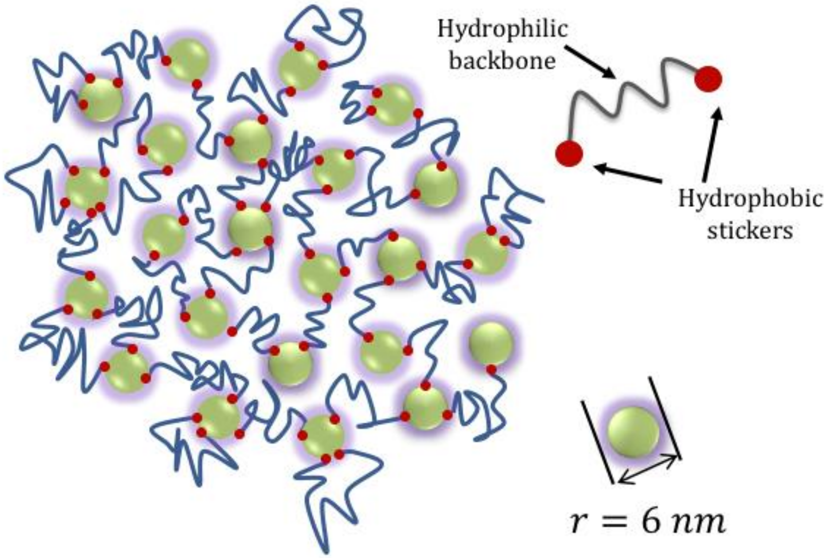
Drop impact

- Impacts of viscoelastic fluids

Low viscosity

Relaxation time ≈ 10 ms





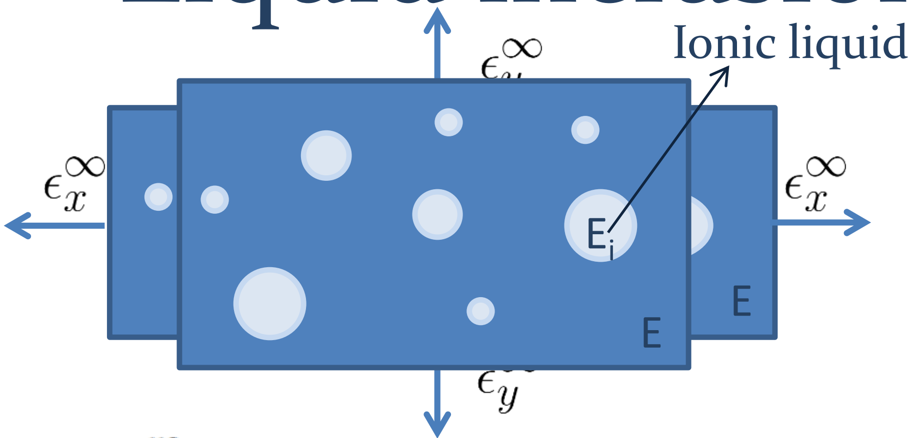
Microemulsions reversibly linked by telechelic polymers,

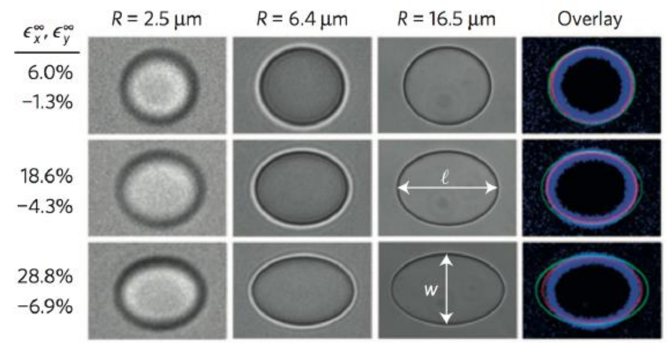
C_n-$(PEO)_{35k}$-C_n (n = 12, 18)

S. Arora et al, 2017

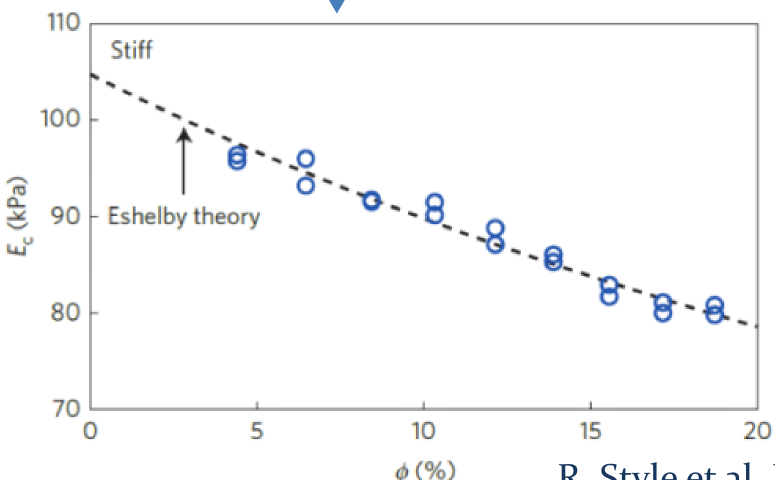
Mixing C12 and C18 to obtain intermediate relaxation times

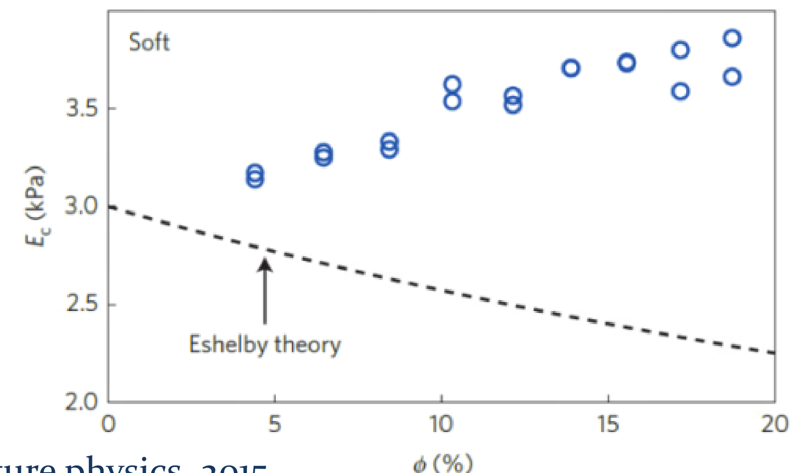
Liquid inclusions in soft matrix





R. Style et al, Nature physics, 2015, 11, 82–87





R. Style et al, Nature physics, 2015

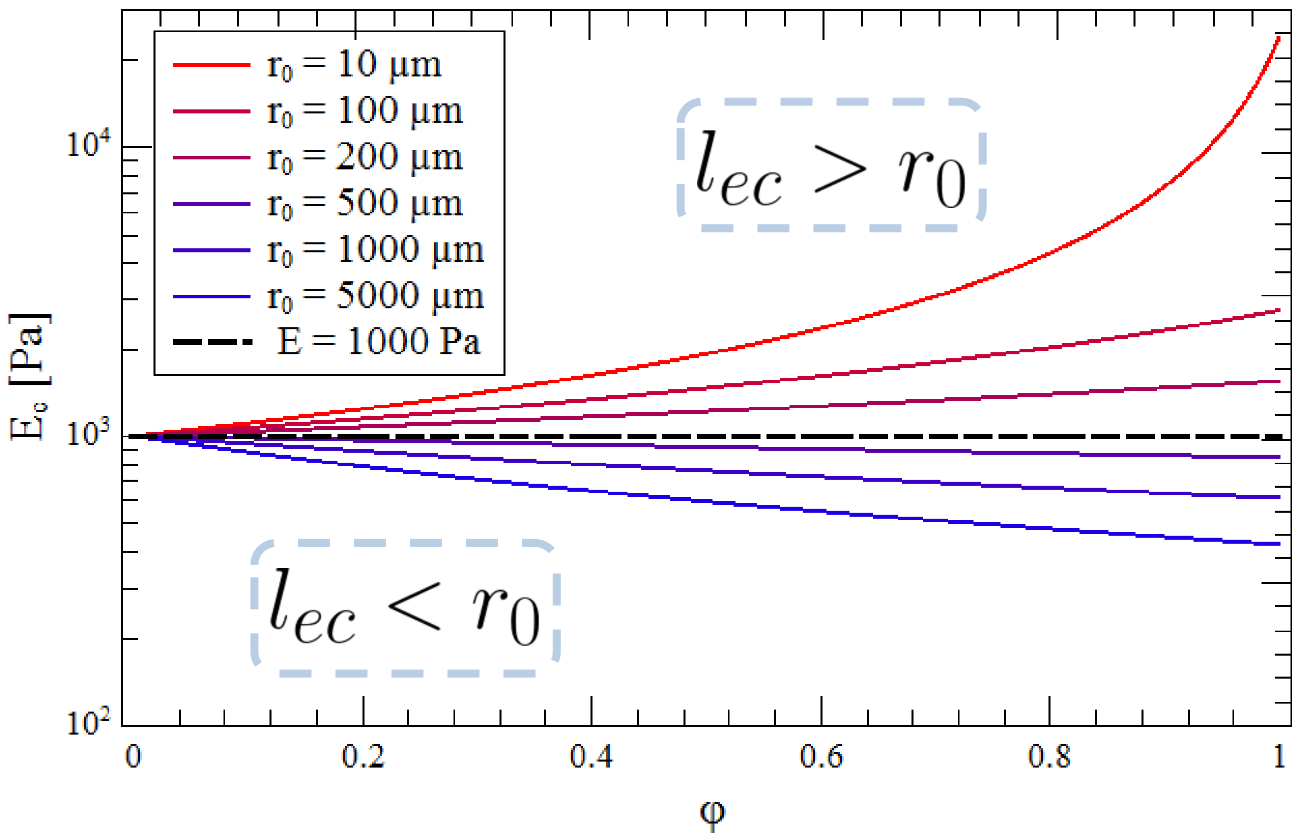
Liquid inclusions should reduce the stiffeness of a solid composite

Small liquid inclusions in a soft matrix stiffen the solid composite

Liquid inclusions in soft matrix

$$E_c = E\frac{1+\frac{5}{2}\frac{\gamma}{E_i r_0}}{\frac{5}{2}\frac{\gamma}{E_i r_0}(1-\phi)+(1+\frac{5}{3}\phi)} \quad \text{with} \quad l_{ec} = \frac{\gamma}{E_i}$$

(R. Style et al, Nature physics, 2015)



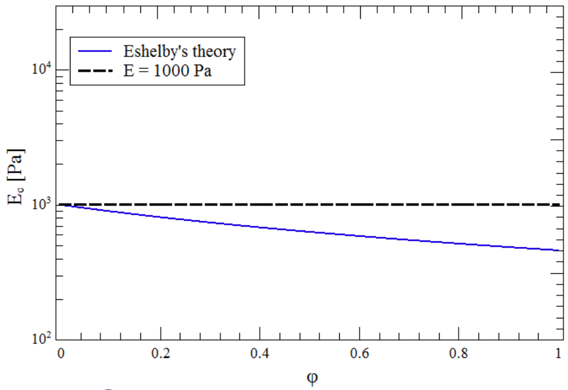
E = 1000 Pa
E_i= 200 Pa
γ = 50 mN/m

Viscoelastic inclusions in soft matrix

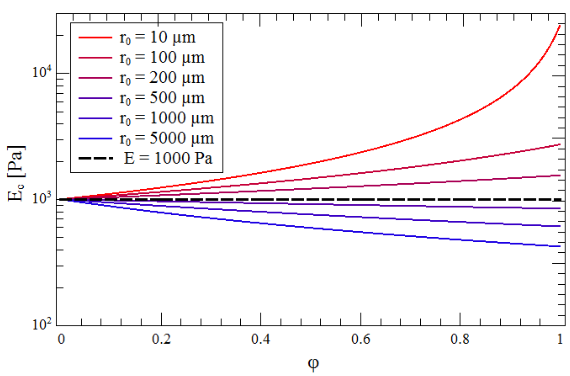
- And for transient networks?

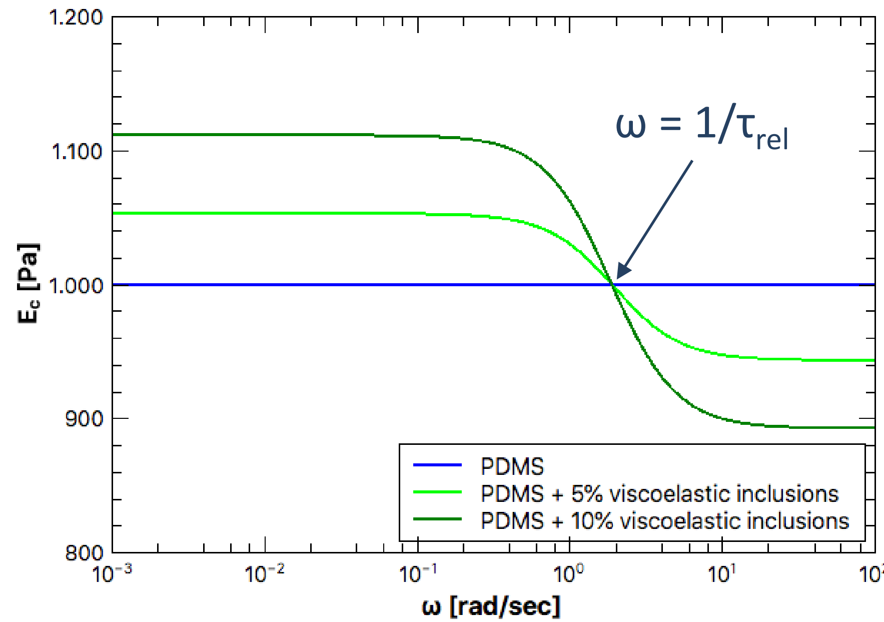
$$l_{ec}(De) = l_{ec}\frac{1 + De^2}{De^2}$$

High frequencies



Low frequencies





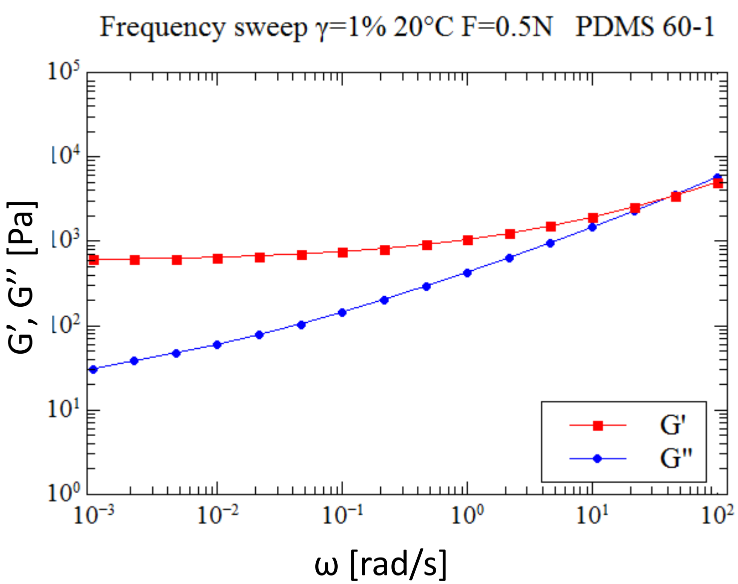
Viscoelastic inclusions in soft matrix

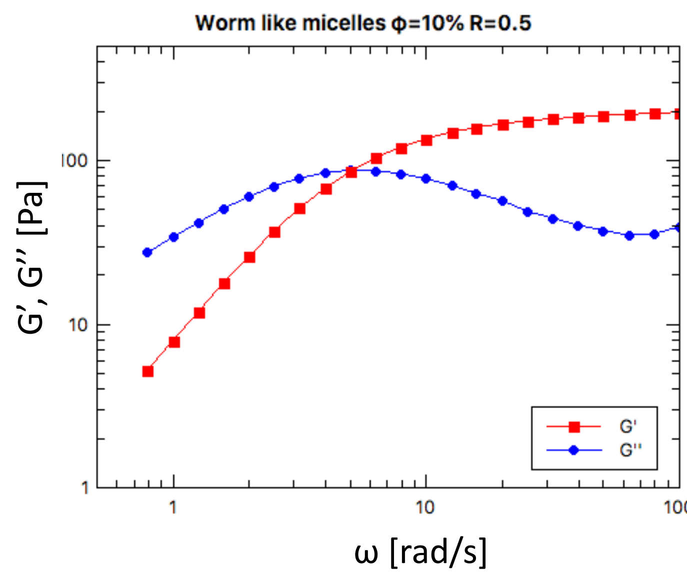
- And for transient networks?

Soft PDMS **+** Worm like micelles

$$\frac{Siloxane}{Tetravalent\ crosslinker} = 60$$

$$Brine + CPCl + NaSal$$

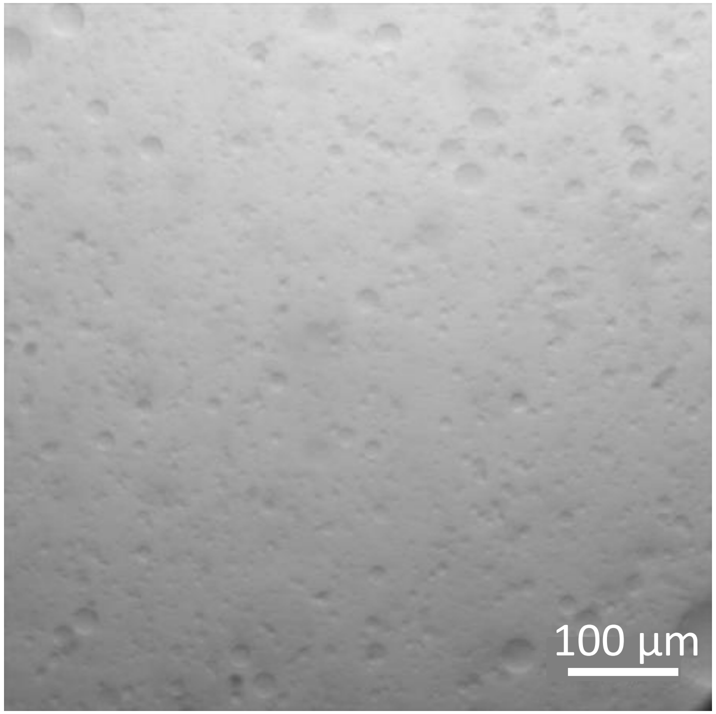




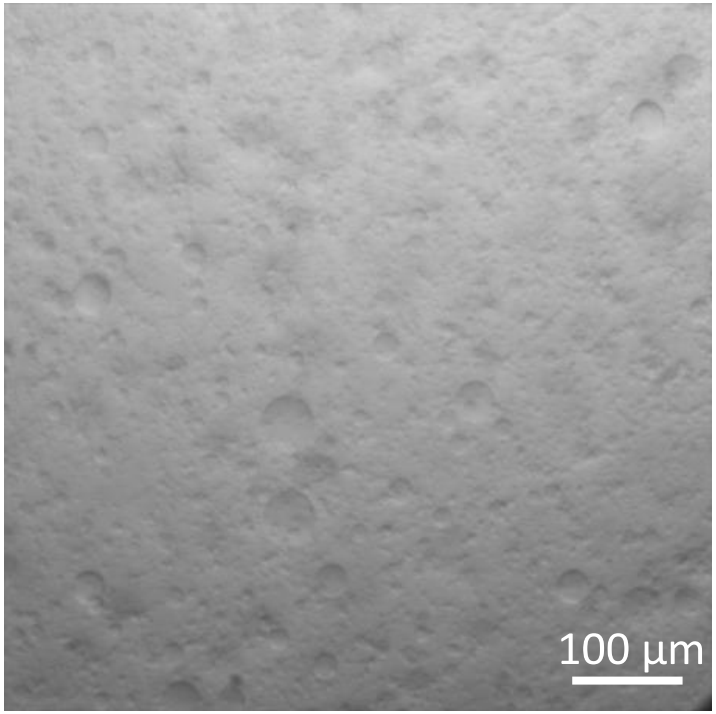
Viscoelastic inclusions in soft matrix

- And for transient networks?

5 % micelles in PDMS 60-1
mixed by hand



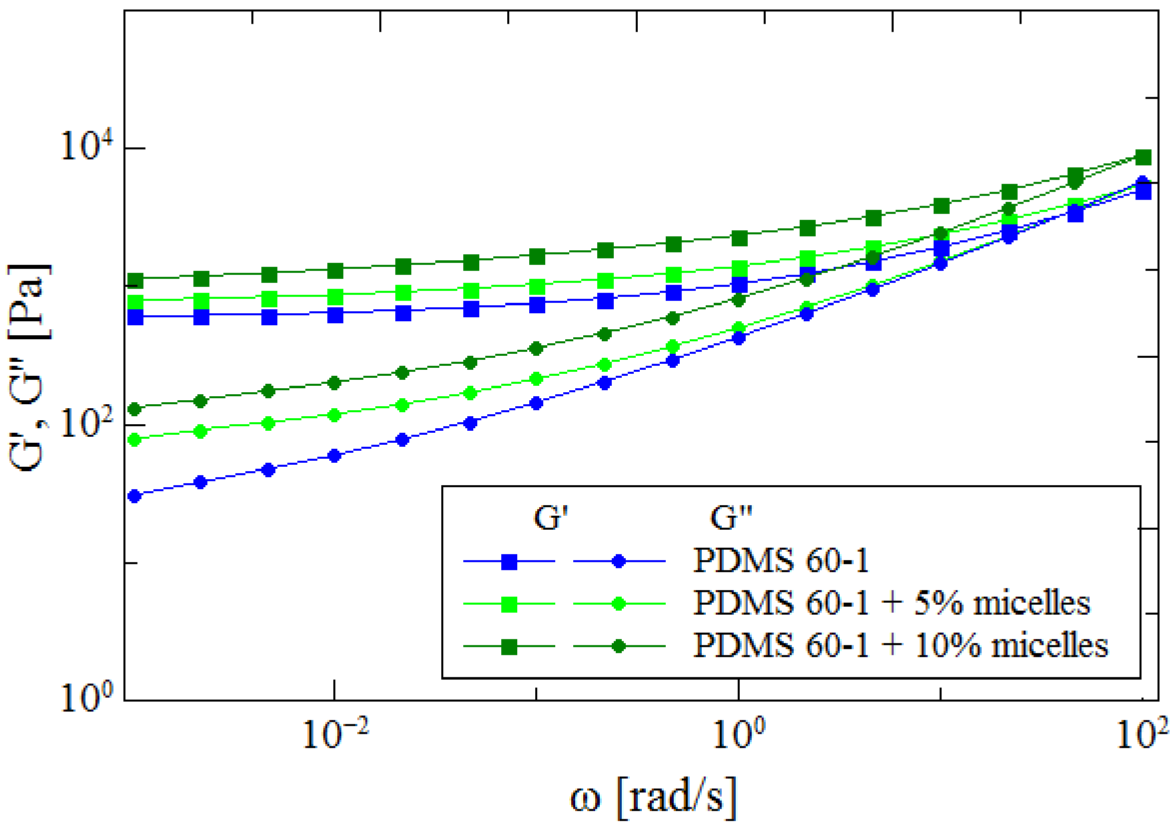
10 % micelles in PDMS 60-1
mixed by hand



Viscoelastic inclusions in soft matrix

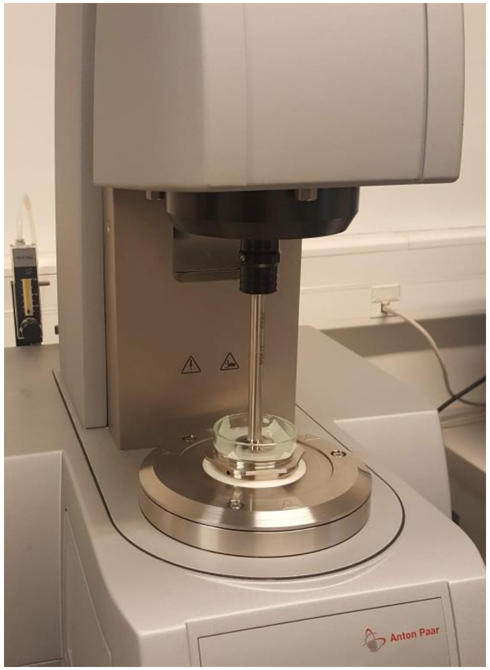
- And for transient networks?

Frequency sweep γ=1% 20°C F=0.5N PDMS 60-1 + micelles mixed by hand



Viscoelastic inclusions in soft matrix

- And for transient networks?

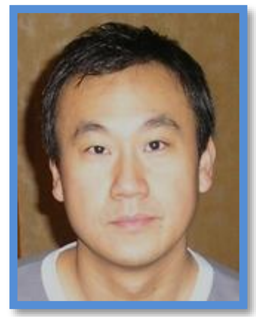


- Error on gap?
- Boundary conditions?
- Effect of the tape?
- Effect from the PDMS viscoelasticity?
- Size distribution?

Acknowledgment

Christian Ligoure

Laurence Ramos



Ty Phou

Jean-Marc Fromental

Ameur Louhichi

Thank you for your attention