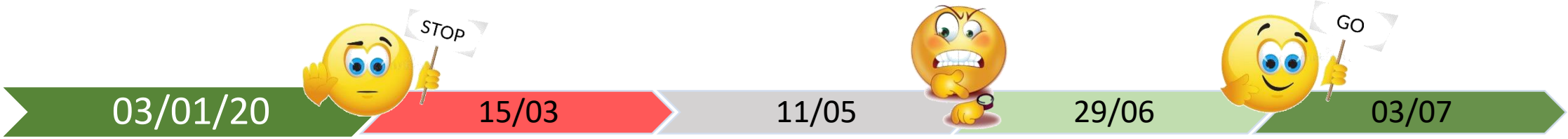
Thesis Subject

"Startup Flow of Associative and Repulsive Microgel Suspensions"

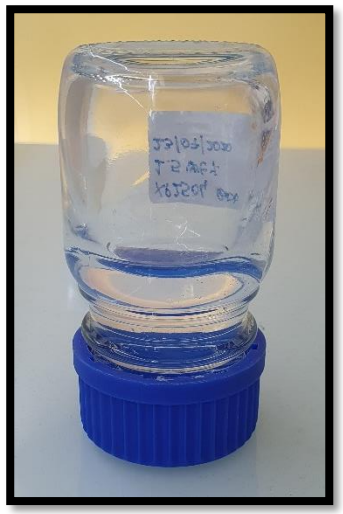
Under the supervision of Michel Cloitre

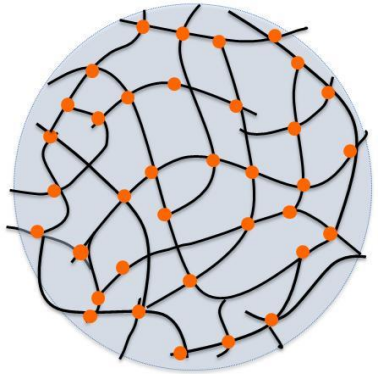
ESPCI PARIS



Double Dynamics Networks: Chemistry Matters

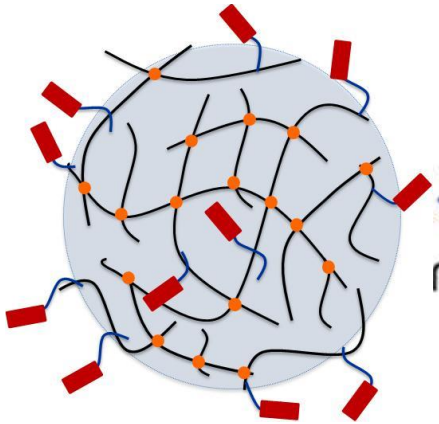
water + microgels

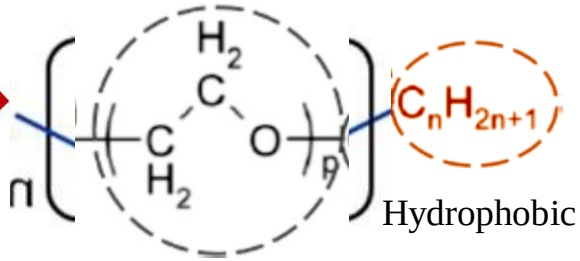




Repulsive

- Colloidal particles made of water (99 %)
- R_H = 10 – 500 nm
- Soft and deformable
- Tunable interactions





Hydrophobic

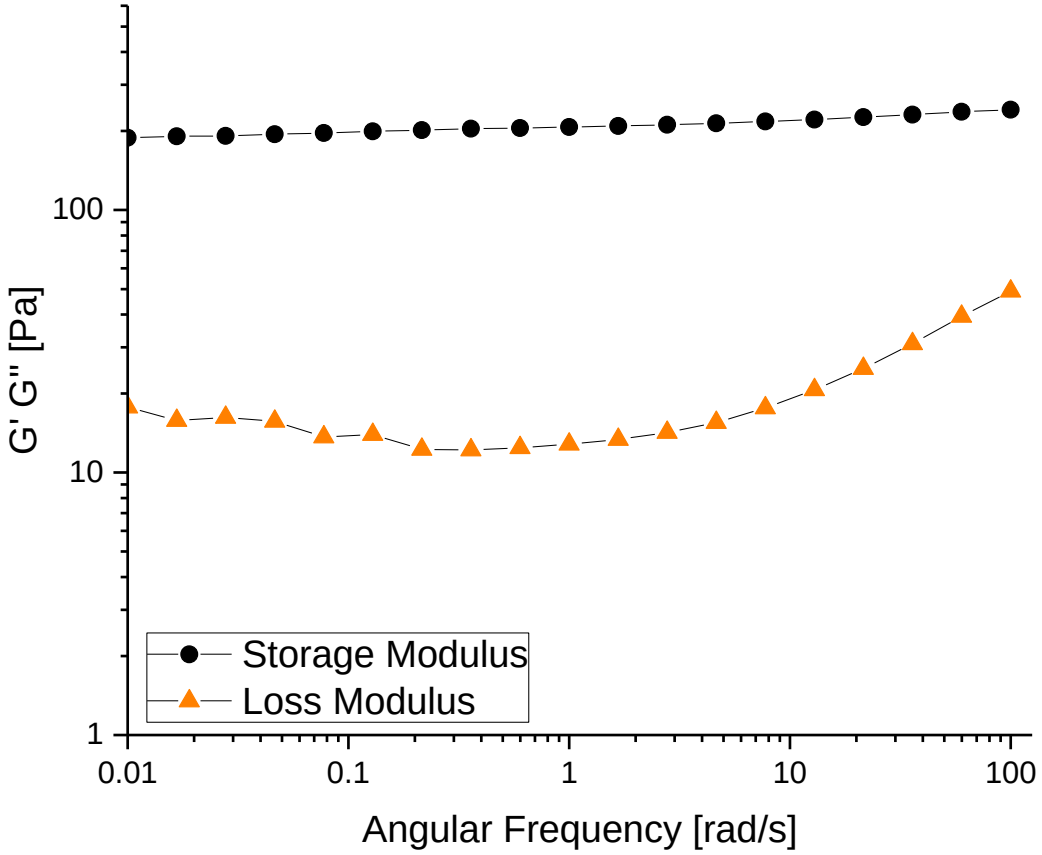
Associative

C22

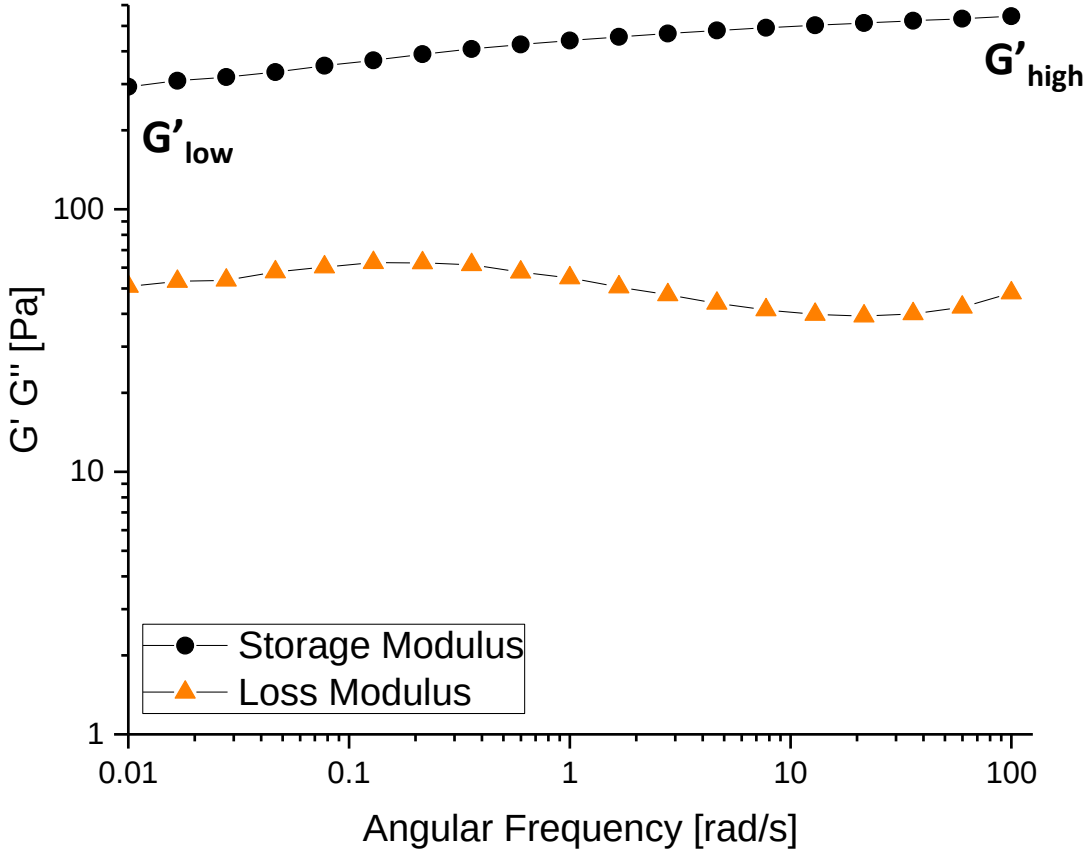
COATEX
ARKEMA GROUP

Linear Viscoelasticity

Repulsive Microgels



Associative Microgels



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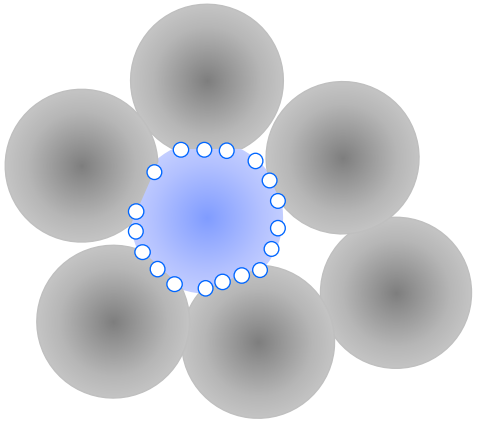
Collaboration foreseen with Dimitris Vlassopulous (high frequency rheology)

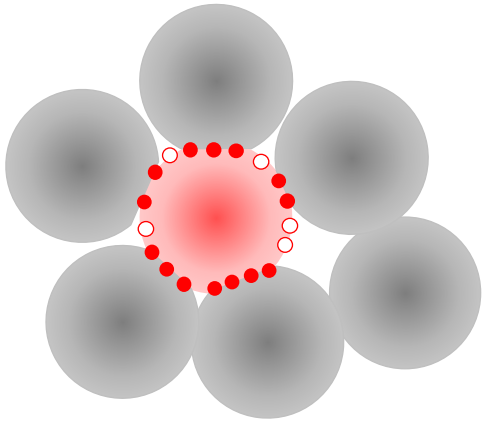
Glass-gel duality

Repulsive cage/glass

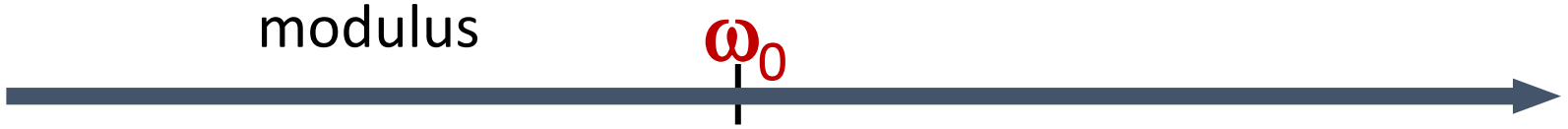


Low frequency modulus

Associative cage/gel



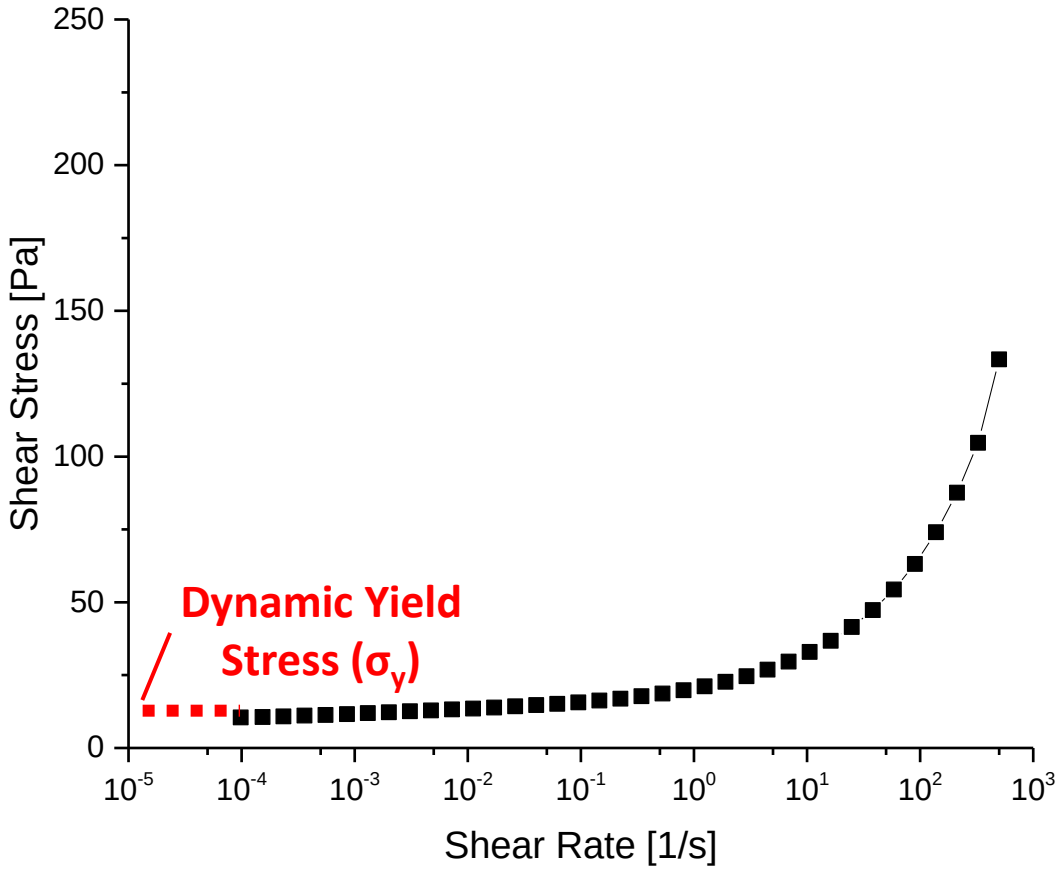
High frequency modulus



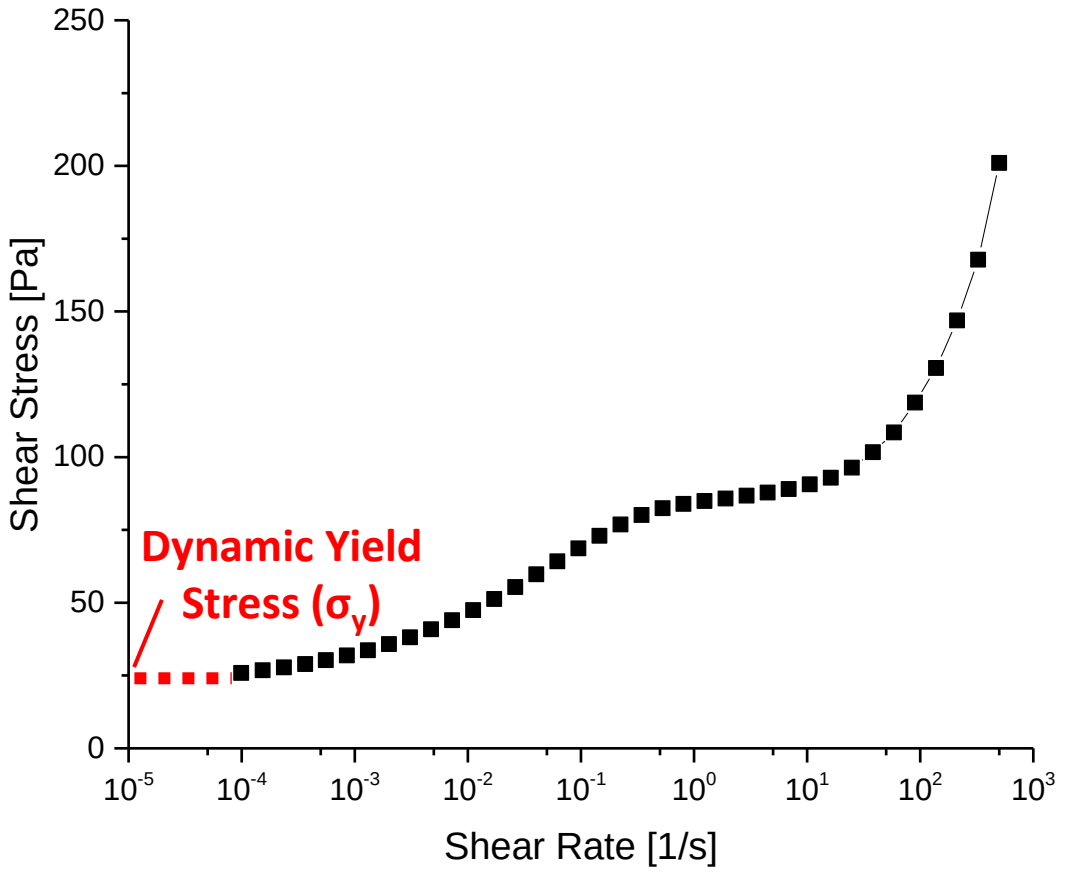
ω_0 is the relaxation frequency of cooperative in-cage associations

Steady Flow Properties

Repulsive Microgels (C = 1.5 wt%)



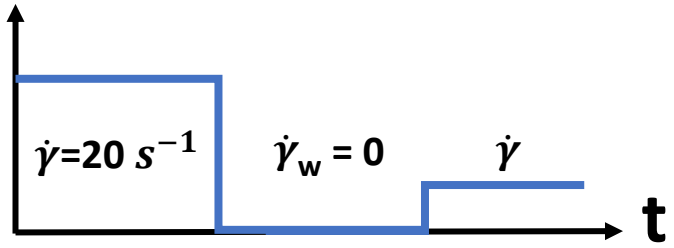
Associative Microgels (C = 1.5 wt%)

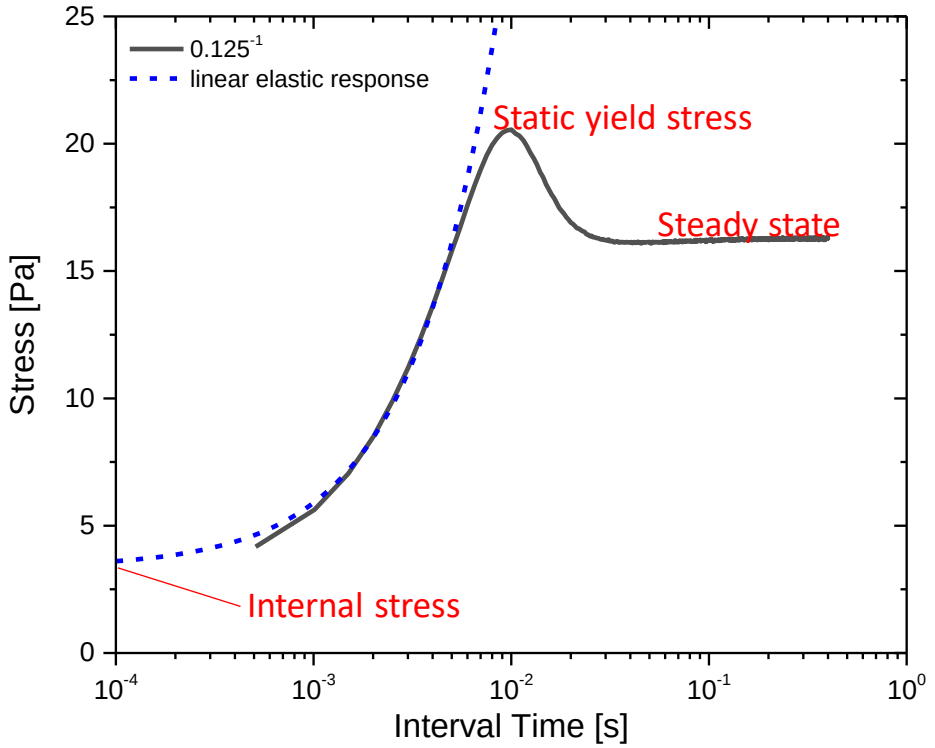


Transients to reach steady state may be very long at low shear rate → time-resolved startup experiments

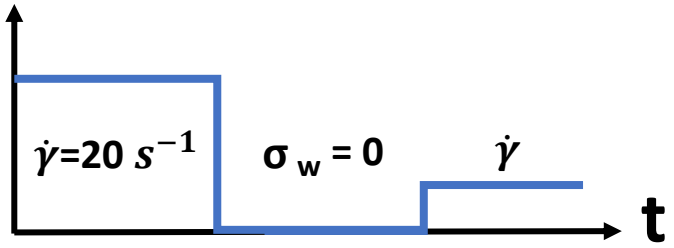
Start-up flow from rest: mechanical history matters

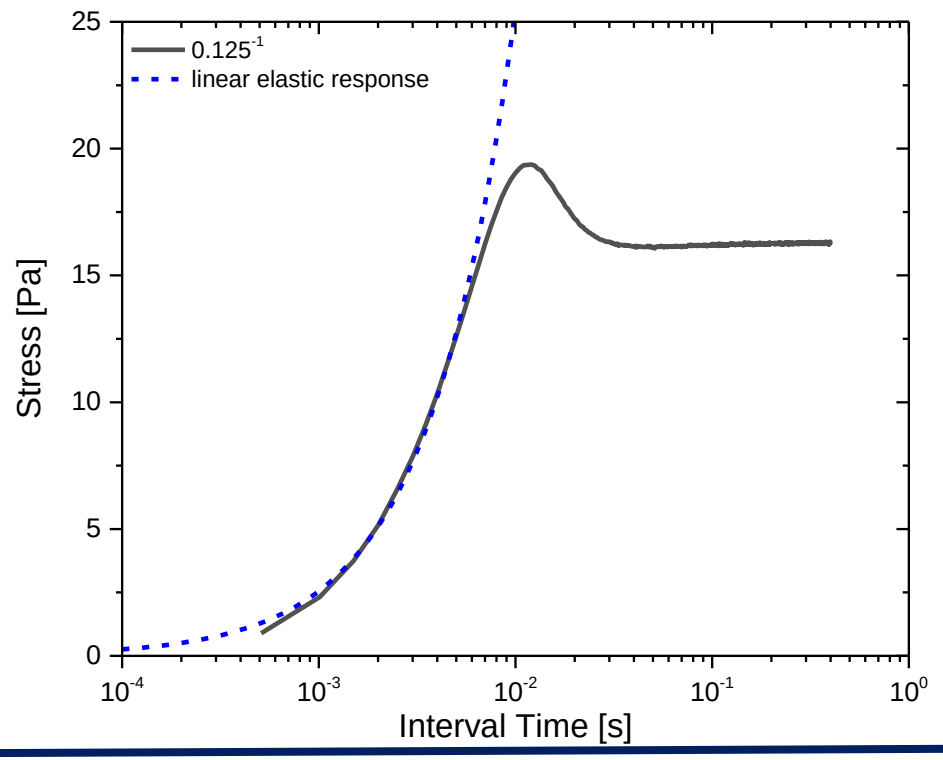
0 rate after pre-shear



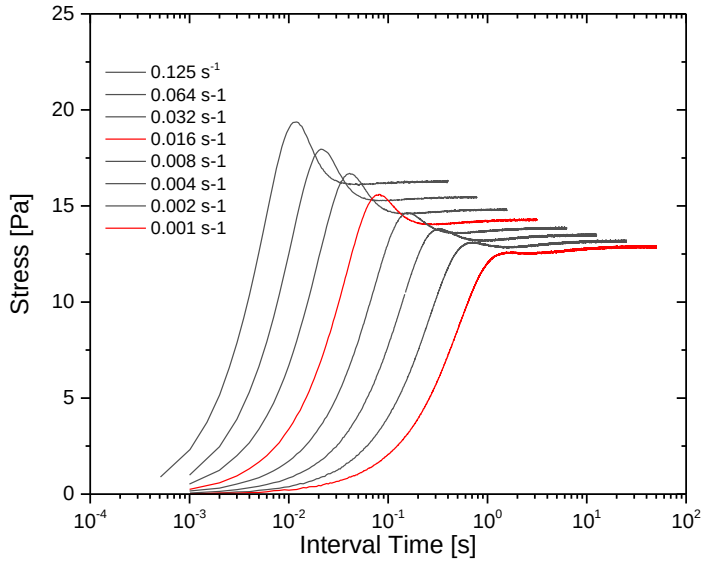


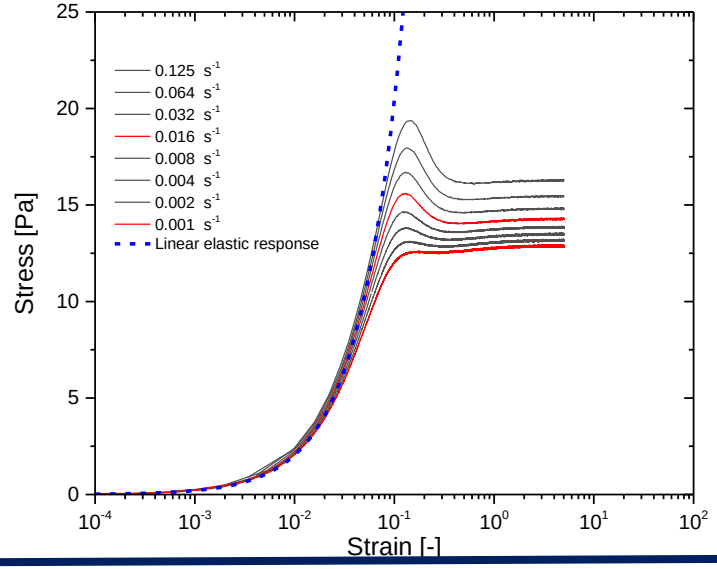
0 stress after pre-shear



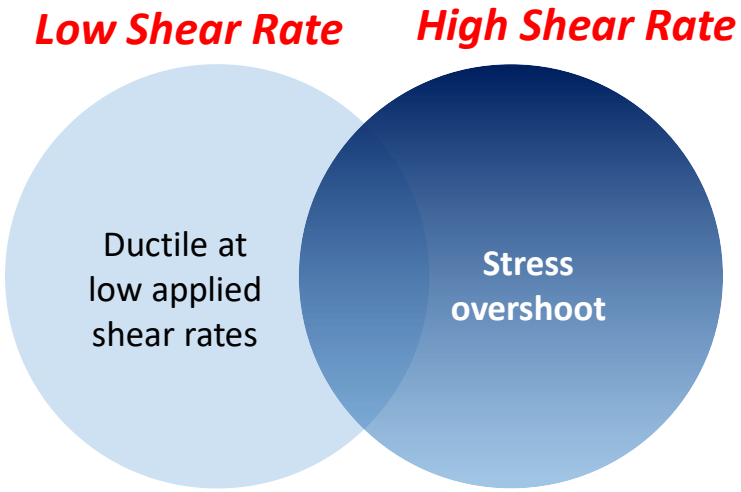


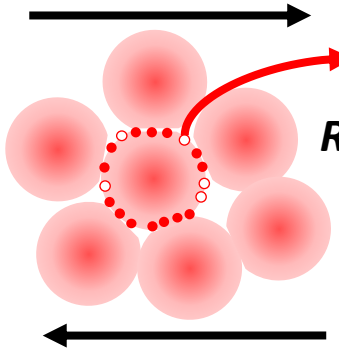
Start-up flow from rest: effect of shear rate on yielding dynamics





- Elastic response at low deformation
- Dynamic yield strain of the order of 0.1/0.2
- Dynamic yield stress increases with shear rate





Cage breaking

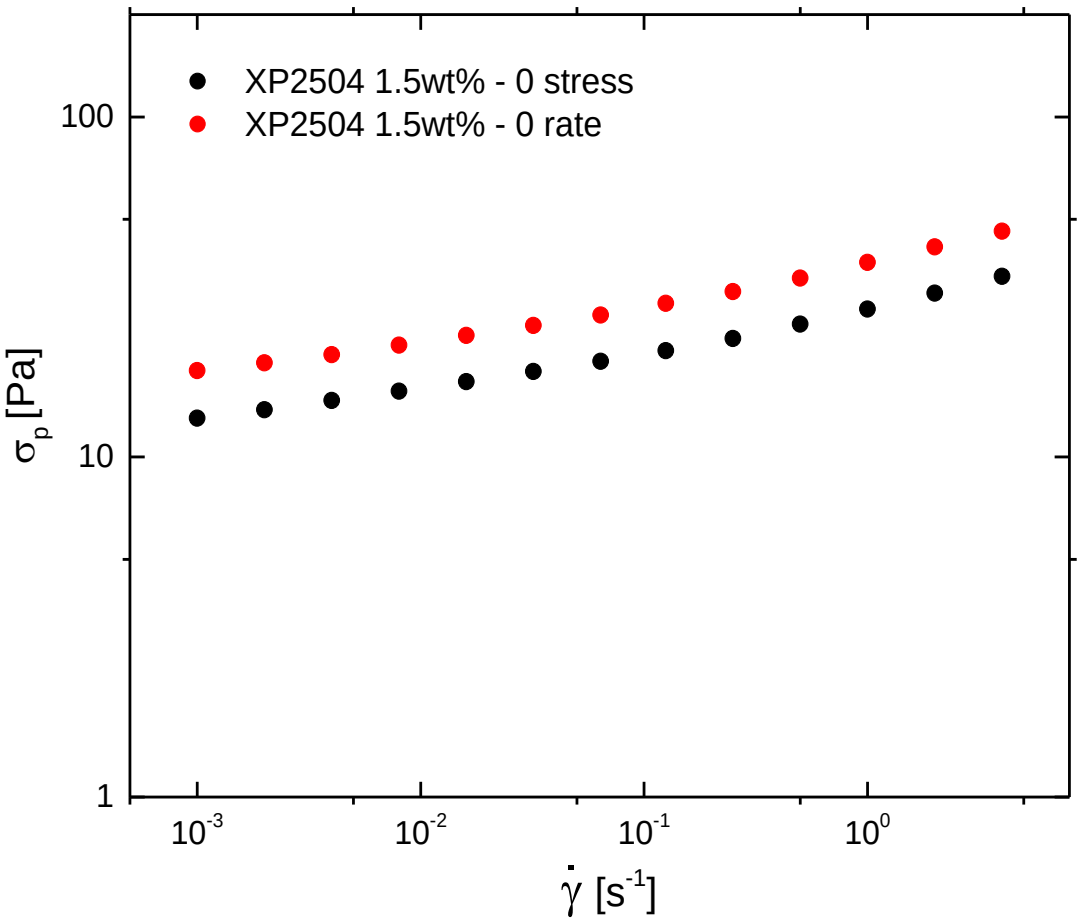
Rearrangement time τ_c

$\dot{\gamma}\,\tau_c << 1$ — ***Ductile (no static yield stress)***

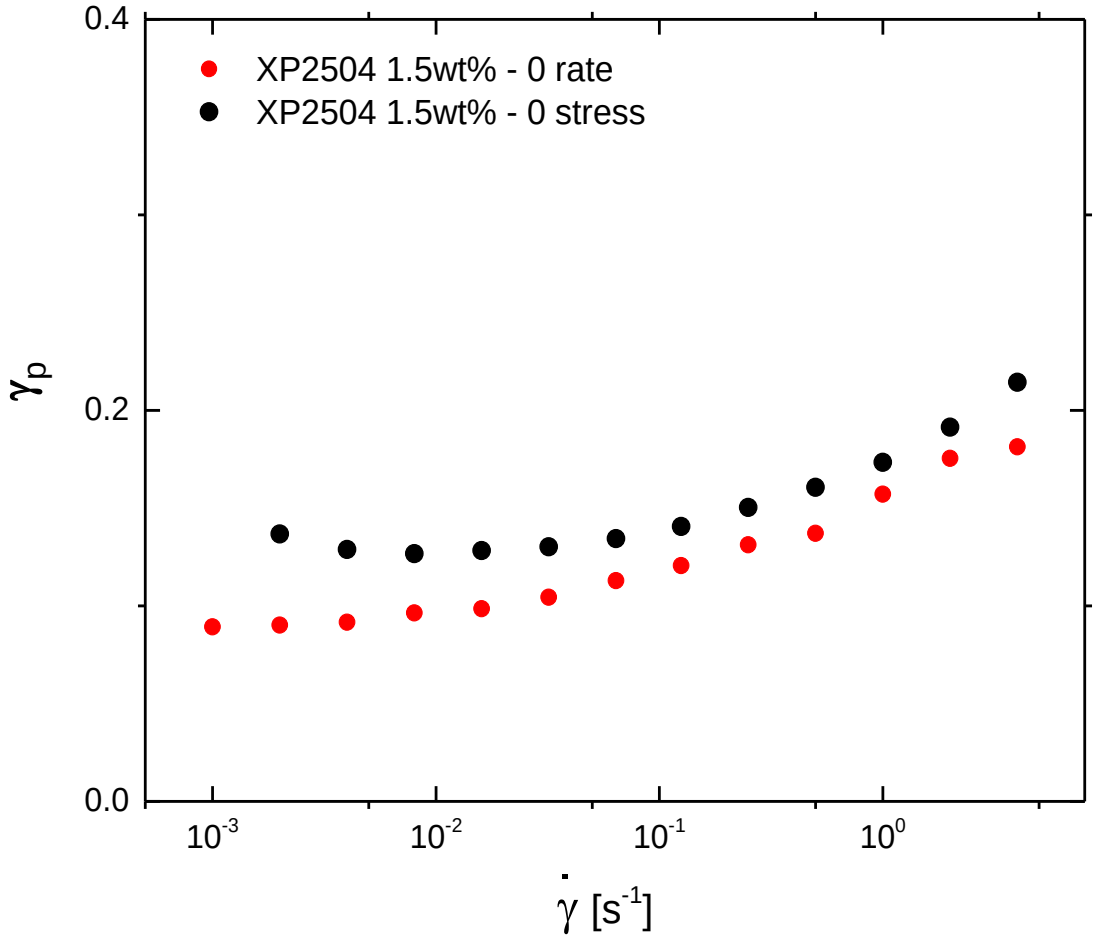
$\dot{\gamma}\,\tau_c >> 1$ — ***Static yield stress***

Start-up flow: : effect of shear rate

Peak value vs. Shear rate

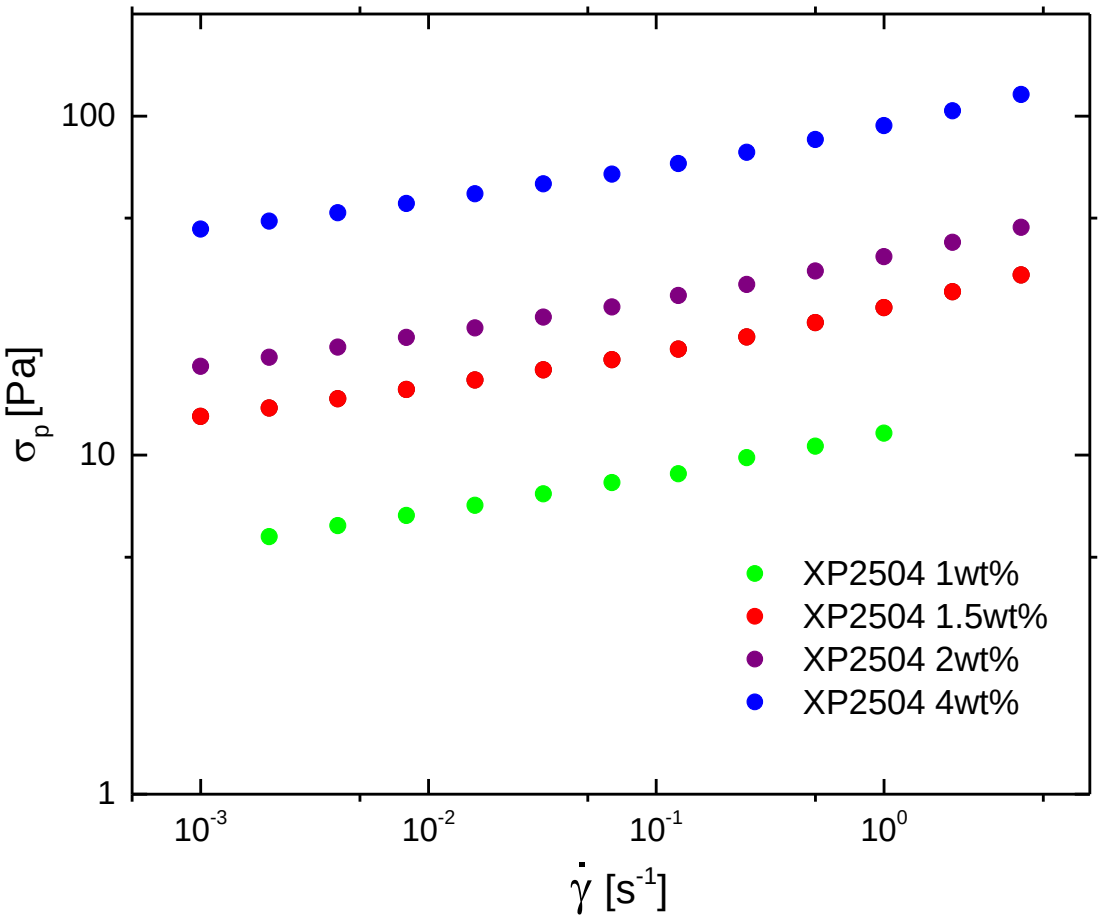


Peak position vs. Shear rate

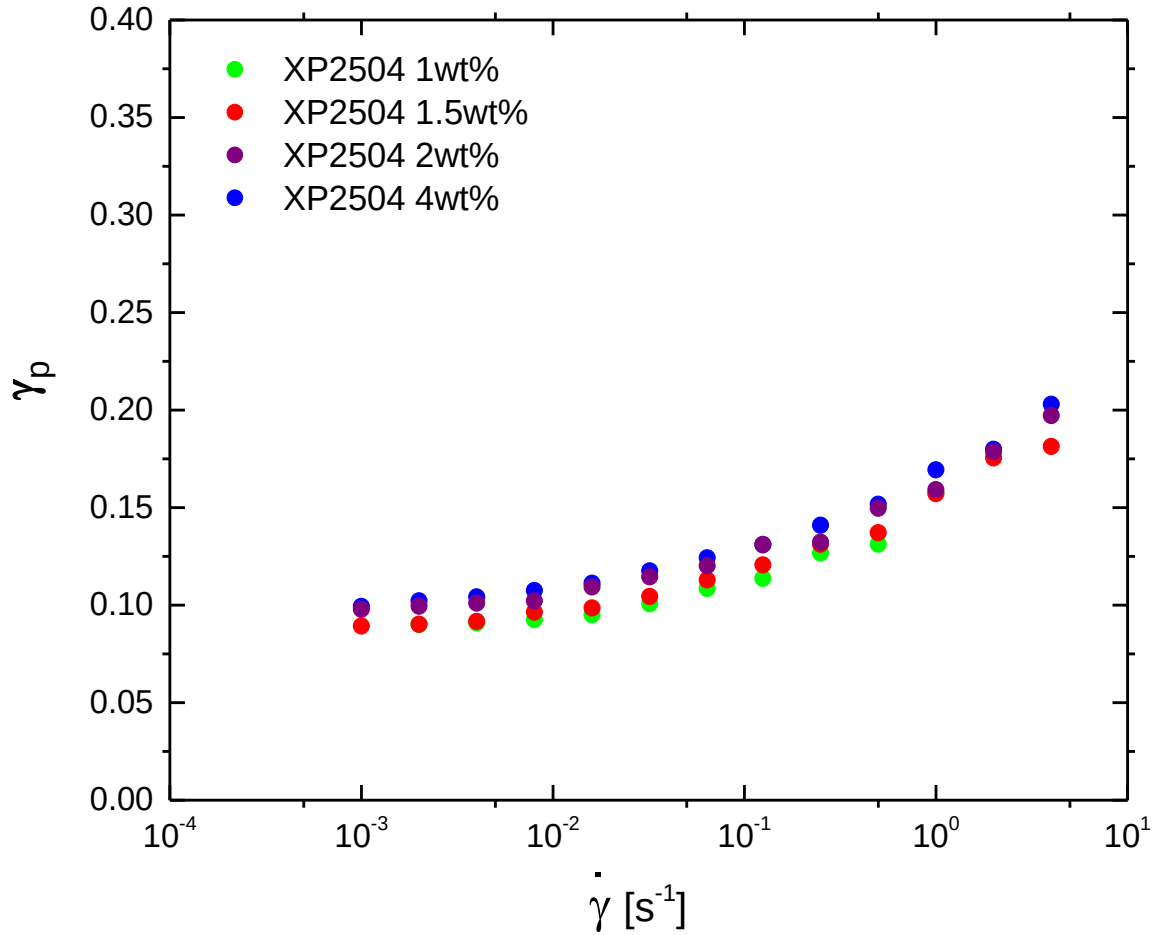


Start-up flow: results for different concentrations

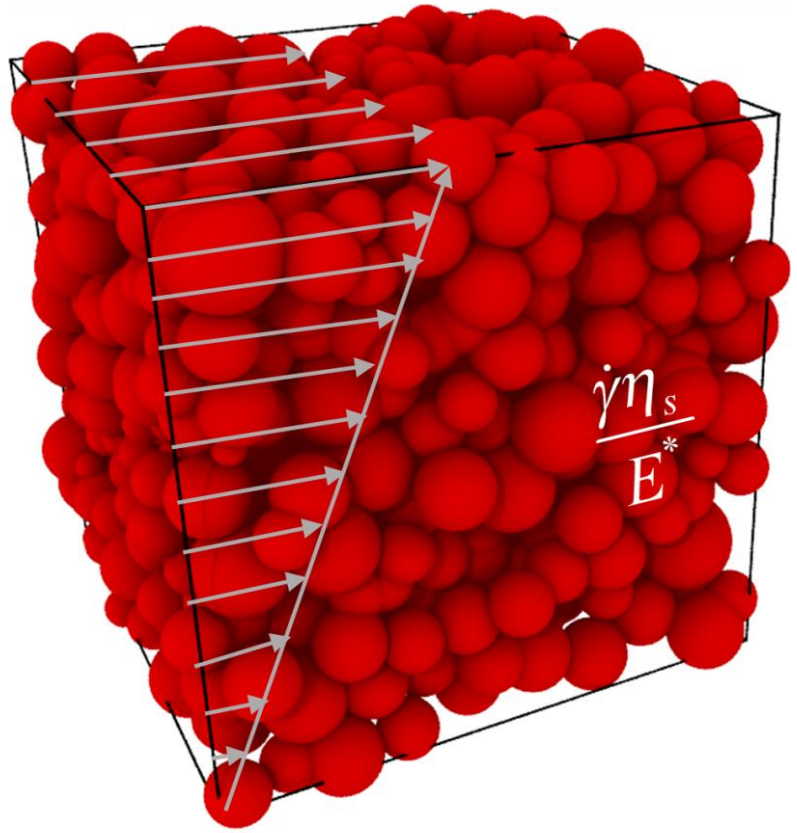
Peak value vs. Shear rate



Peak position vs. Shear rate



Particle dynamic simulation of jammed suspensions



Volume fraction: 0.70 - 0.95

η_s : solvent viscosity

E^* : ≅ particle Young modulus

$$\vec{\mathbf{v}}_\alpha = \dot{\gamma} y \vec{\mathbf{e}}_x + \bar{\bar{\mathrm{M}}}_\alpha \sum_\beta \left[\vec{\mathbf{f}}^{\,e}_{\alpha\beta} + \vec{\mathbf{f}}^{\,\mathrm{lub}}_{\alpha\beta} \right]$$

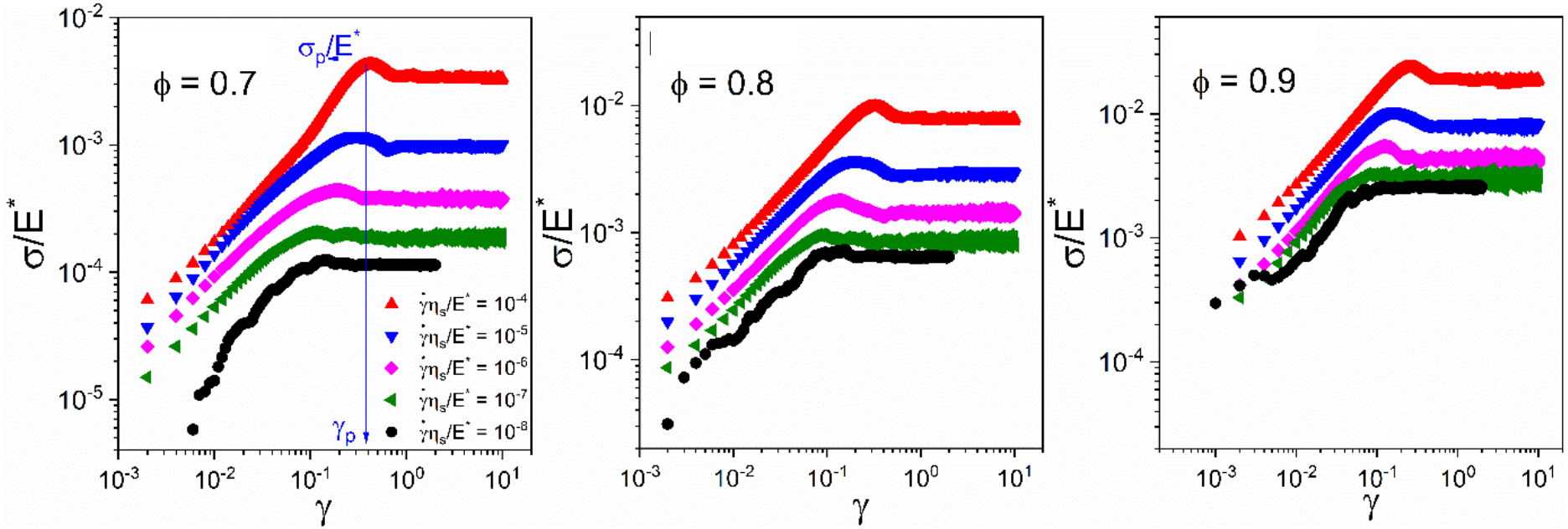
Periodic conditions

$10^4 – 10^6$ particles

Roger Bonnecaze, Fardin Khabaz

TEXAS
The University of Texas at Austin

Particle dynamic simulation of jammed suspensions

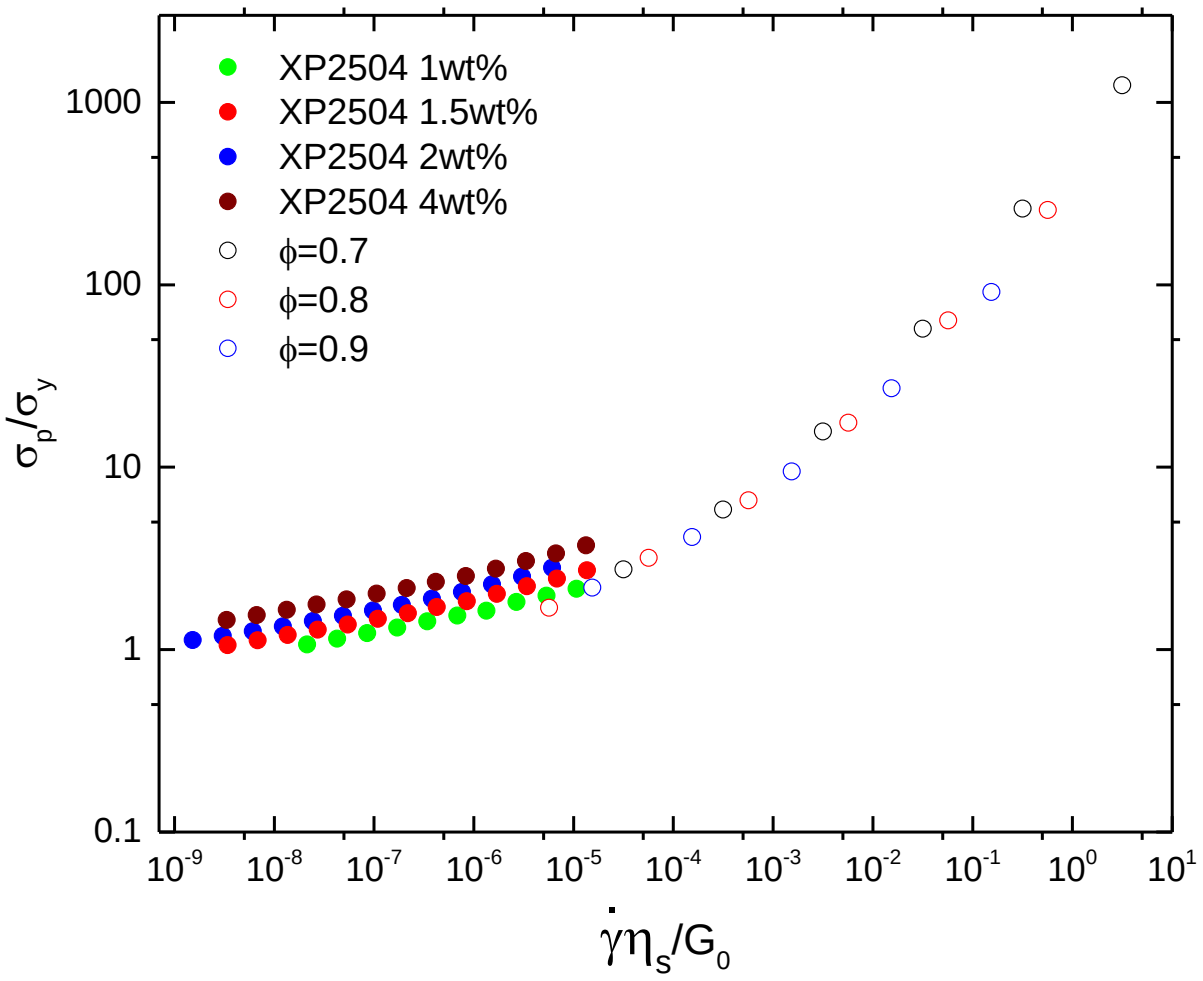


Same trends as in experiments:

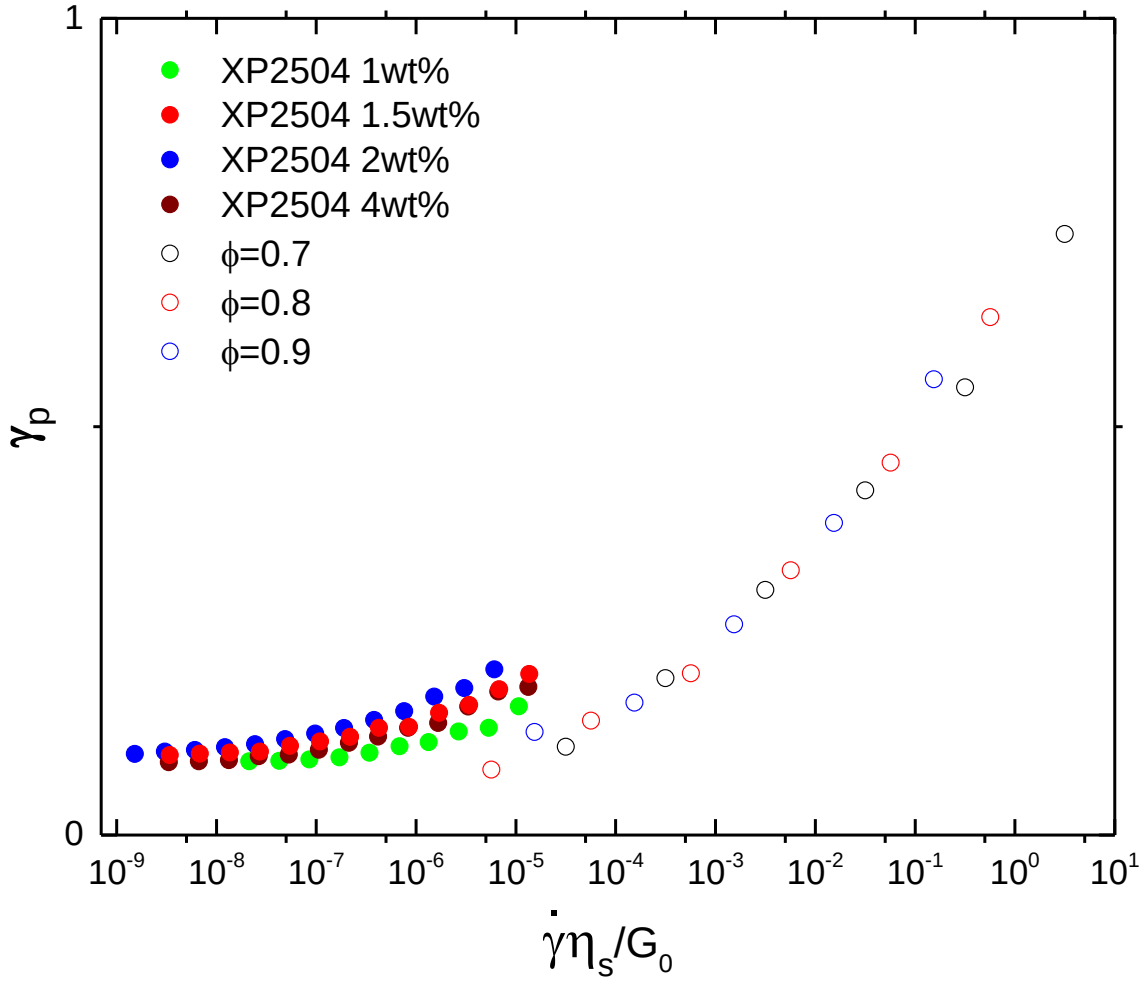
- Ductile at low shear rates; static yield static at high shear rates
- Static yield strain increases with the applied shear rate
- Static yield stress increases with the applied shear rate

Start-up flow: comparison with simulations

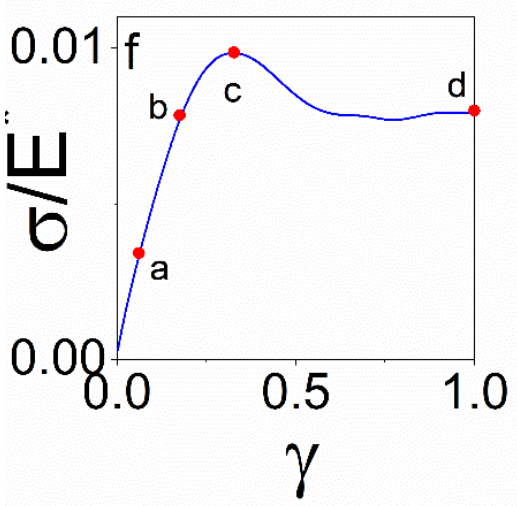
Peak value vs. Shear rate

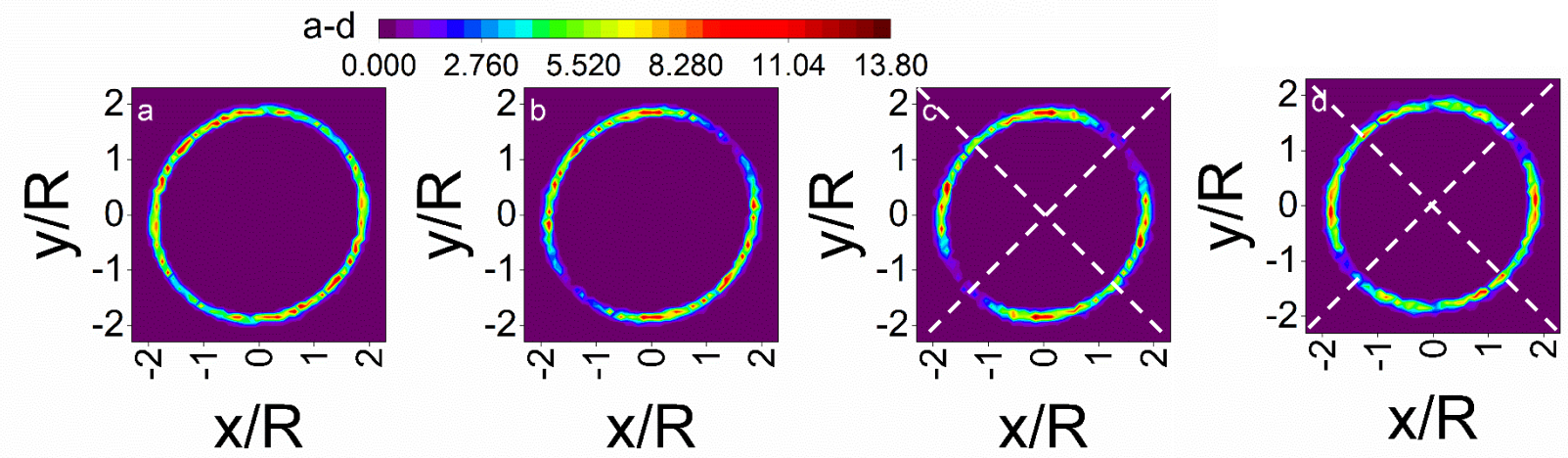


Peak position vs. Shear rate



Dynamical microstructure during yielding



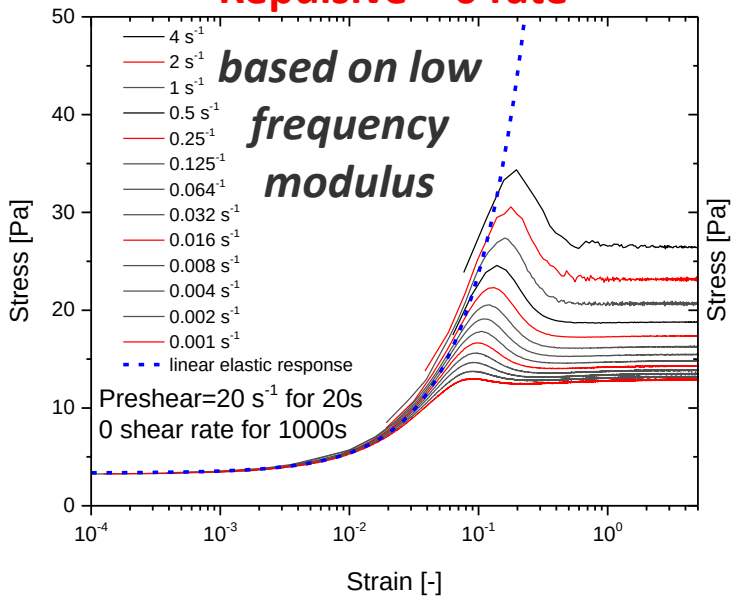


Observations

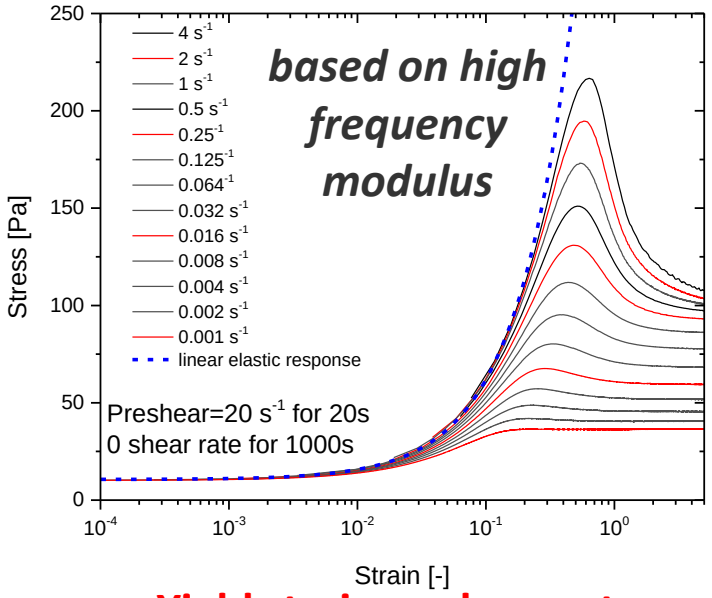
- The particle distribution at steady state is asymmetric
- The static yield stress corresponds to an extra asymmetry which is released as the particles gets more compressed

SUF results based on high and low frequency modulus

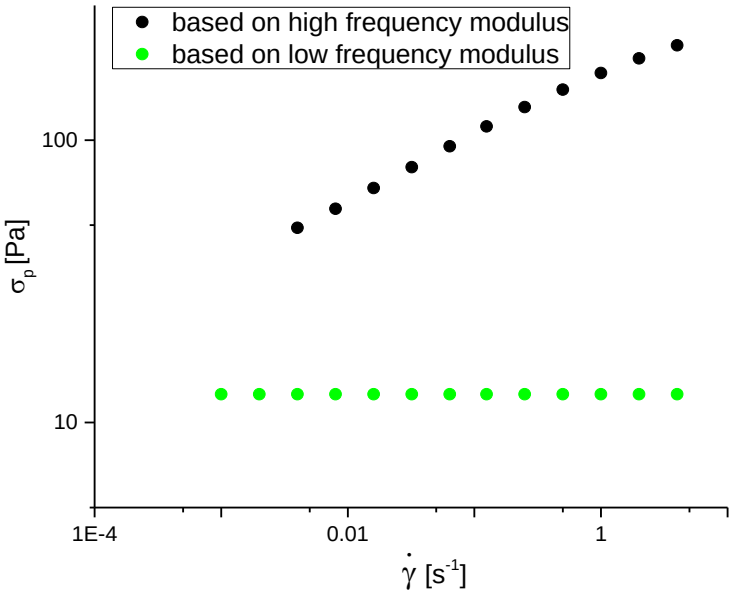
Repulsive – 0 rate



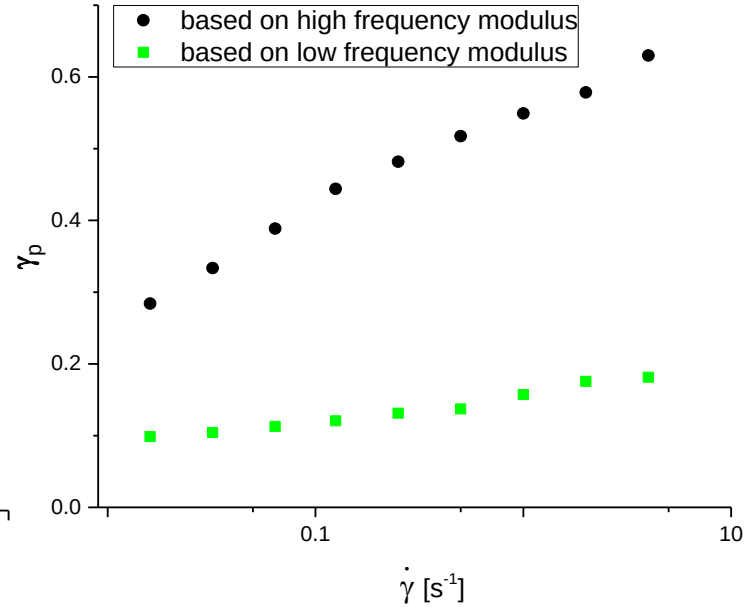
Associative – 0 rate



Peak stress vs shear rate



Yield strain vs shear rate



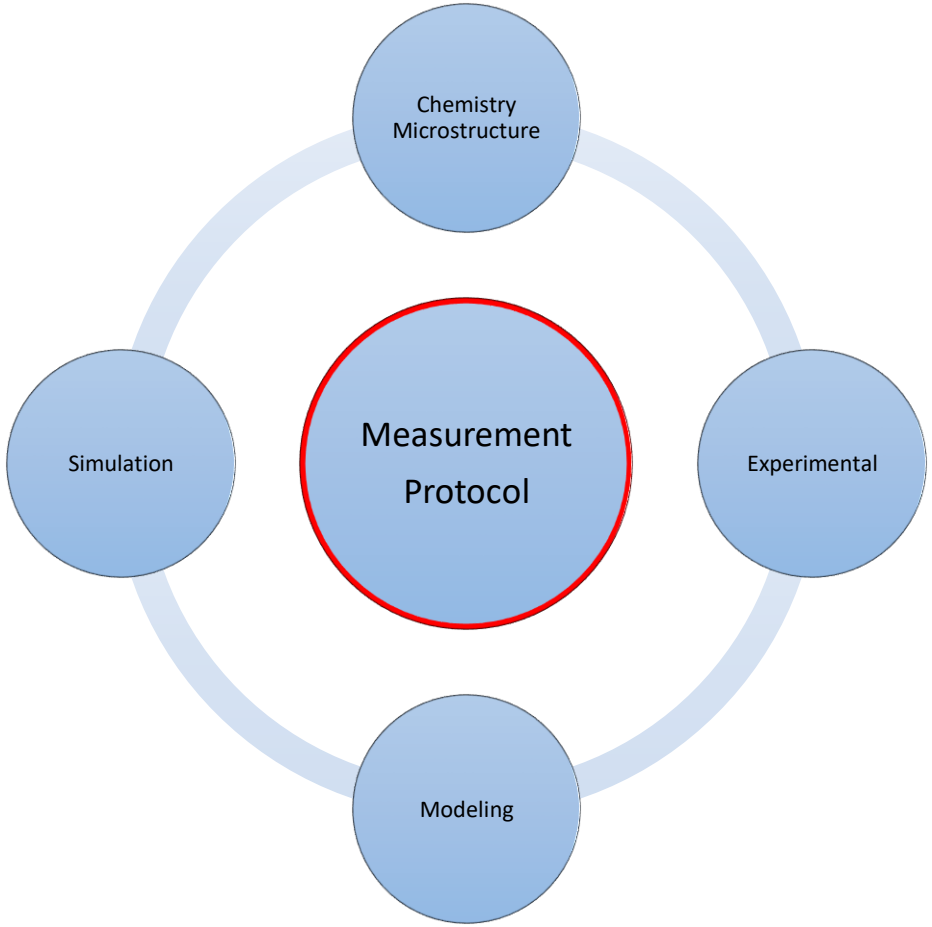
Same trends as repulsive microgels:

- Ductile at low shear rates; static yield static at high shear rates
- Static yield strain increases with the applied shear rate
- Static yield stress increases with the applied shear rate

Differences

- The elastic modulus G' corresponds to the high frequency modulus
- The yielding point is shifted to significantly higher values in the case of the associative microgels: ~ 0.6 - 0.7 for the 1.5wt% XP2671 suspension and ~ 0.1 - 0.2 for the 1.5wt% XP2504 suspension

Conclusions



Remarks

- **Mechanical history matters**
- **There is a strong effect of the applied shear rate in the startup flow response: ductile vs. yielding**
- **The startup flow response depends on the concentration, but an appropriate scaling collapses the data onto a master curve**
- **There are some important common features between the associative and repulsive microgel suspensions, but also substantial differences that need to be investigated deeper**

Thanks for your attention!