Yielding in an athermal dense suspension

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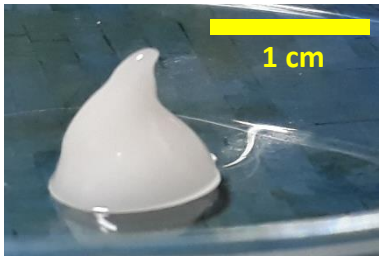
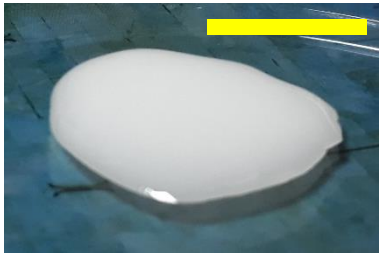
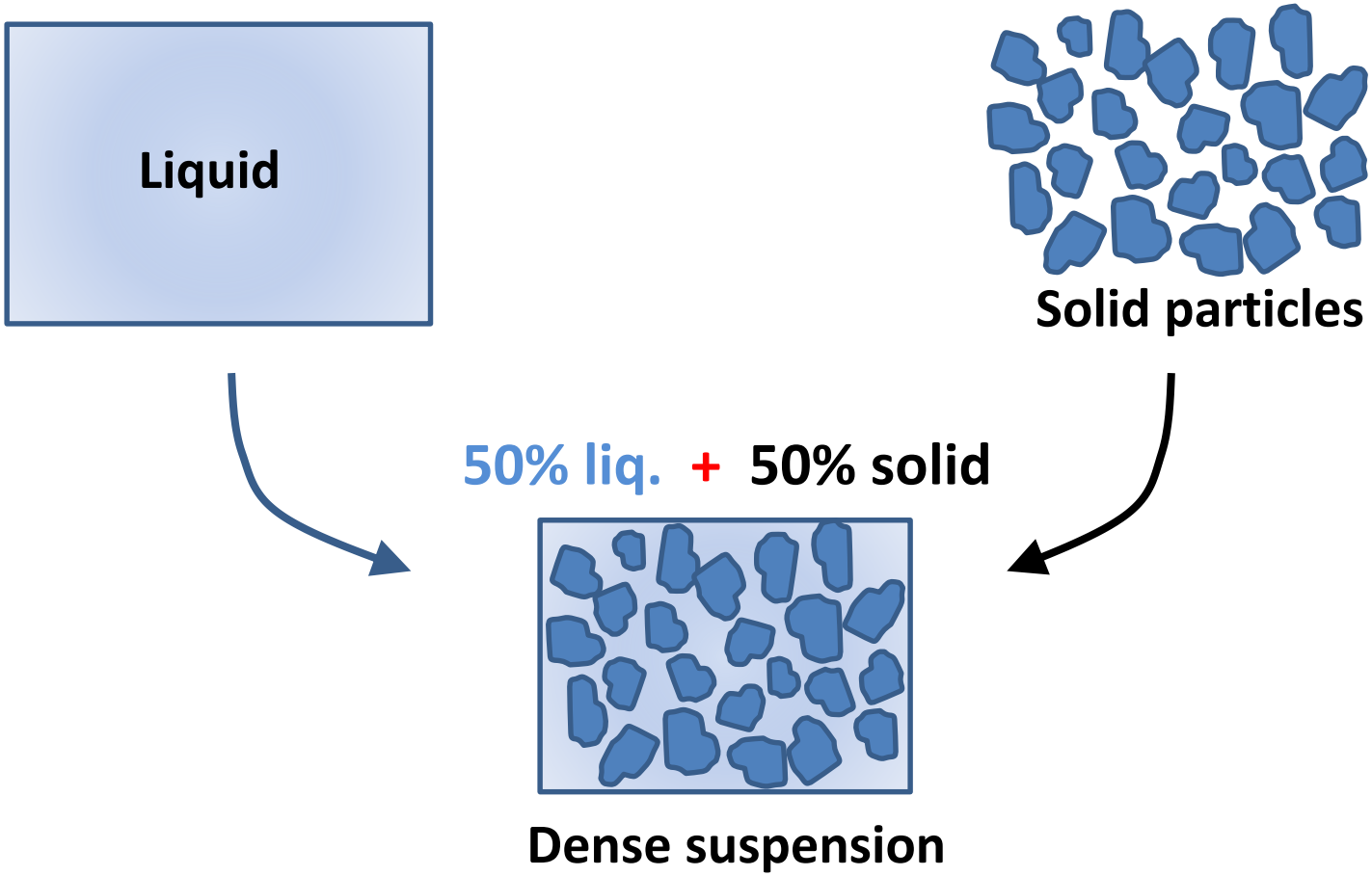




ISPCM, ICTS (2019)

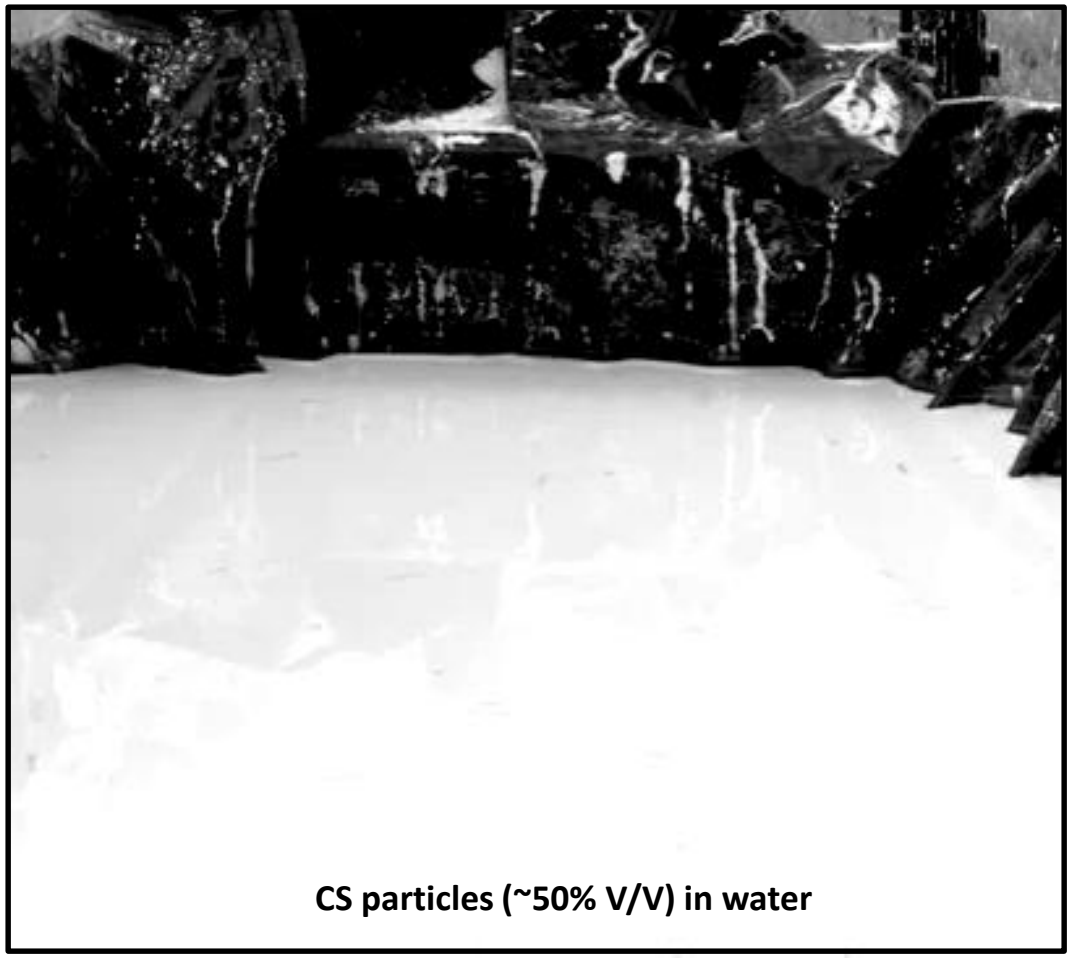
Dense suspensions : New physics



Industrial and fundamental interests

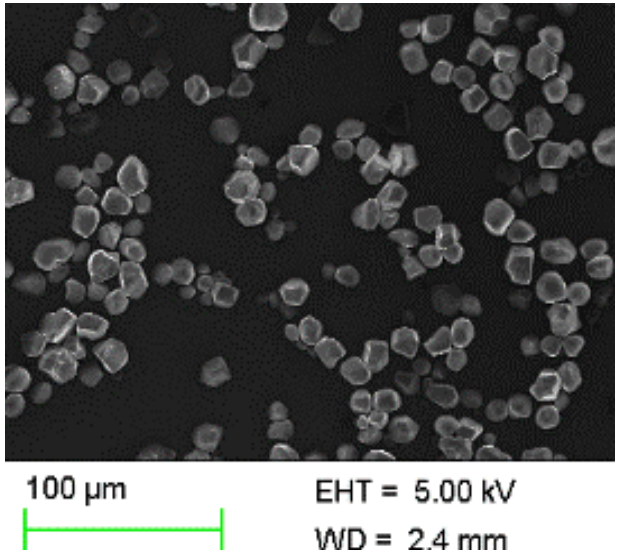
Can’t be understood from the properties of liquid and solid

Reversible liquid-solid transition under force



CS particles (~50% V/V) in water

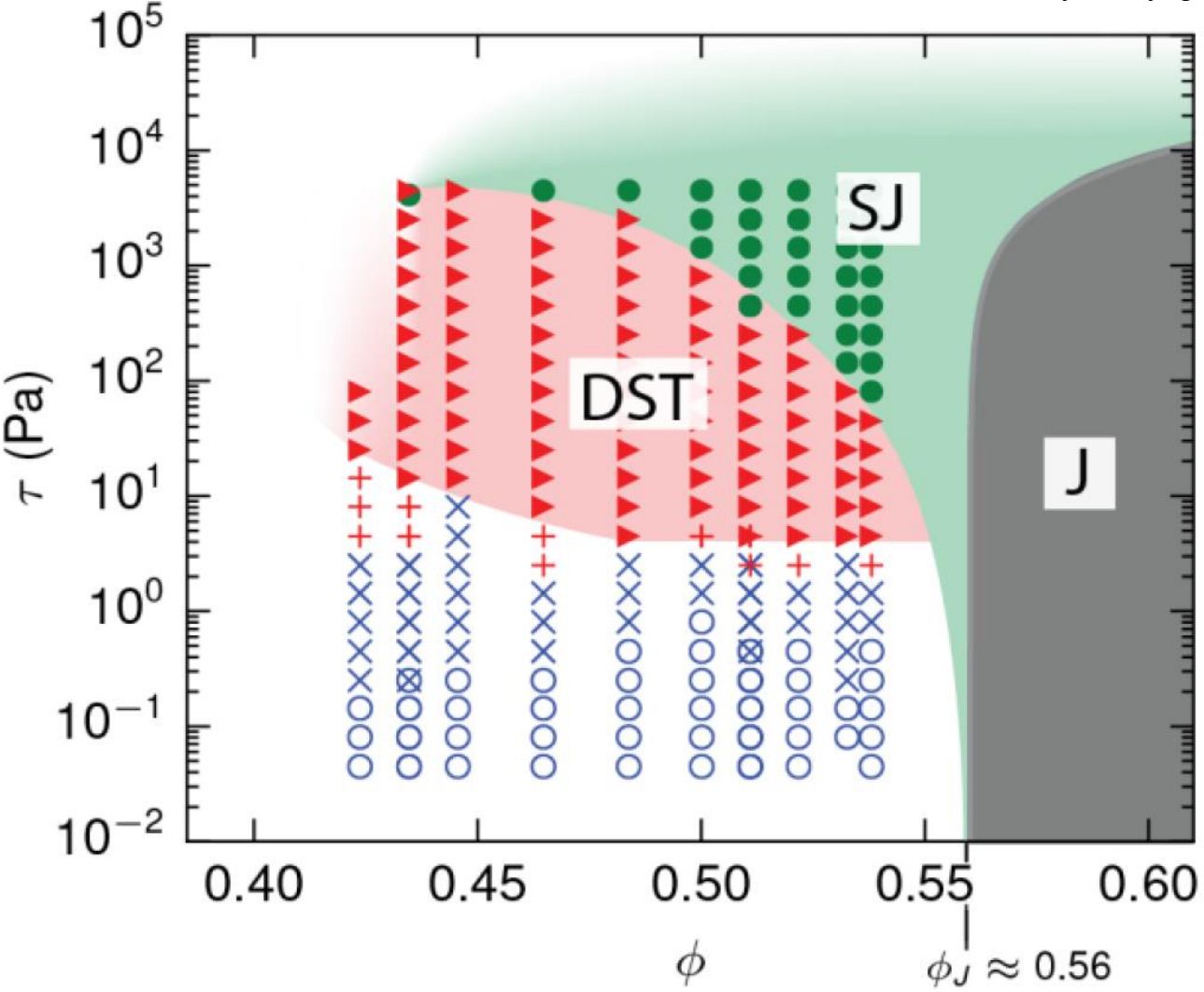
Ben Allen, Yale University



SEM Image: S. Chattopadhyay, RRI

Volume-fraction control the flow-deformation properties

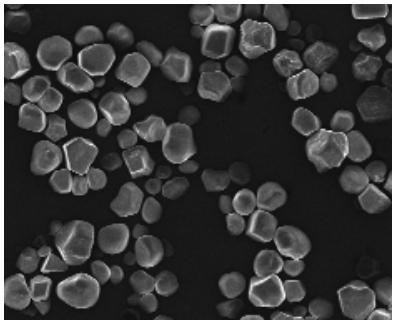
Peters, Majumdar, jaegers (2016)



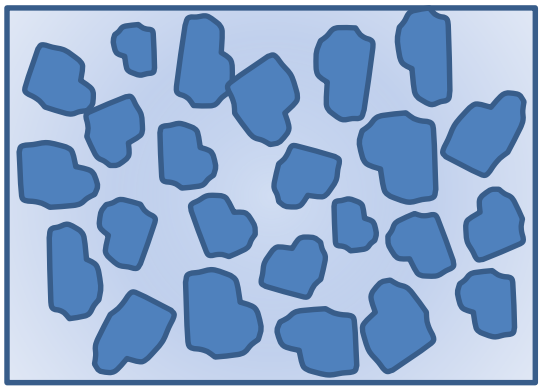
Solid-like state under arbitrarily small stresses for $\phi_J > 56\ \%$

Solvent mediated interparticle interactions

CS (Hydrophilic)



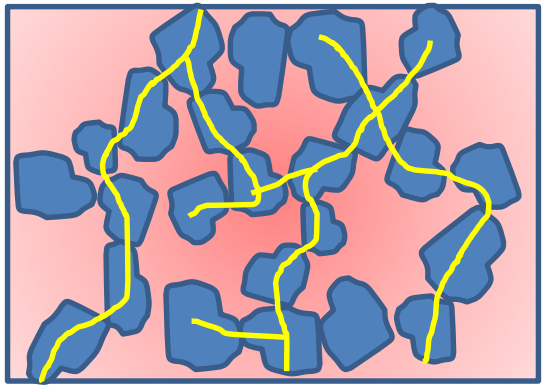
Hydrophilic Solvent
(water, glycerol)



Well dispersed system

$\phi_J \sim 56\ \%$

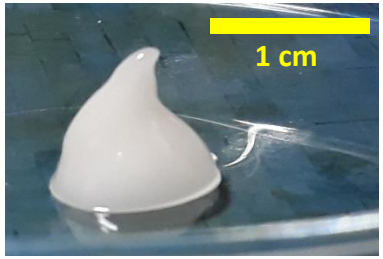
Hydrophobic Solvent
(different types of oil)



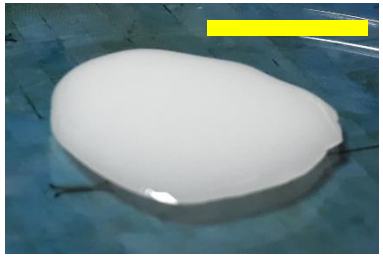
Fractal clusters

Solid-like state for $\phi << \phi_J$

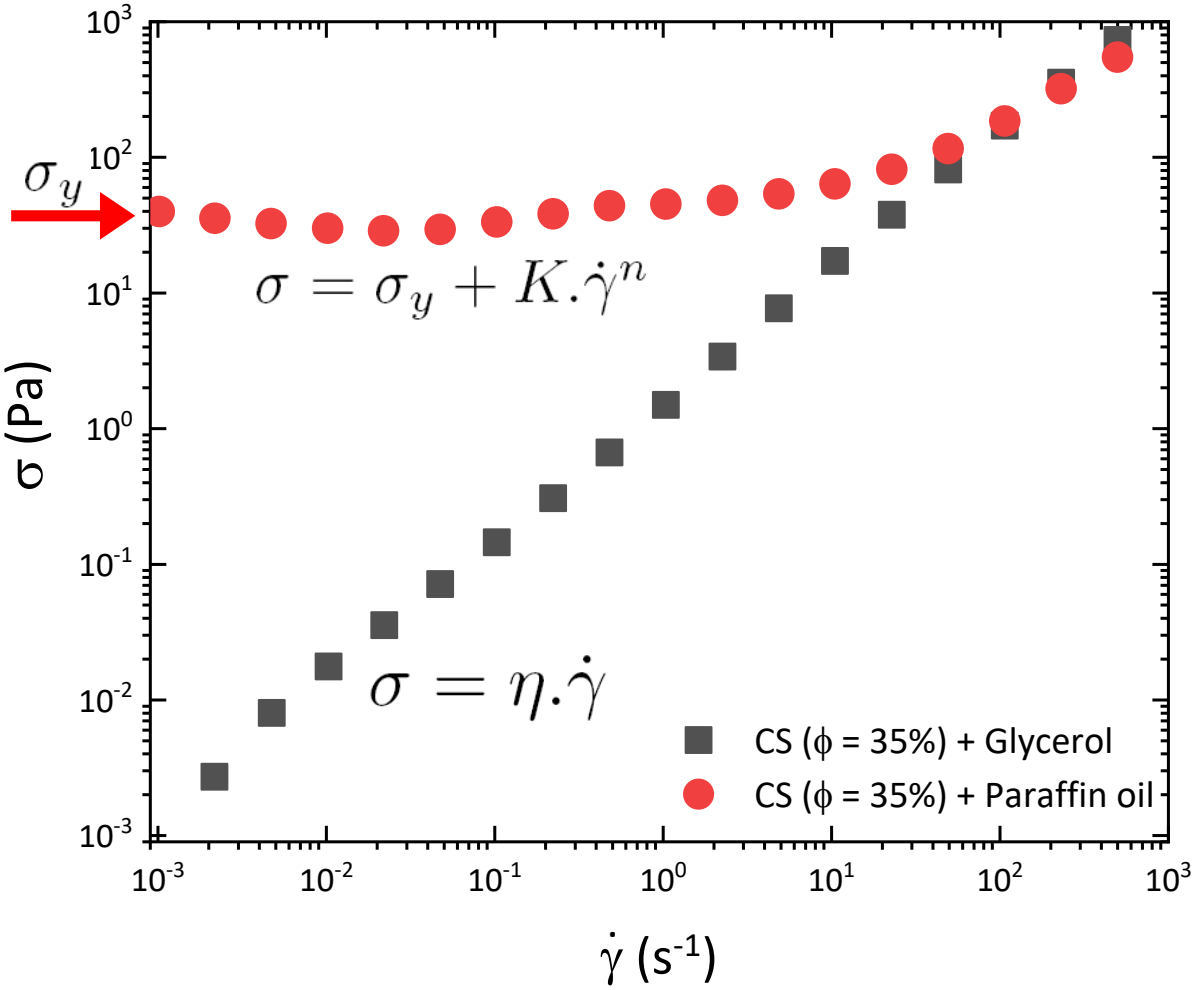
Formation of soft amorphous solid below yield stress



CS (ϕ = 35%) + Paraffin oil



CS (ϕ = 35%) + Glycerol



Athermal amorphous solids below yielding for 25% < ϕ < 50%

Yielding in disordered materials

Transition from a disordered solid to liquid-like state under applied stress

Amorphous athermal solids with soft attractive particles:

Irani, Chaudhuri, Heussinger (2014, 2016)
Lin, Lerner, Rosso, Wyart (2014)

Lennard-Jones binary glasses under cyclic deformation:

Leishangthem, Parmar, Sastry (2017)

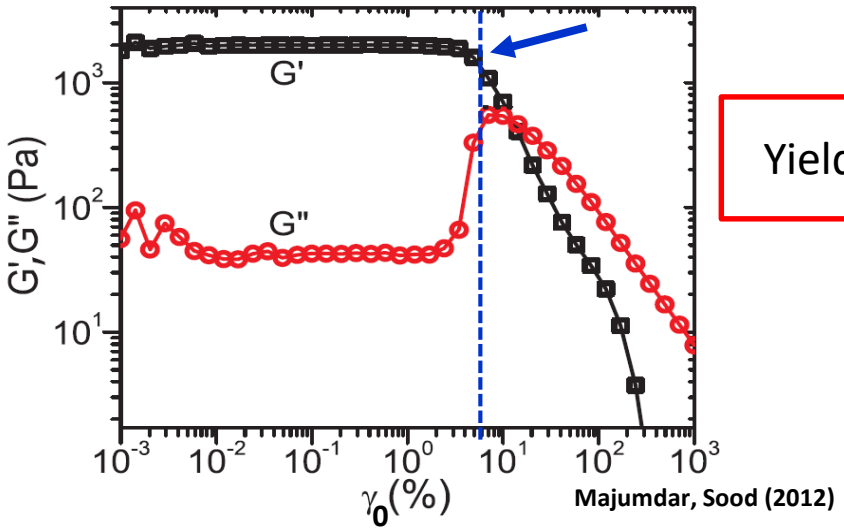
LAOS study of dense colloidal suspensions of soft and hard particles:

van der Vaart et al. (2013)

Applied oscillatory strain: $\gamma(t) = \gamma_0 \sin\omega t$

Stress response: $\sigma(t) = \gamma_0 \left[G'(\omega) \sin(\omega t) + G''(\omega) \cos(\omega t)\right]$

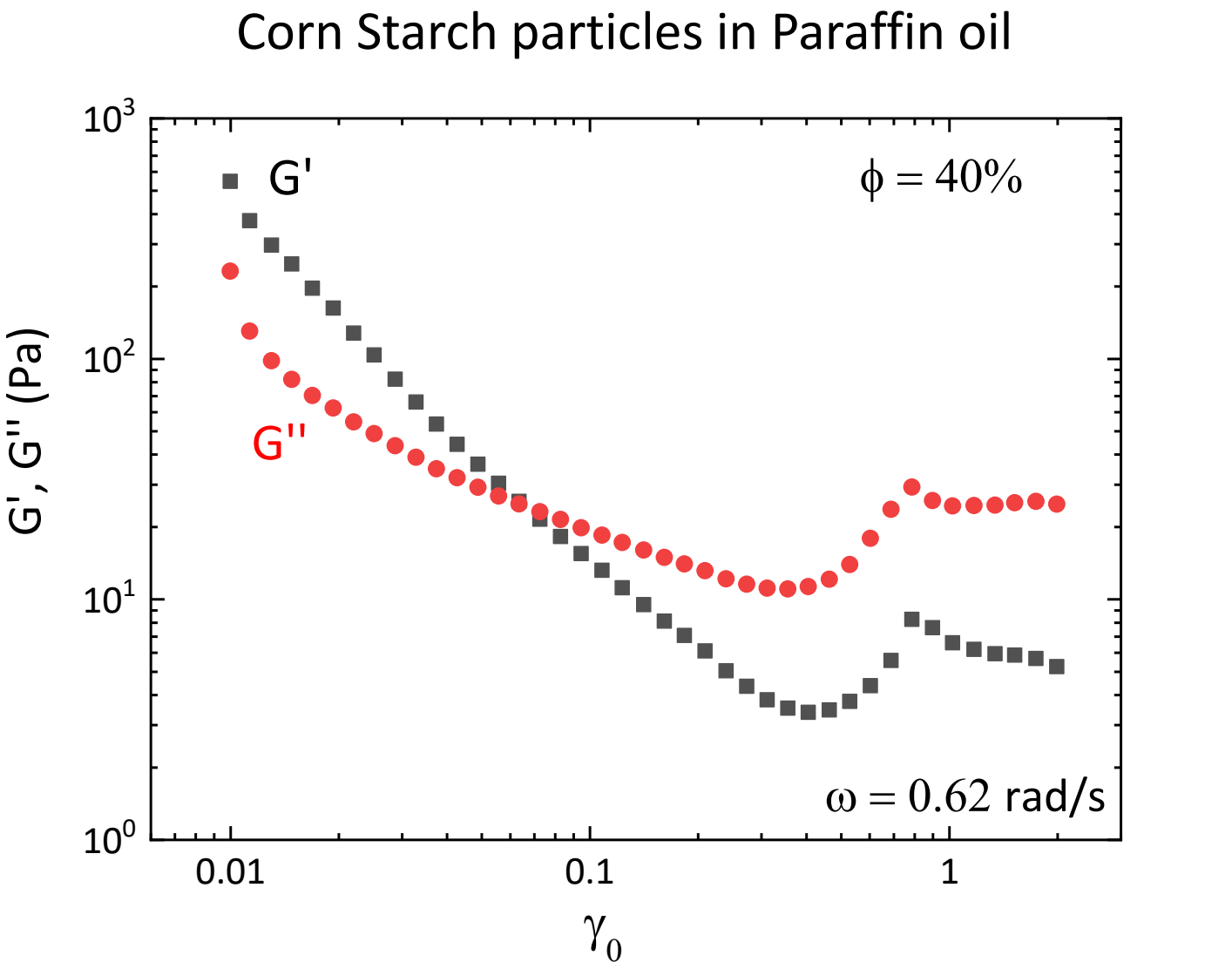
Elastic modulus Viscous modulus



Majumdar, Sood (2012)

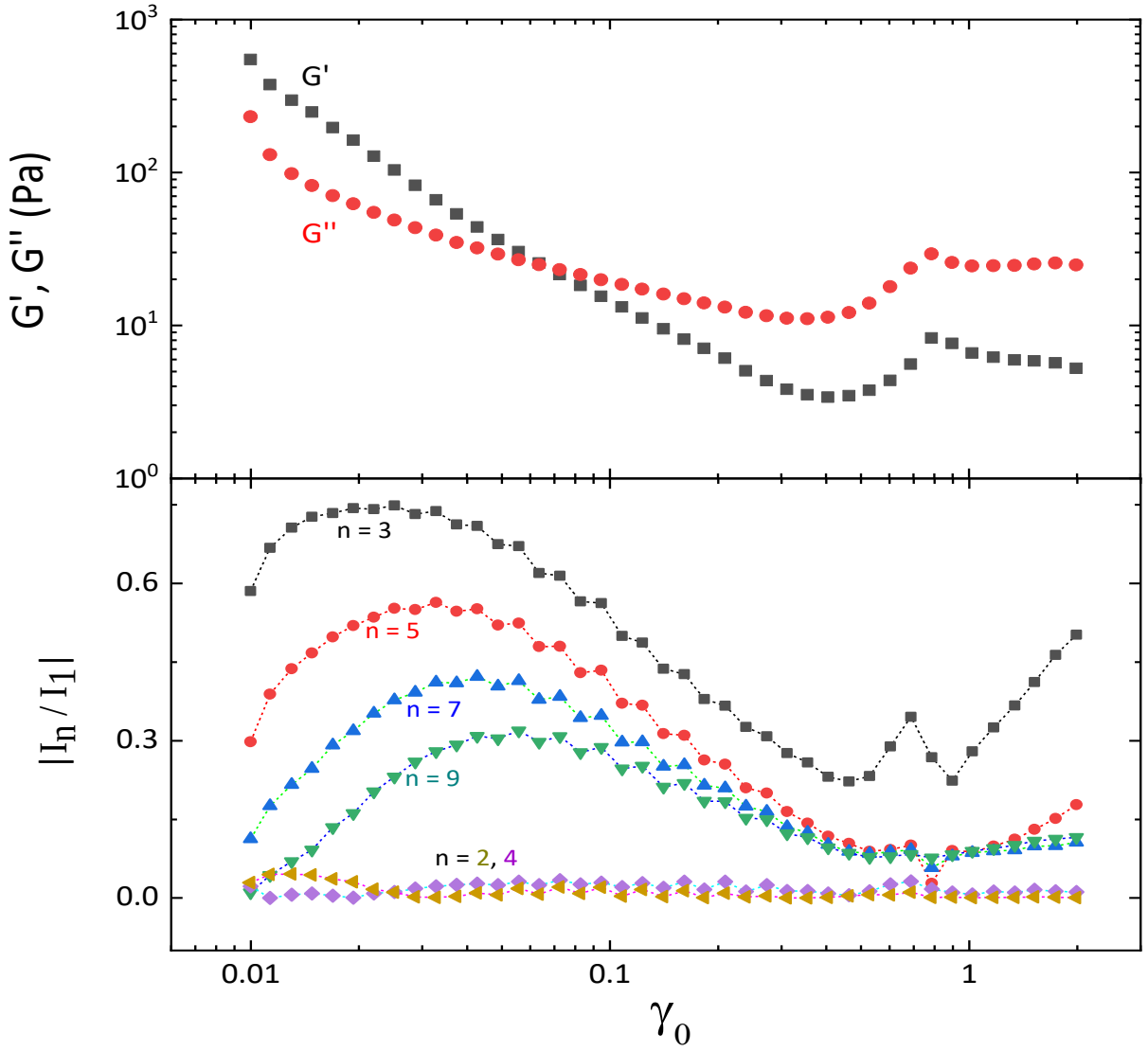
Yielding in a repulsive colloidal glass (laponite)

Intra-cycle stress response



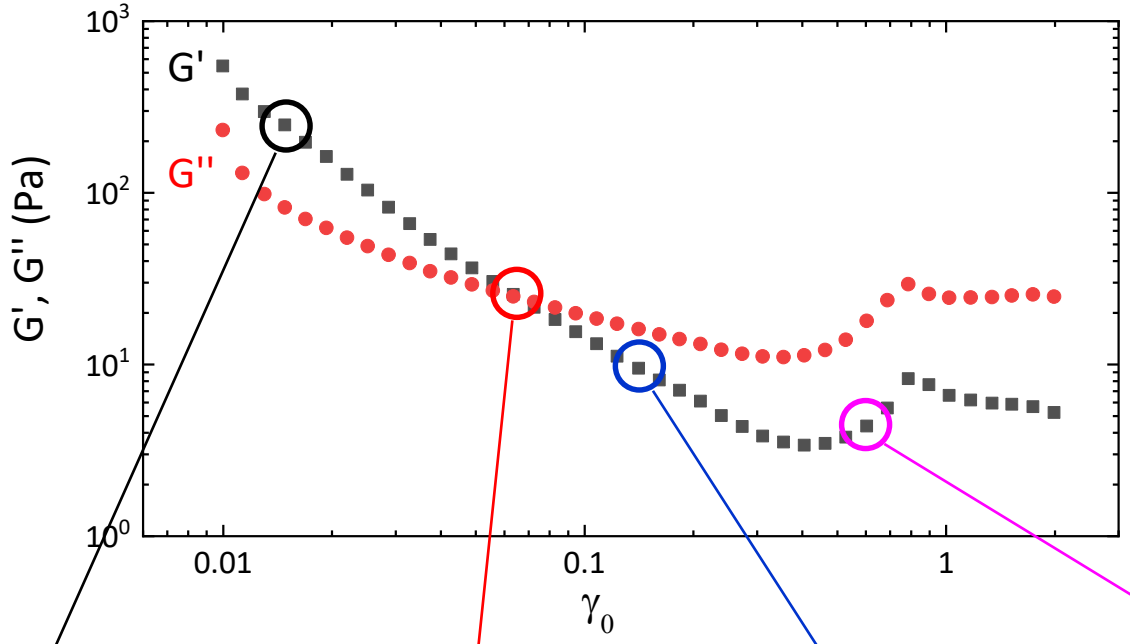
No observable feature near the cross-over amplitude

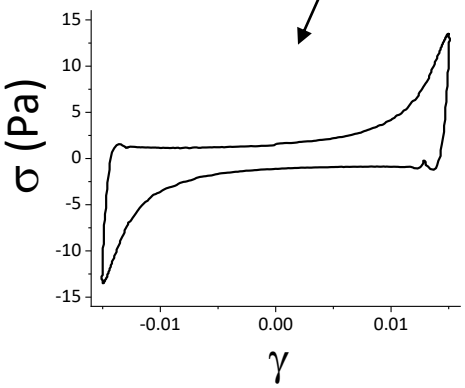
Contribution of higher harmonics

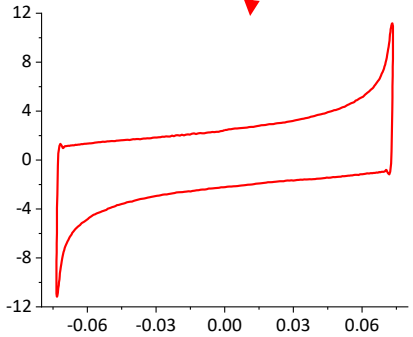


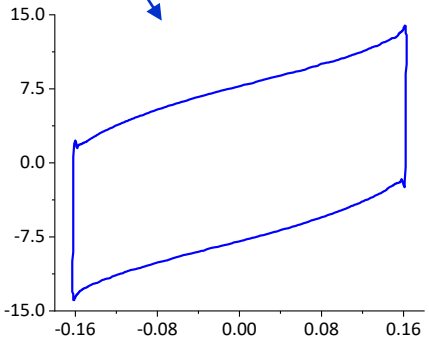
Highly non-linear even at small strains: G', G'' not meaningful

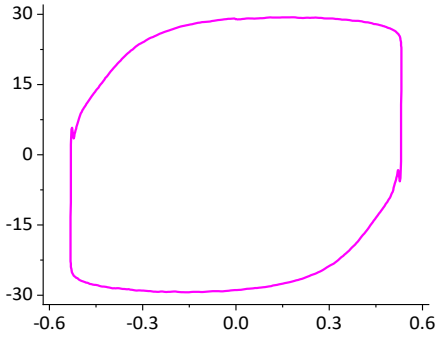
Intra-cycle stress response





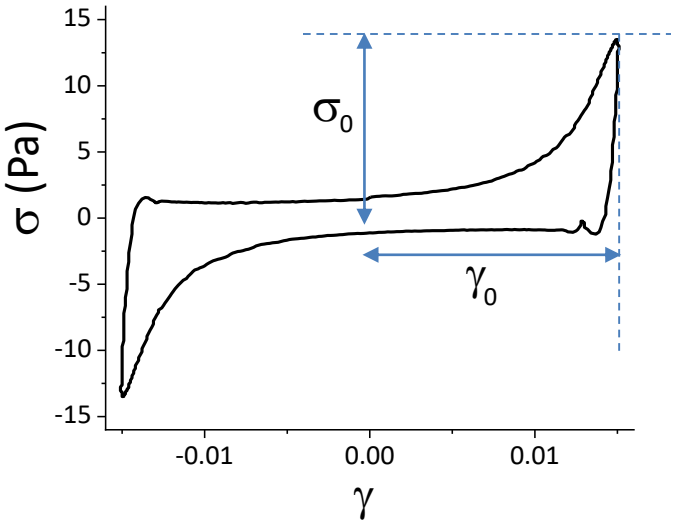


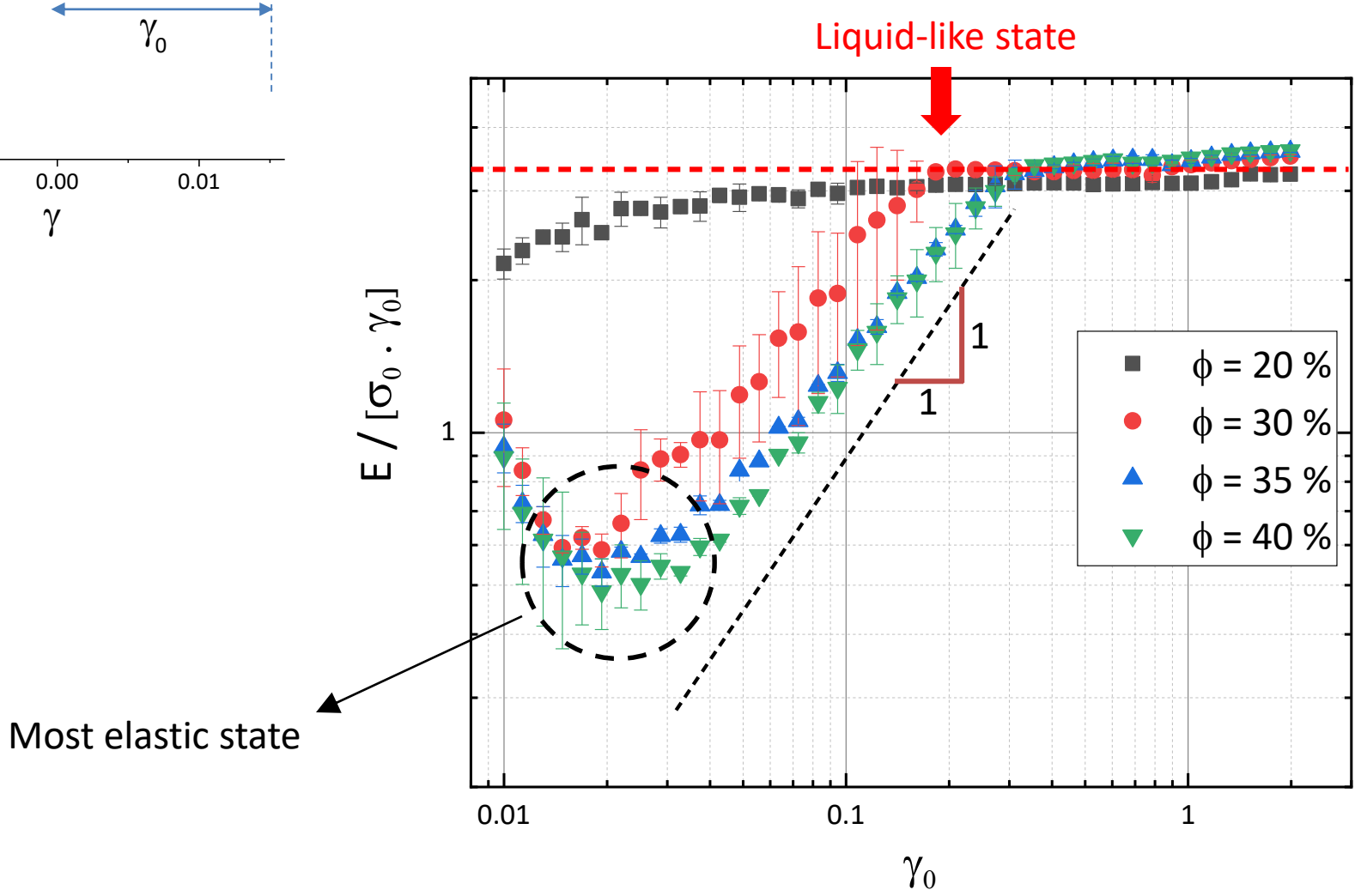




Area of Lissajous curves proportional to the dissipative energy per cycle

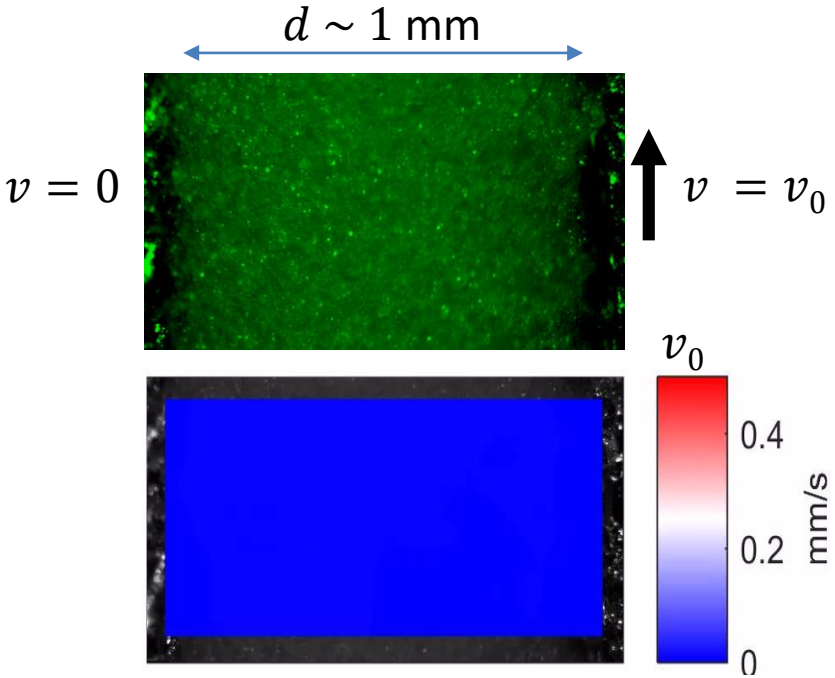
Energy dissipation per cycle



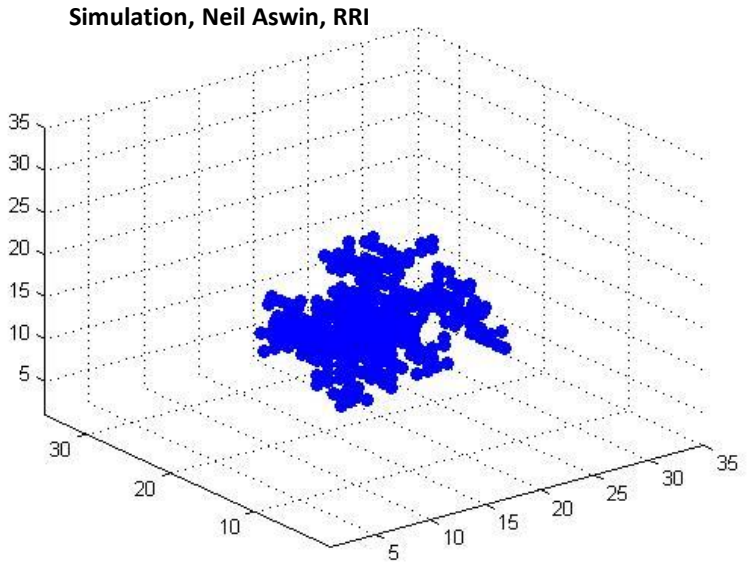


Conclusions and outlook

- Yielding transition in athermal dense suspension of attractive particles.
- Highly non-linear process: G’ and G’’ do not give much information
- Intra-cycle energy dissipation capture the transition (why non-monotonic??)
- Differentiate solid-like states of attractive and repulsive systems?



Shear banding



Dynamics of fractal clusters

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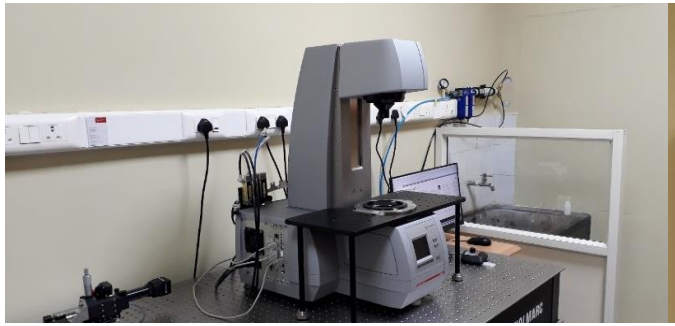

Thank you for your attention