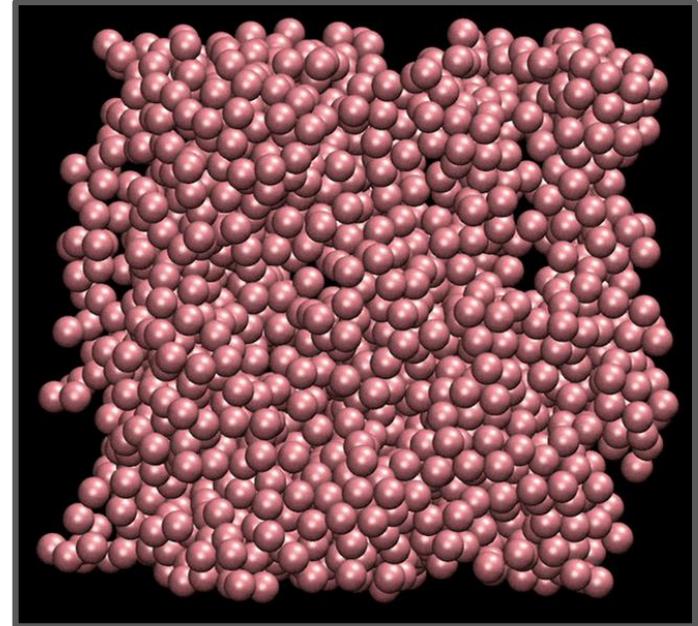
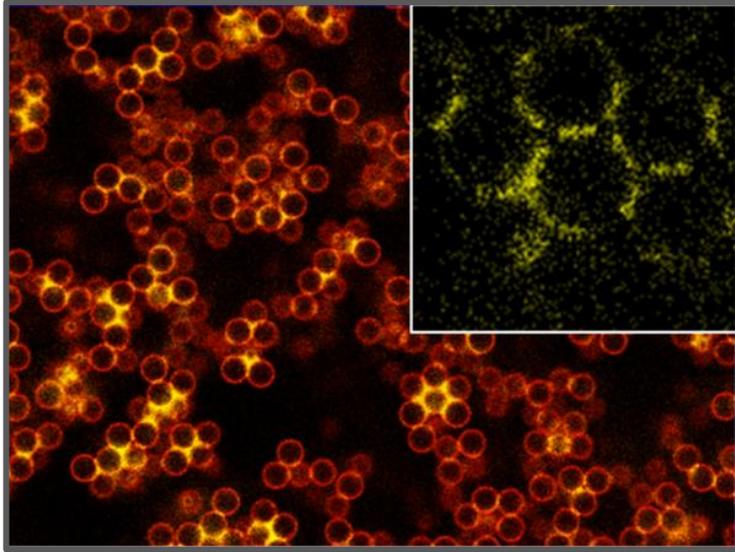


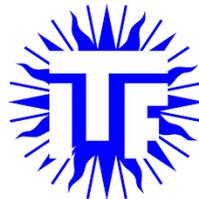
Hydrodynamic Modeling of Sheared Capillary Suspensions



Allard *et al.*, *Colloids Surf. A*
648 (2022)

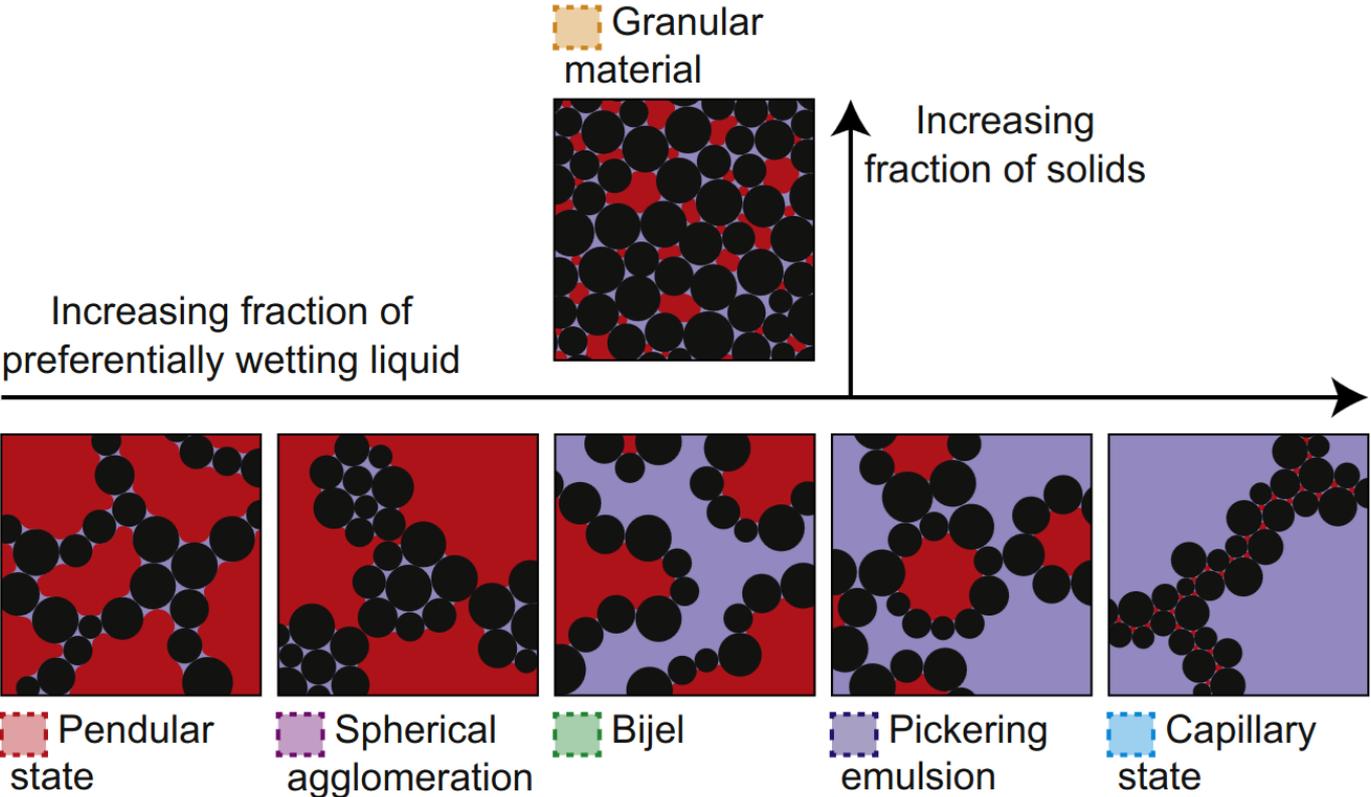
KU LEUVEN

IFPRI Collaboration Project
Associated with KU Leuven
Group of Prof. Erin Koos

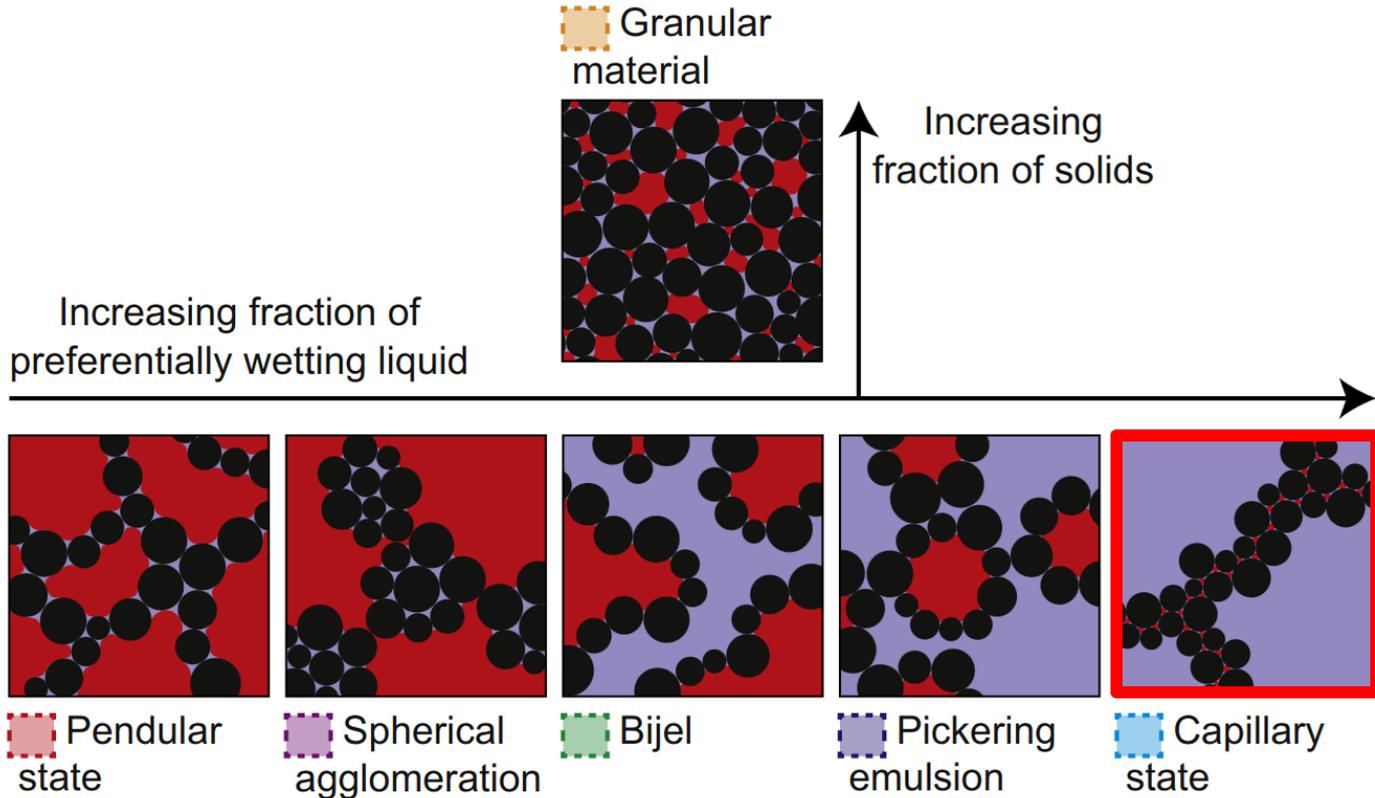


William Torre & Joost de Graaf
Institute for Theoretical Physics
Utrecht University

Capillary Suspensions



Capillary Suspensions



Outline

- Simulation method (JFSD)
- Particle initial configuration
- Capillary Bridges
- Results

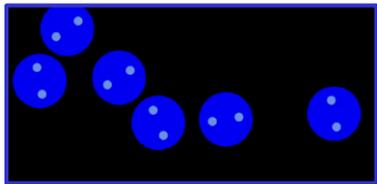


JAX Fast Stokesian Dynamics

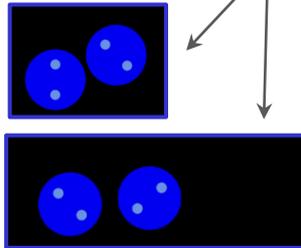
Monodisperse Spherical Particles

$$\overbrace{U - U^\infty}^{\text{Velocity}} = \mathbf{R}_{\text{FU}}^{-1} \cdot \left(\overbrace{F^{\text{P}}}^{\text{Applied Force}} + \underbrace{\mathbf{R}_{\text{FE}} \cdot \mathbf{E}^\infty}_{\text{Applied Shear}} \right)$$

$$\mathbf{R}_{\text{FU}} = \underbrace{\mathcal{B}^T \cdot \mathcal{M}^{-1} \cdot \mathcal{B}}_{\text{Hydrodynamic Resistance}} + \mathbf{R}_{\text{FU}}^{\text{nf}}$$

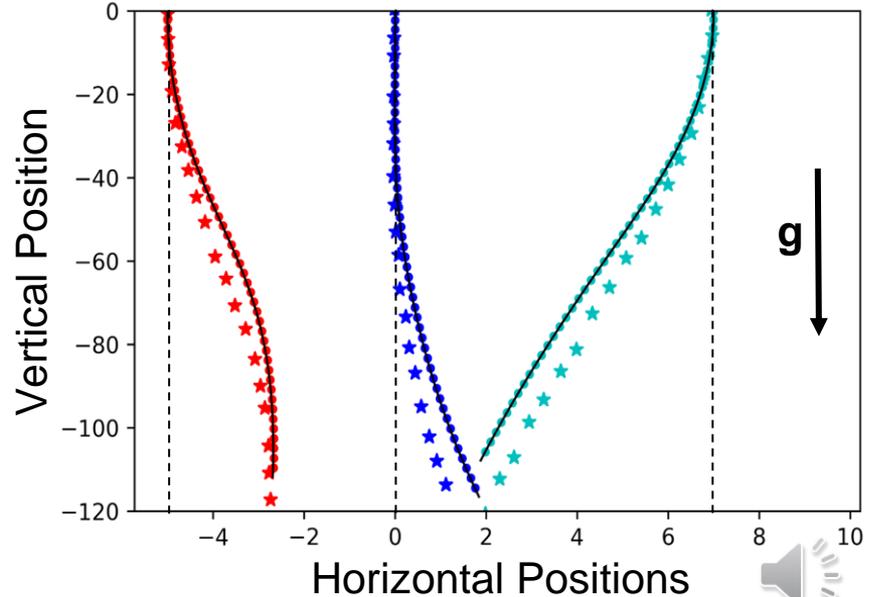


Far-Field (many-body)



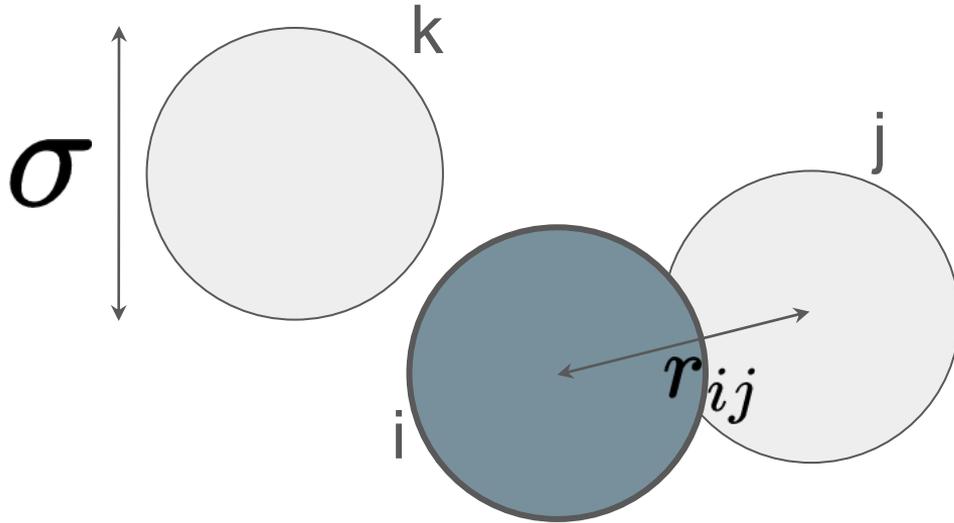
Near-Field (two-body)

Three Sedimenting Spheres



Brady *et al.*, J. Fluid Mech. **180** (1987)
Fiore & Swan, J. Fluid Mech. **878** (2019)

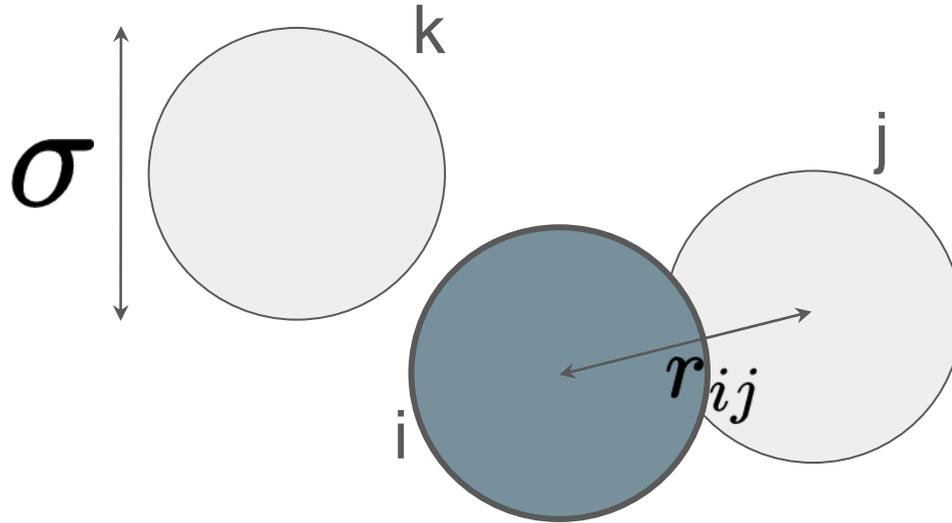
“Potential Free” Hard-Spheres



$$\mathbf{F}_i^{hs} = - \sum_j k(r_{ij} - \sigma) \hat{\mathbf{r}}_{ij}$$



“Potential Free” Hard-Spheres

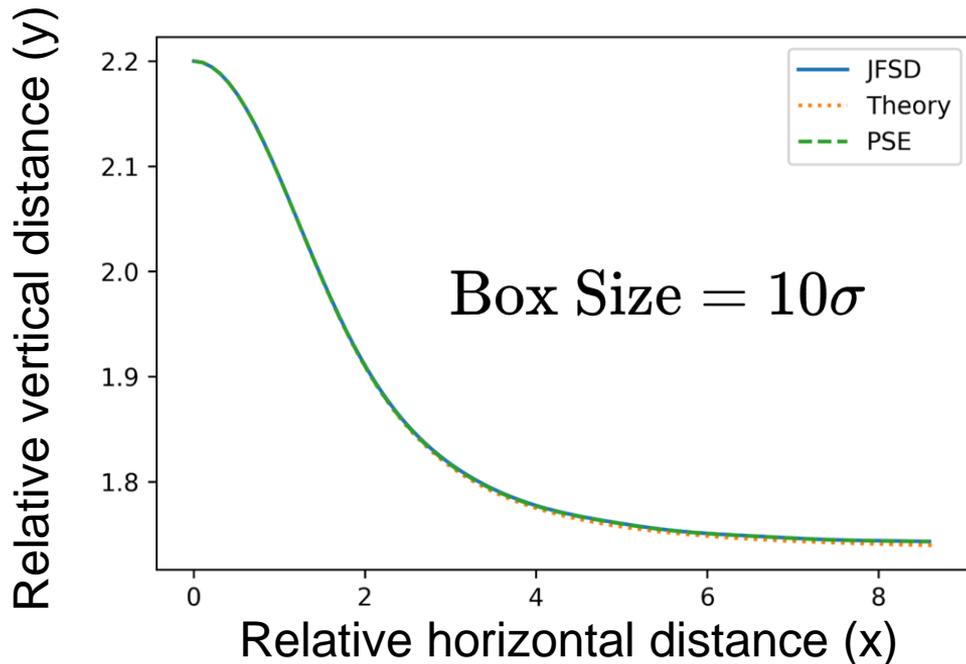
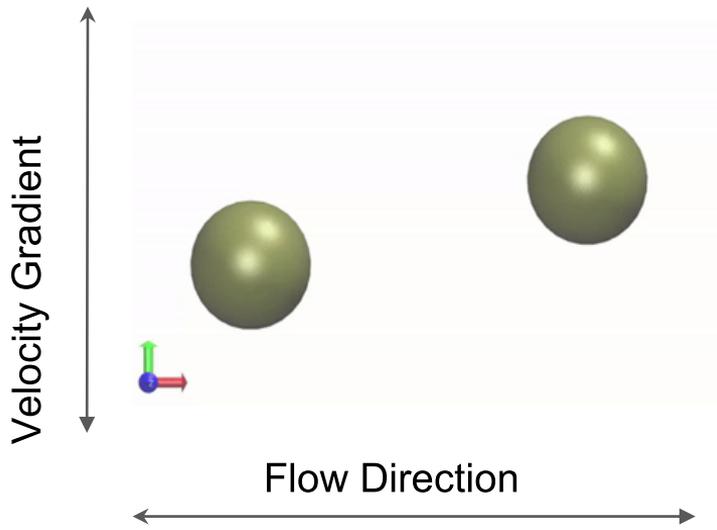


$k \gg 1$ because
of lubrication!

$$\mathbf{F}_i^{hs} = - \sum_j k(r_{ij} - \sigma) \hat{\mathbf{r}}_{ij}$$



Testing Simple Shear



$$\mathbf{v}_\infty // \hat{\mathbf{x}}$$

Outline

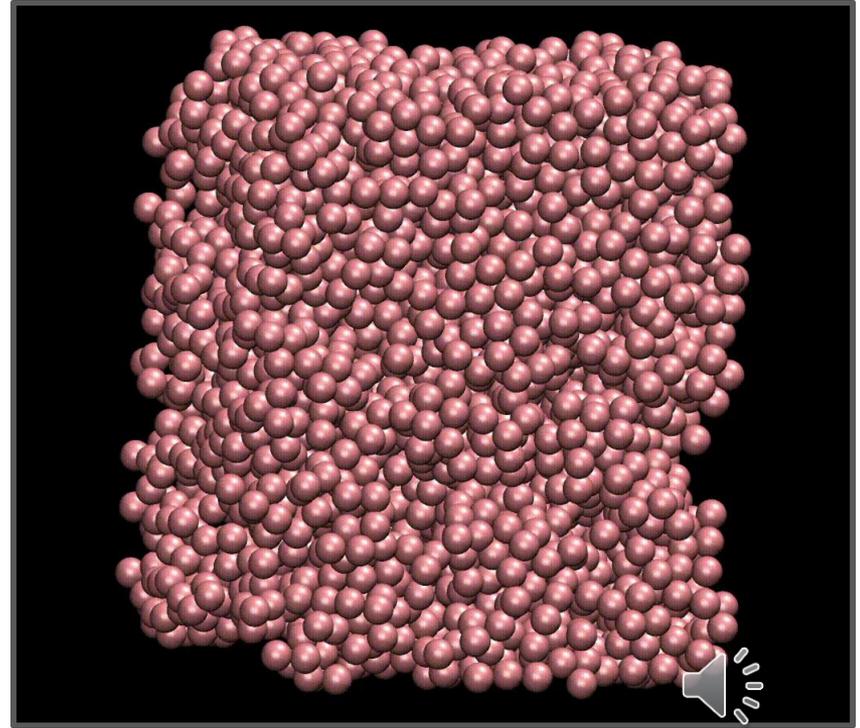
- Simulation method (JFSD)
- **Particle initial configuration**
- Capillary Bridges
- Results



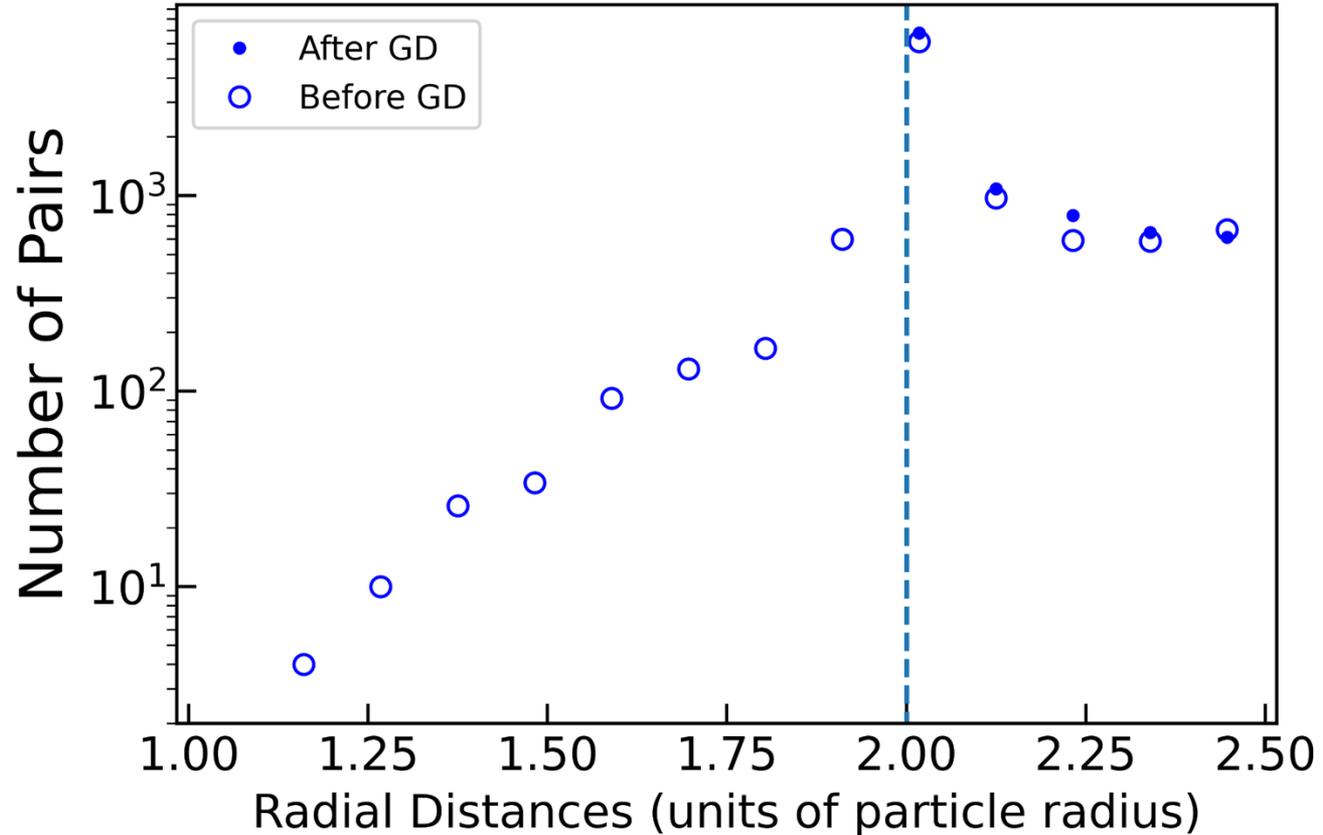
Gradient Descent

$$V = \begin{cases} \sum_{i,j} \frac{1}{2} (\Delta r_{i,j})^2 & \Delta r < \sigma \\ 0 & \Delta r \geq \sigma \end{cases}$$

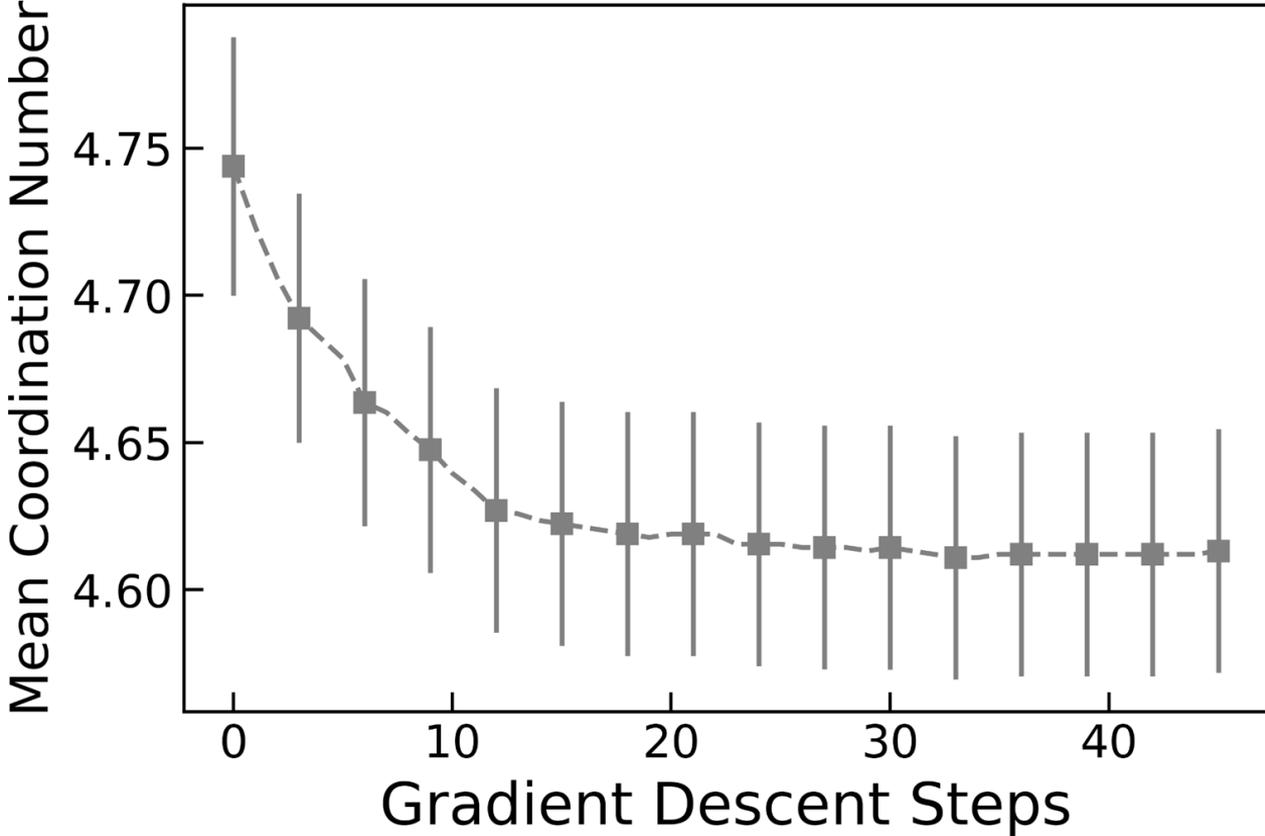
$$\mathbf{r}_{\text{new}} = -\epsilon \nabla V$$



Gradient Descent



Gradient Descent



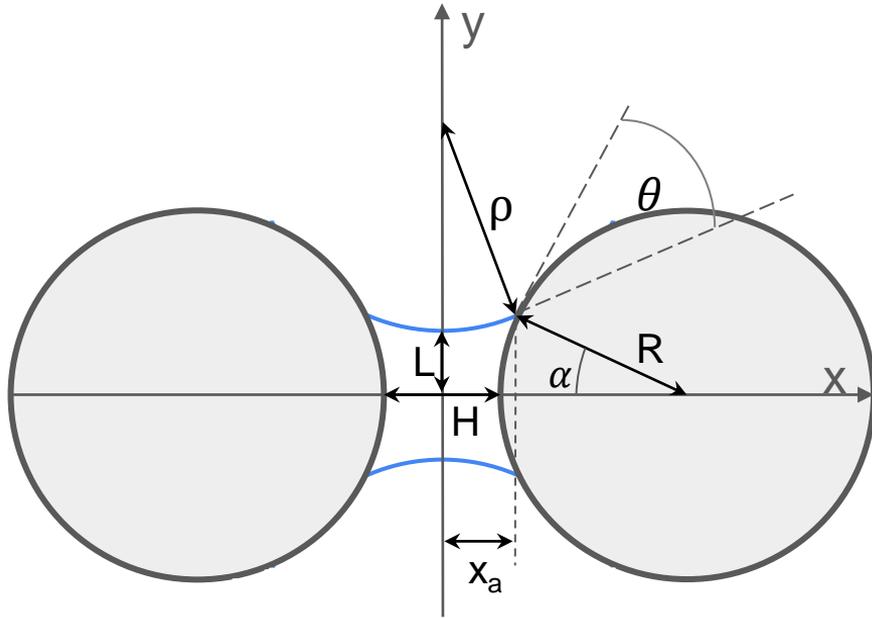
Outline

- Simulation method (JFSD)
- Particle initial configuration
- **Capillary Bridges**
- Results



Capillary Forces

$$\frac{F_{cap}}{T\sigma} = -\pi \sin \alpha \sin (\alpha + \theta) - \frac{\pi\sigma}{4} \sin^2 \alpha \left(\frac{1}{L} - \frac{1}{\rho} \right)$$



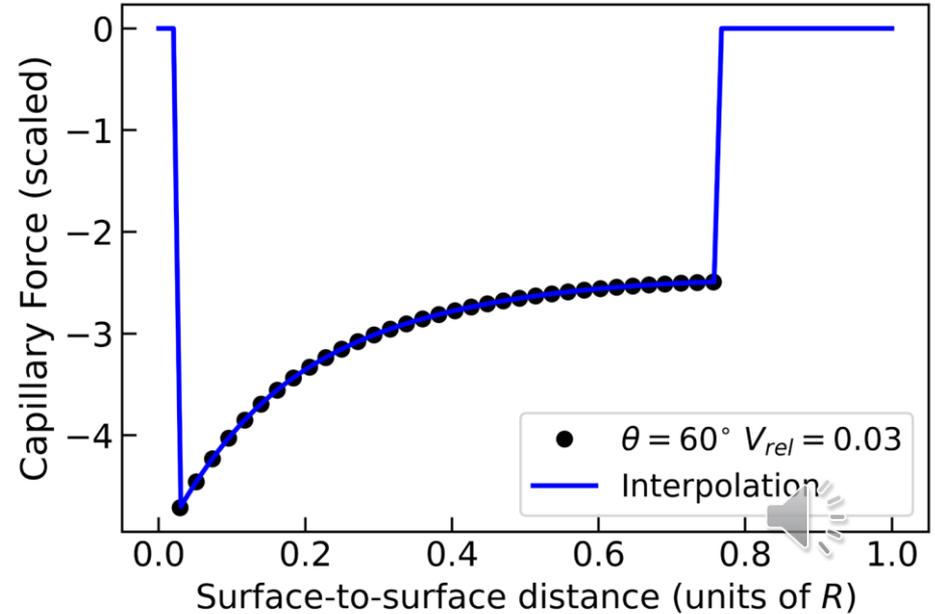
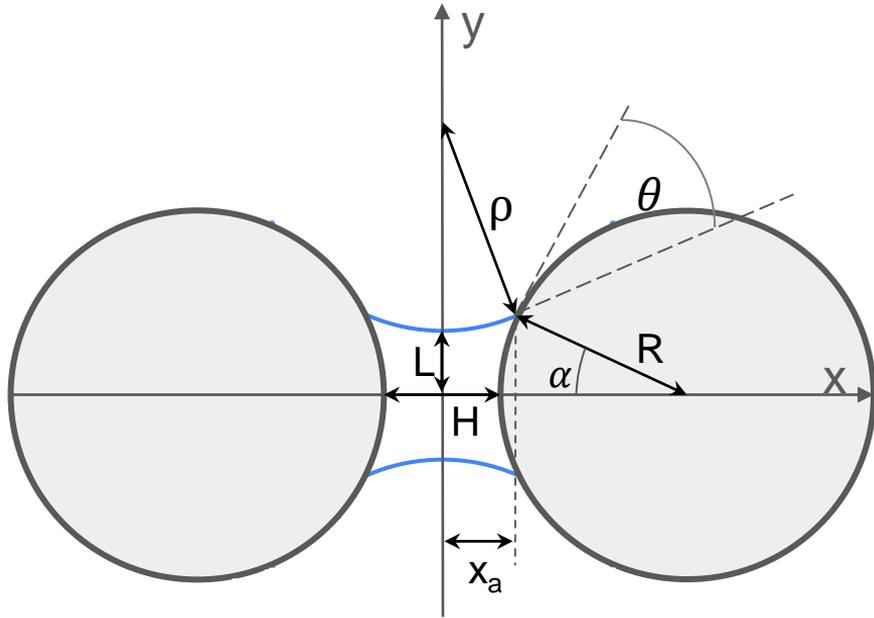
$$\text{Mason number} = \frac{3\pi\eta\sigma\dot{\gamma}}{T} \ll 1$$

$$\left\{ \begin{array}{l} \eta = \text{Dynamic Viscosity} \\ \dot{\gamma} = \text{Shear Rate Amplitude} \\ T = \text{Surface Tension} \end{array} \right.$$



Capillary Forces

$$\frac{F_{cap}}{T\sigma} = -\pi \sin \alpha \sin (\alpha + \theta) - \frac{\pi\sigma}{4} \sin^2 \alpha \left(\frac{1}{L} - \frac{1}{\rho} \right)$$

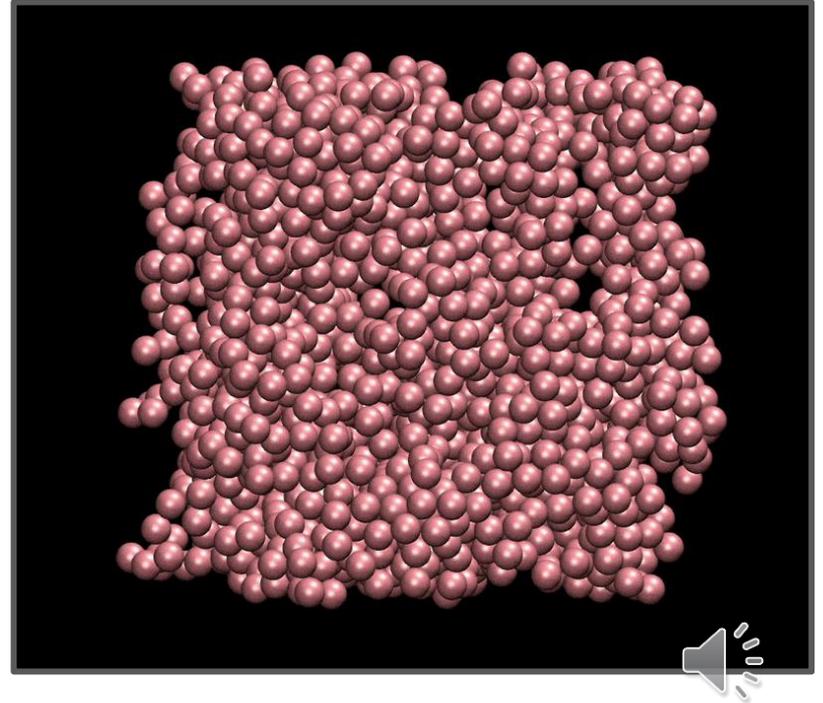
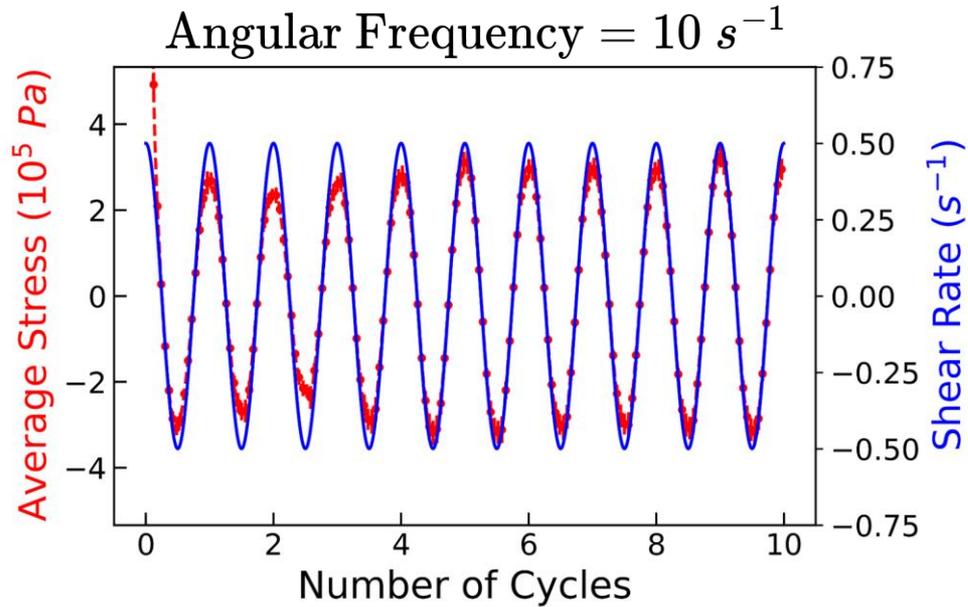


Outline

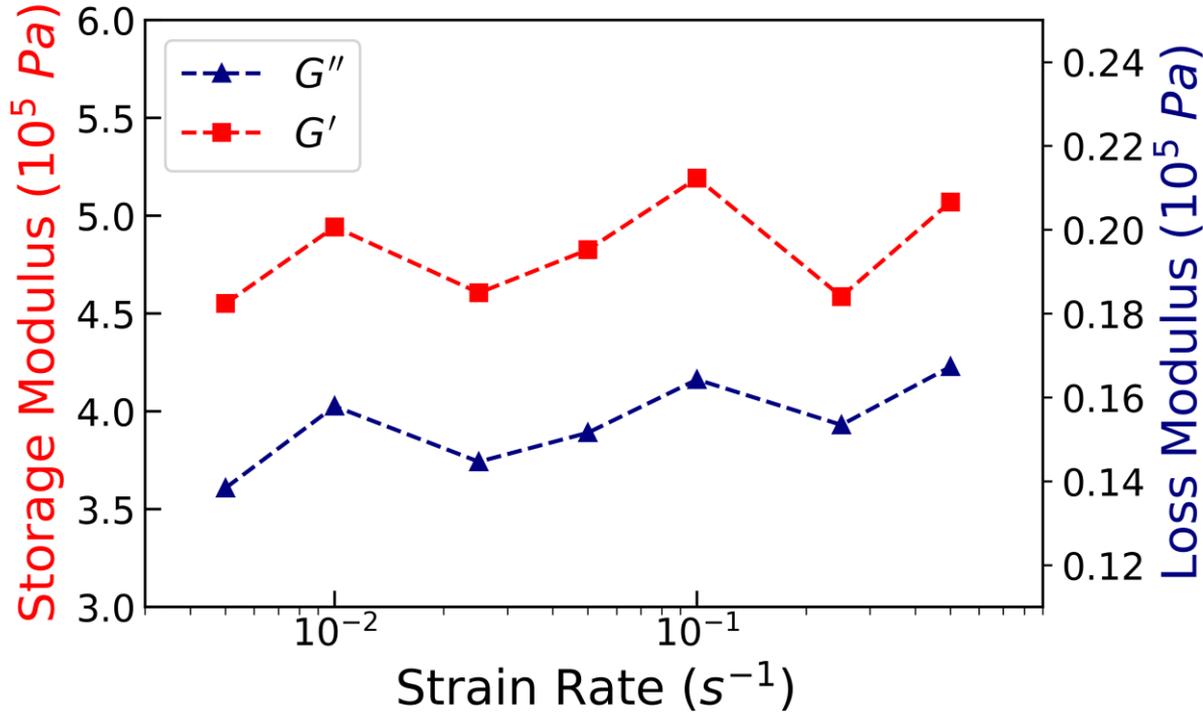
- Simulation method (JFSD)
- Particle initial configuration
- Capillary bridges
- **Results**



Oscillatory Shear



Storage and Loss Moduli



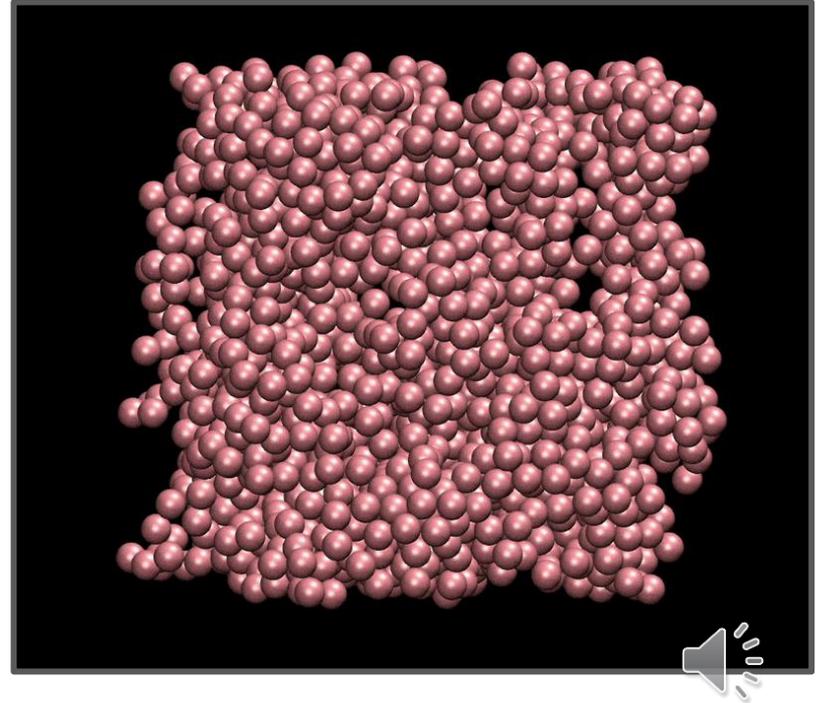
Mason number $\lesssim 1$

Smaller values
computationally challenging
(longer simulations)



Conclusion & Outlook

- Shear simulations
- Exp. configurations
- First testing done
- Finish comparison



Thank you for your attention



Are there any questions?

