Dynamic jamming in dense particulate suspensions

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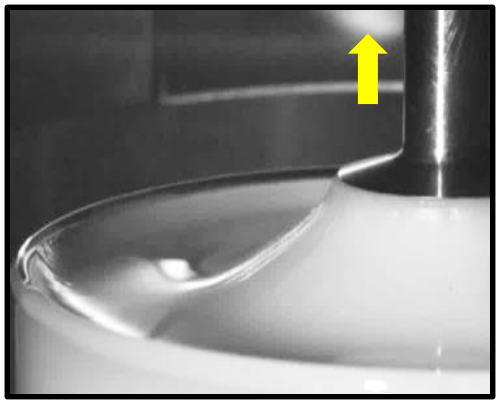
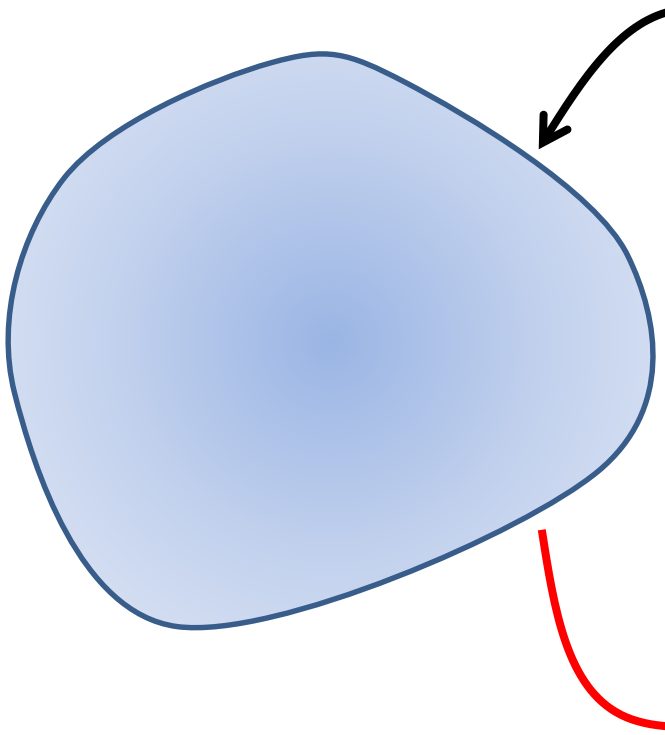


Adaptive materials



External stimuli

(Electric/magnetic field, force, pH etc.)

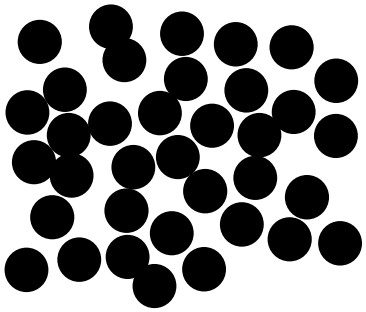
Material Response

Rapid, controlled reversible changes: adapting to changing environment

Designing such materials is extremely challenging

Dense suspensions : New physics

Liquid



Dry granular material

50% liq. + 50% solid

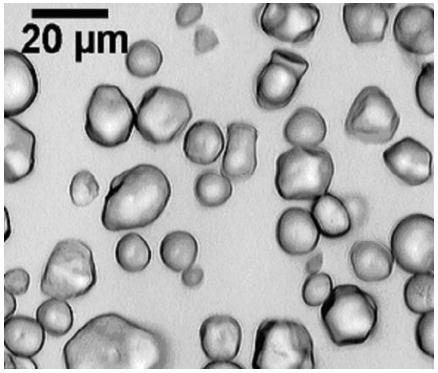
Dense suspension

Unusual flow properties

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

Impact Activated Solidification

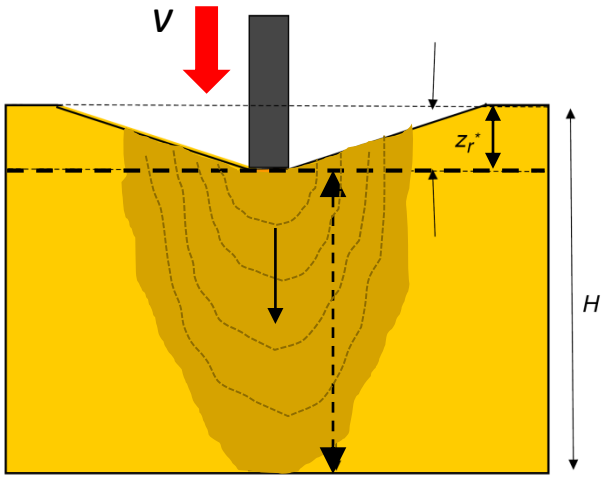
Dense suspensions can turn into a transient solid under rapid impact



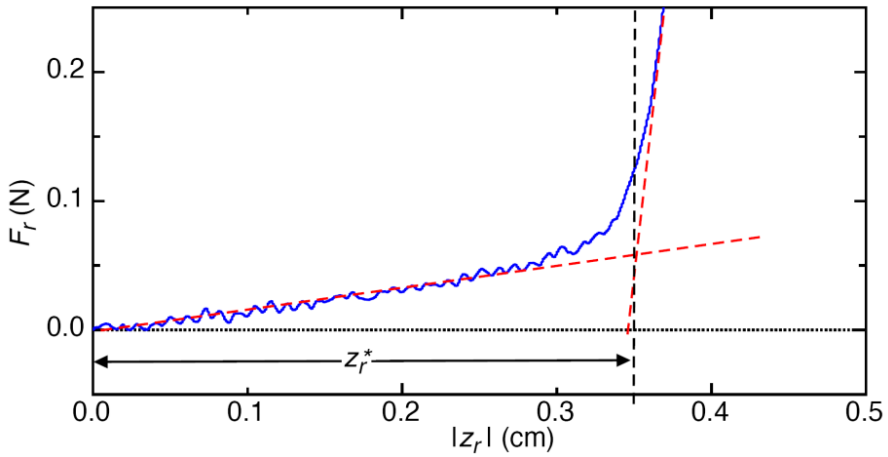
Fall et al., JoR (2012)

Brown and Jaeger (2014)

Impact Activated Solidification



Dense cornstarch suspension



Waitukaitis and Jaeger, Nature (2012)

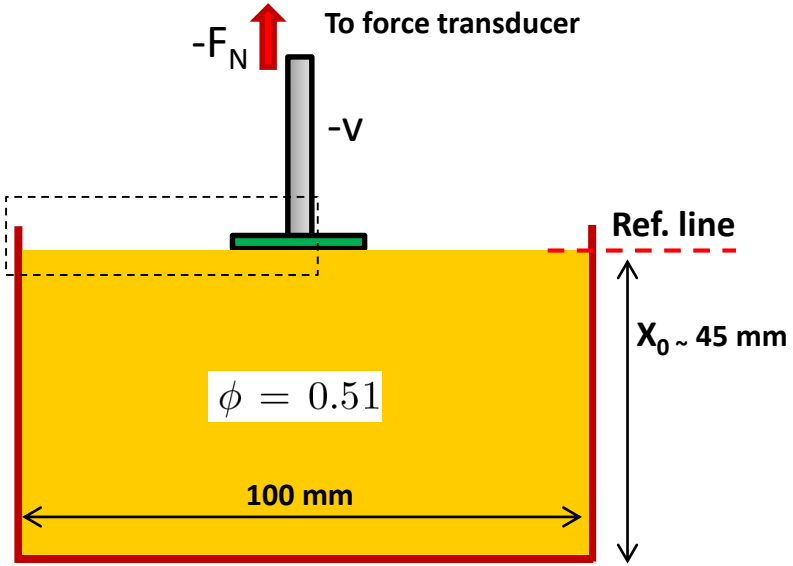
Waitukaitis, PhD Thesis (2013)

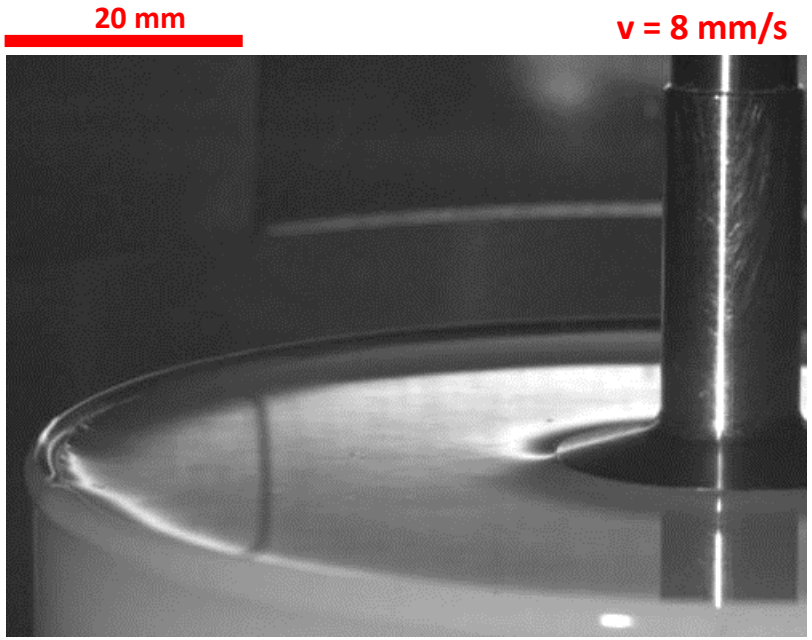
Growing solid-like jammed region → Dynamic 'jamming front'.

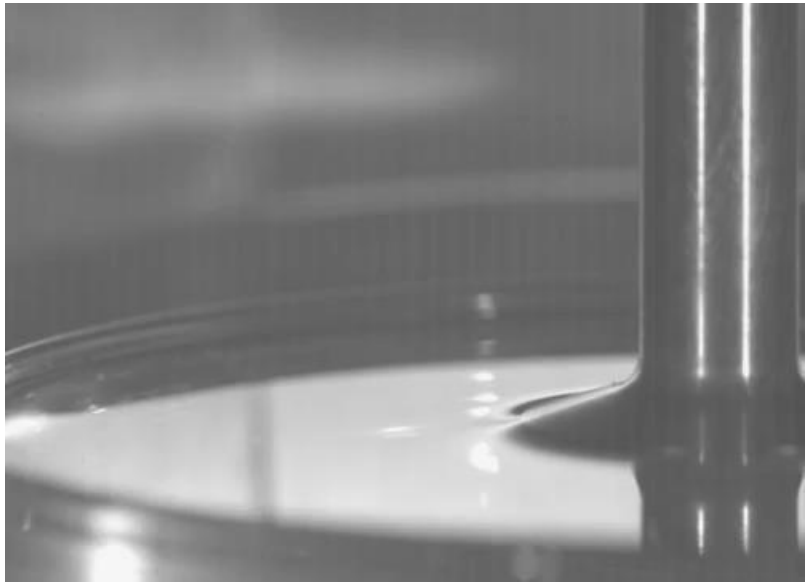
'Jamming front' travels much faster than impact speed.

What happens under non-compressive deformations??

Transient response under extension

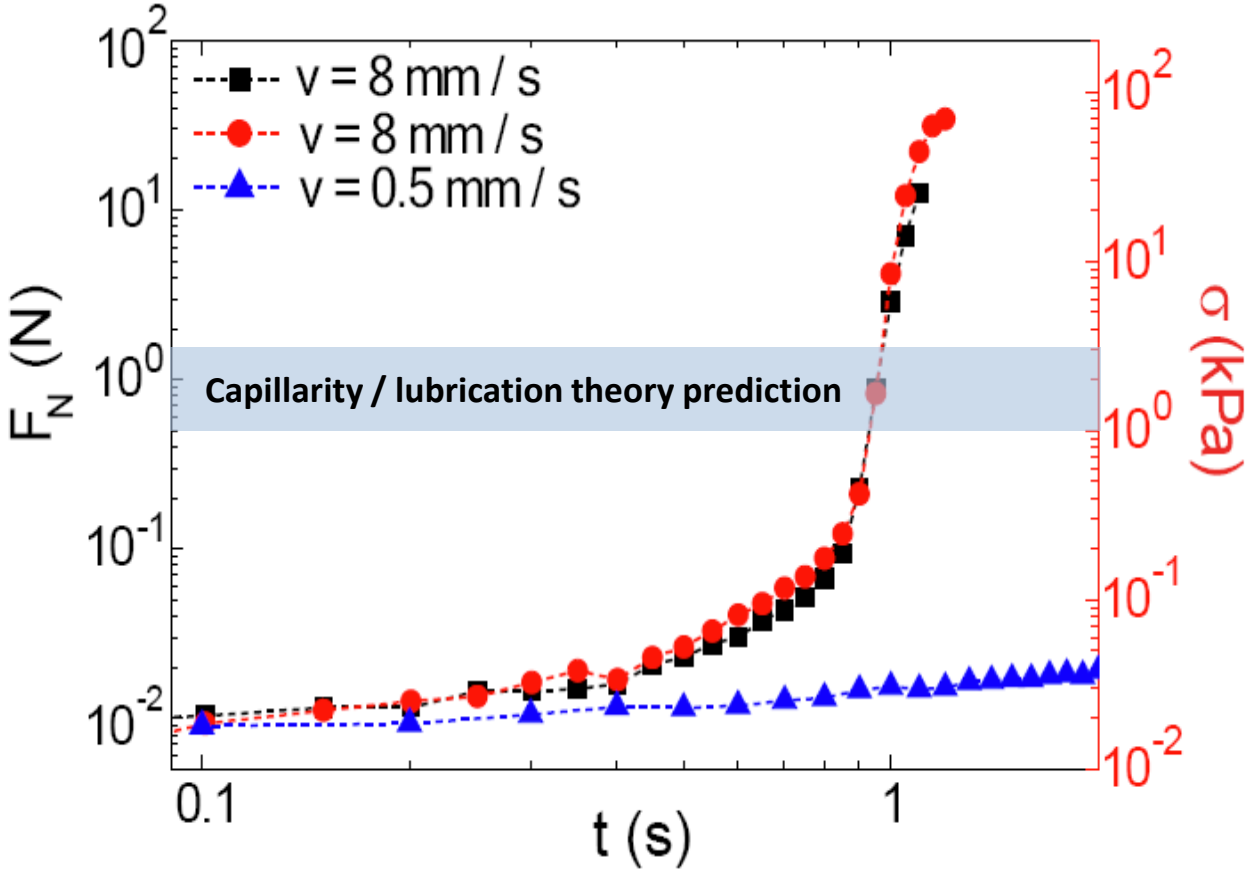






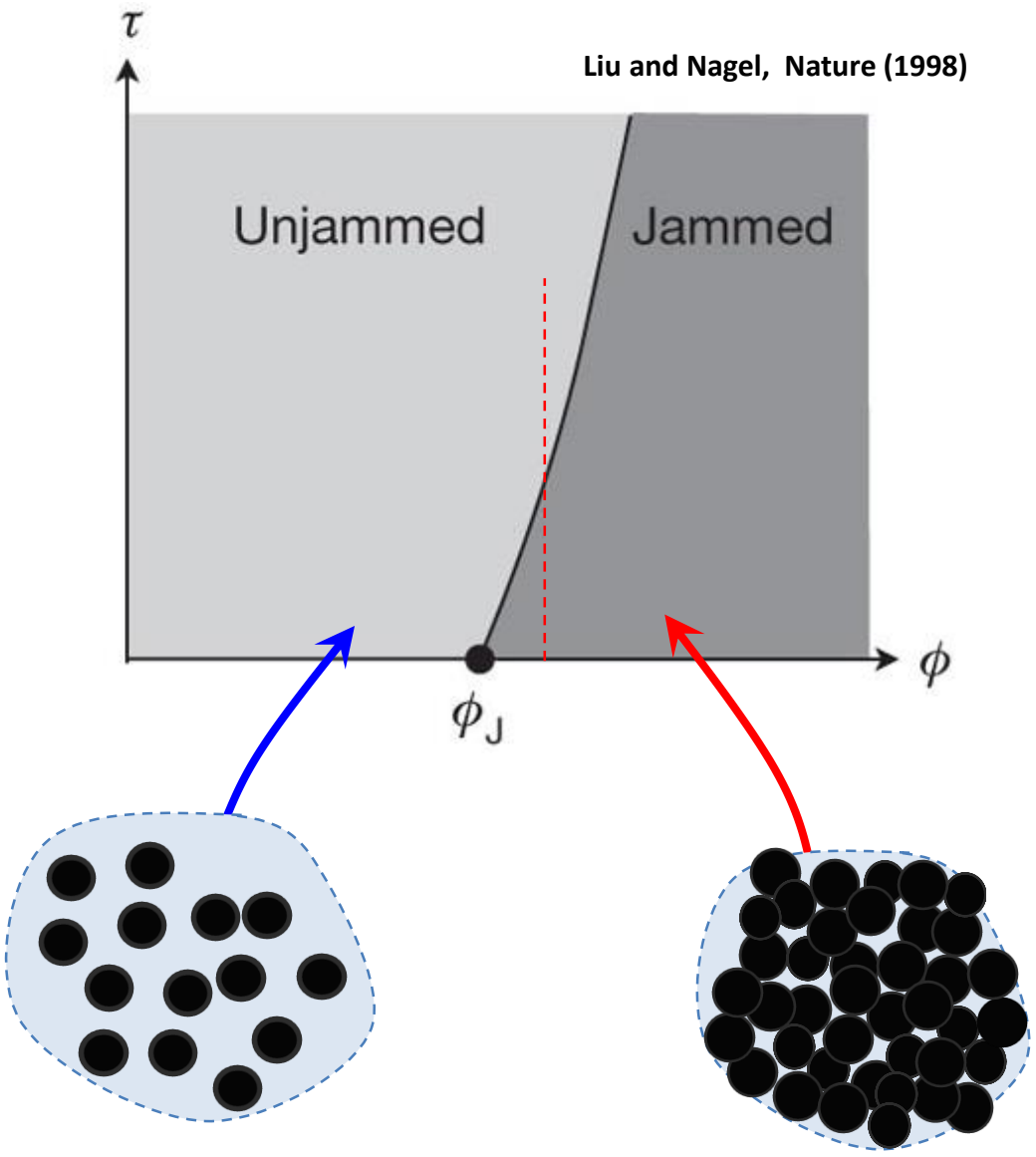
10 Pas Silicone oil
(10000X more Viscous than water)

Force / stress response under extension

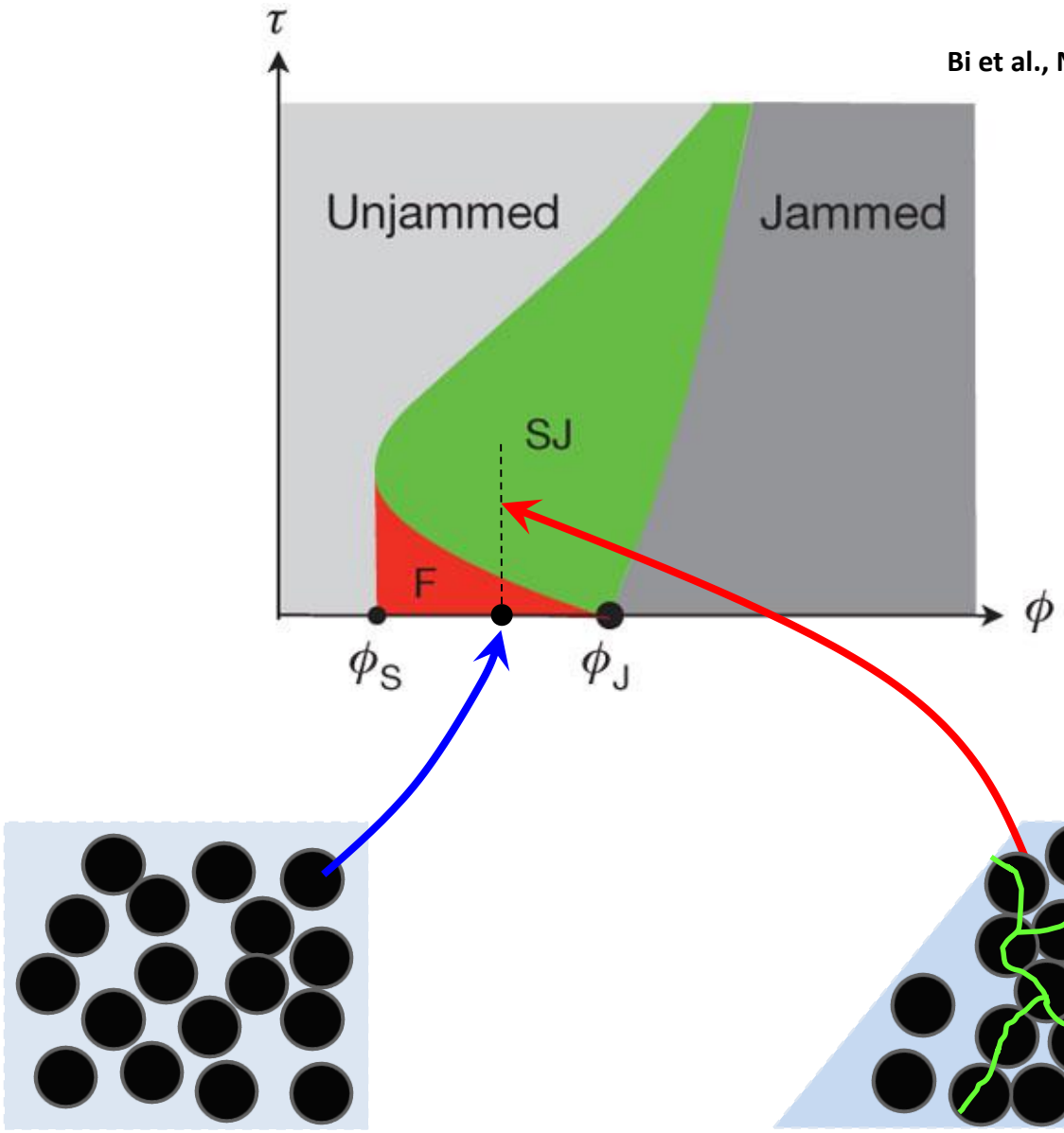


Observed high stresses cannot be rationalized by hydrodynamic approaches

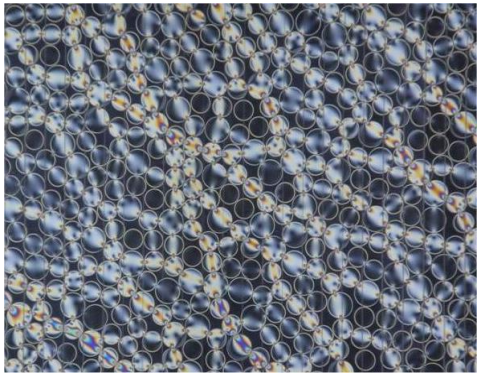
Isotropic jamming transition



Anisotropic jamming transition: Shear jamming

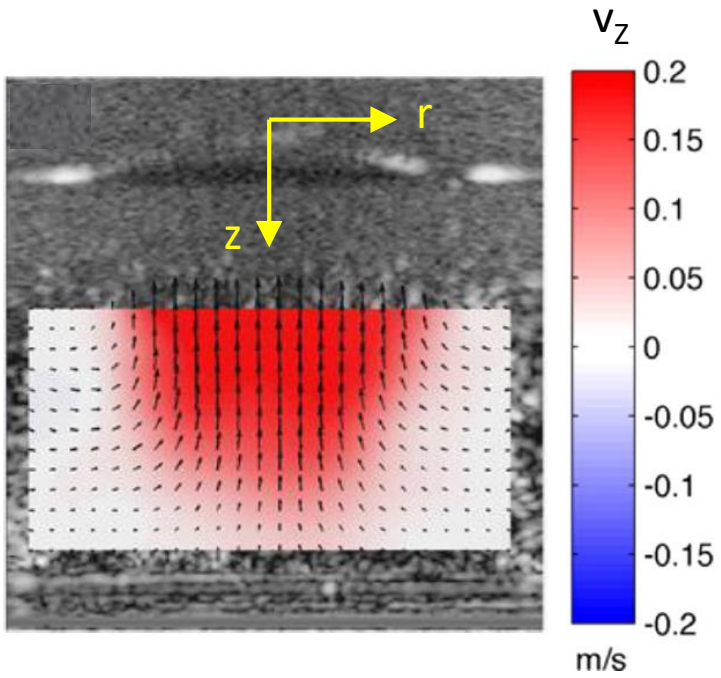


Bi et al., Nature (2011)

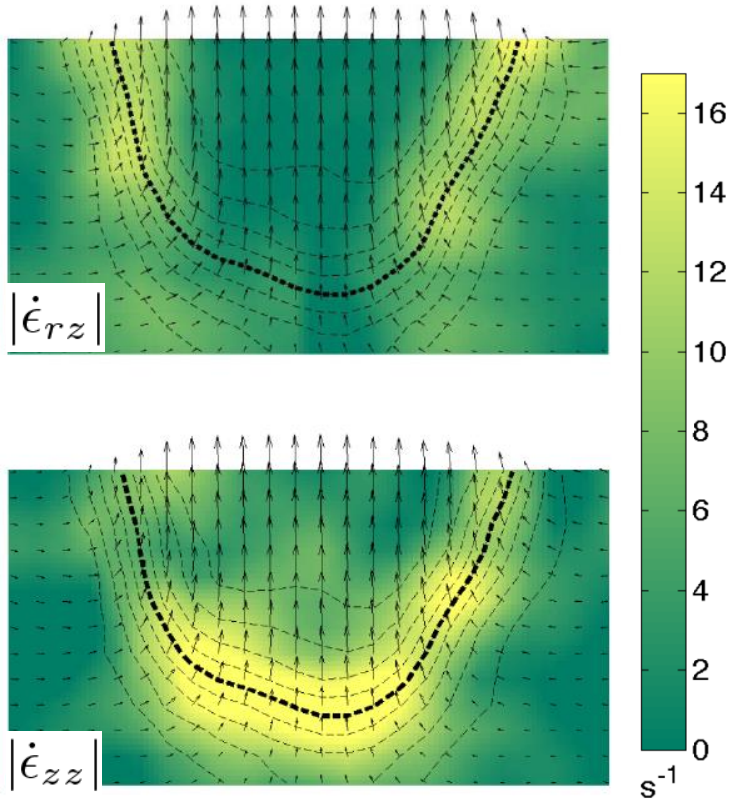


Behringer group website

Boundary shear maintains the growing jammed region



$$\dot{\epsilon}_{r\theta z} = \begin{bmatrix} \dot{\epsilon}_{rr} & \dot{\epsilon}_{r\theta} & \dot{\epsilon}_{rz} \\ \dot{\epsilon}_{\theta r} & \dot{\epsilon}_{\theta\theta} & \dot{\epsilon}_{\theta z} \\ \dot{\epsilon}_{zr} & \dot{\epsilon}_{z\theta} & \dot{\epsilon}_{zz} \end{bmatrix}$$



Growing correlated region
small velocity gradient

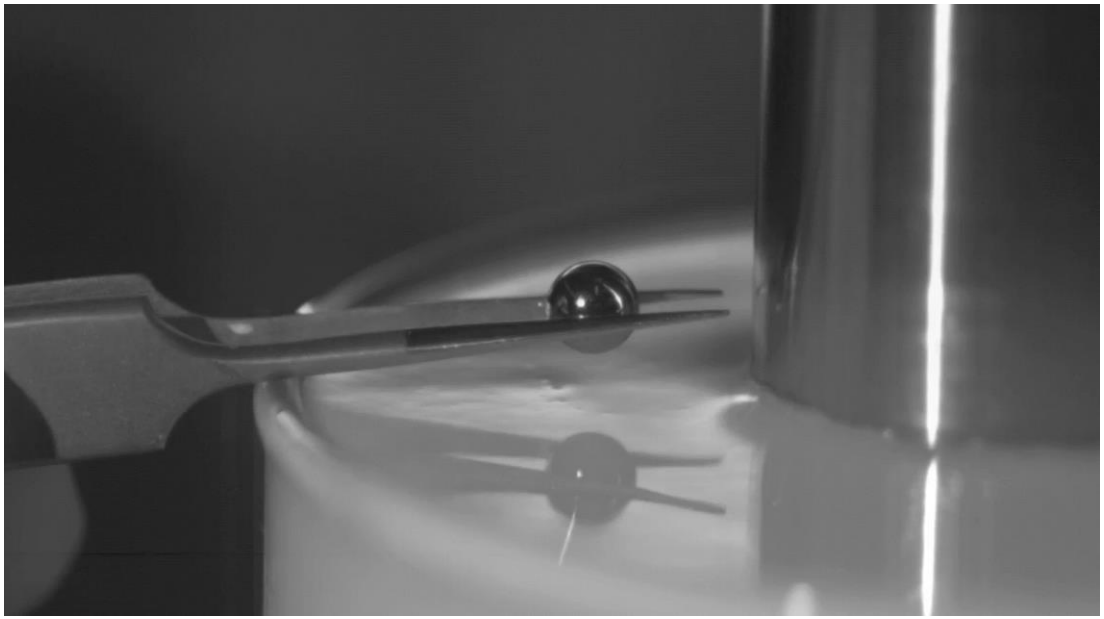
➡ **Solid-like jammed region**

The jamming is purely shear-induced

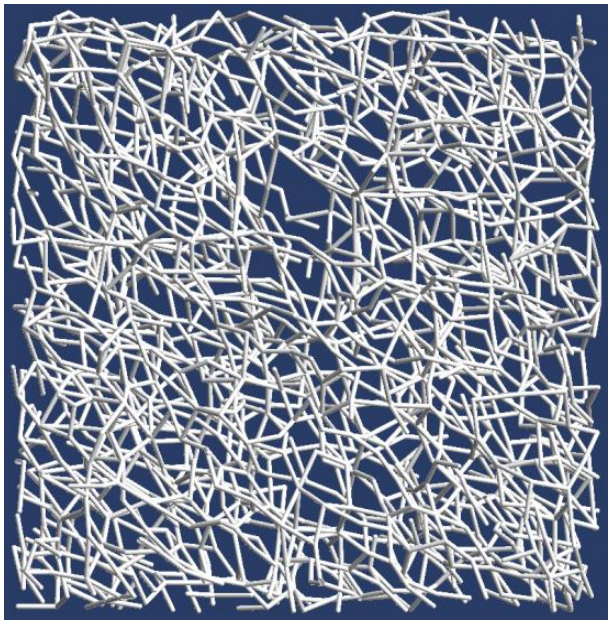
Majumdar *et al.*, Phys. Rev. E (2017)

Solid-like jammed states in dense suspensions

Jamming under simple shear



Peters, Majumdar and Jaeger, Nature, 2016

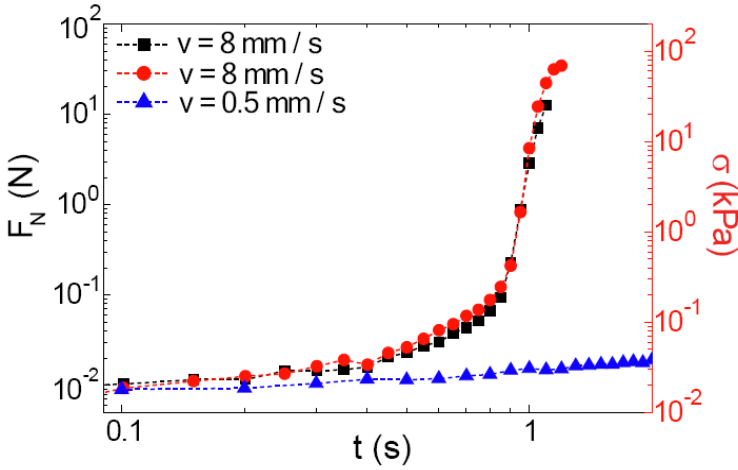


Seto et al., PRL (2013)

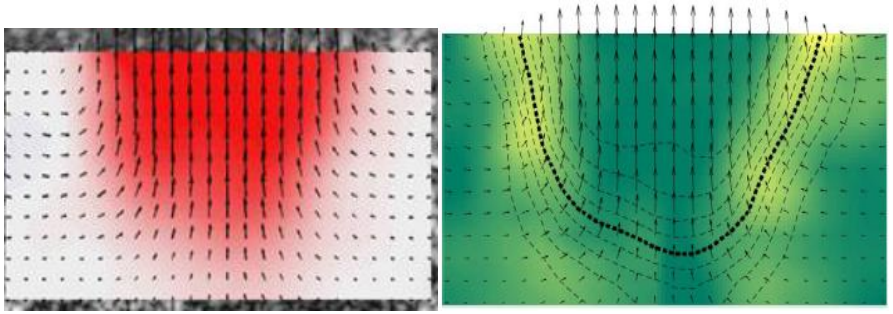
Dense suspension with frictional particles show solid like jammed state under shear

Conclusions

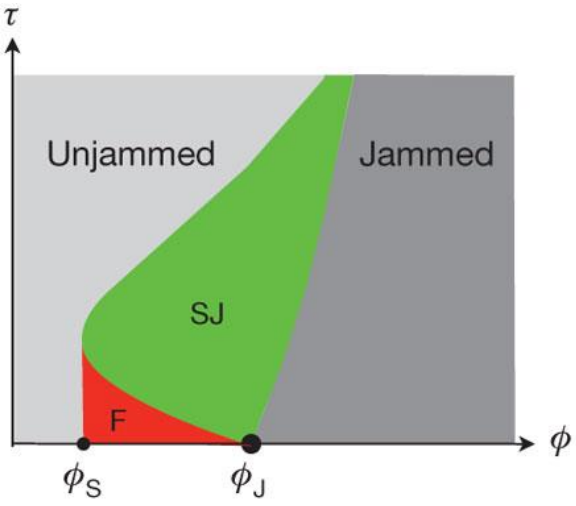
1. Transient jamming dynamics under extension is very similar to impact activated solidification (IAS).
Upper limit of stresses are well beyond the prediction of capillarity and lubrication hydrodynamics.



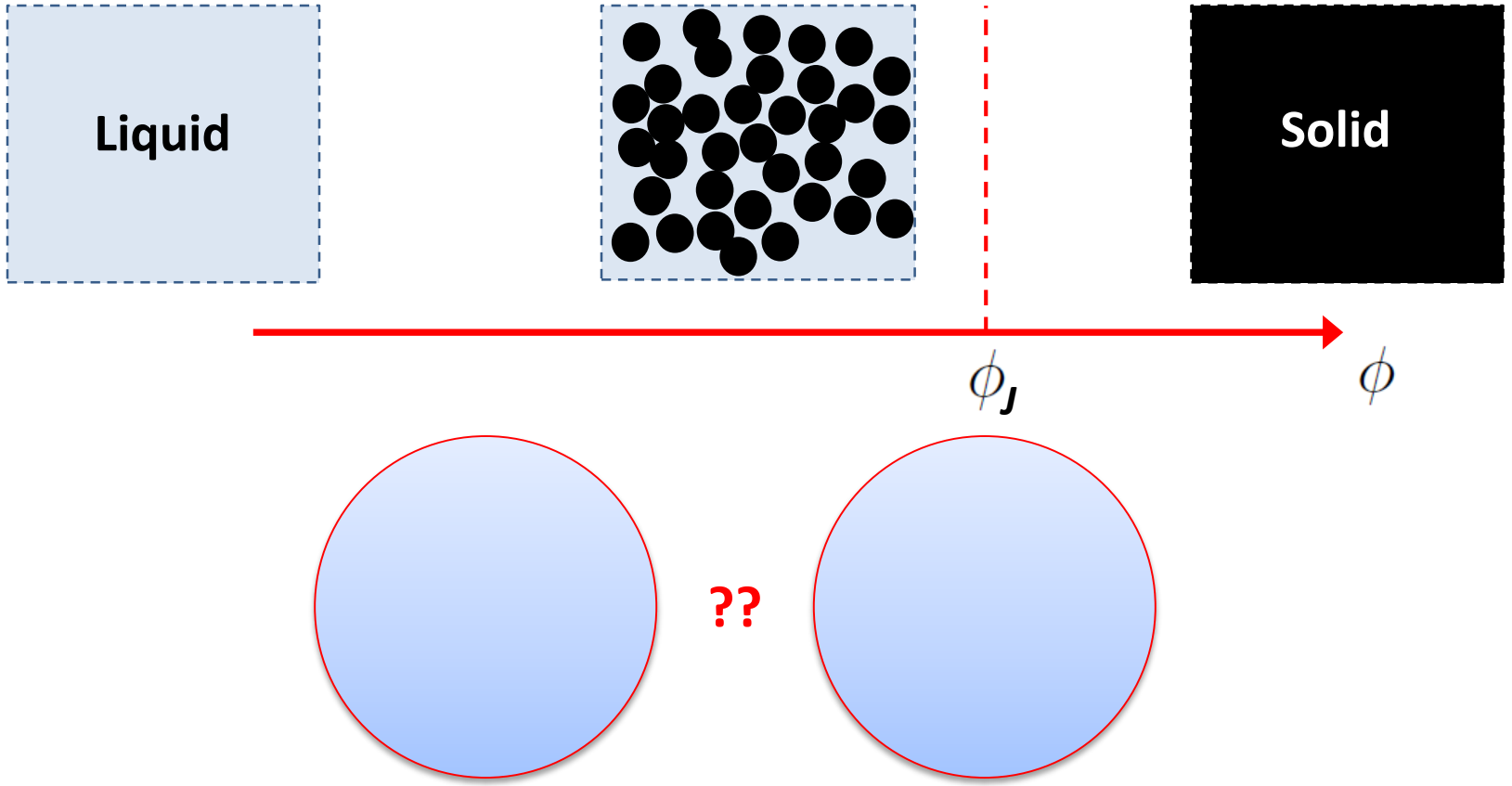
2. Unlike IAS, under extension the jamming front travels opposite to the forcing direction.



3. The jamming is entirely shear induced.



Jamming transition: Future challenges



Microscopic surface interactions → **Bulk properties**

- **Controlling microscopic properties**
- **What ‘interparticle friction’ means ?**

Acknowledgements

Collaborators

Prof. Heinrich Jaeger
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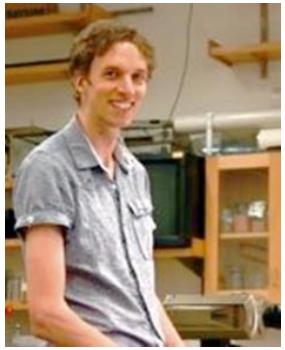

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Thank you for your attention