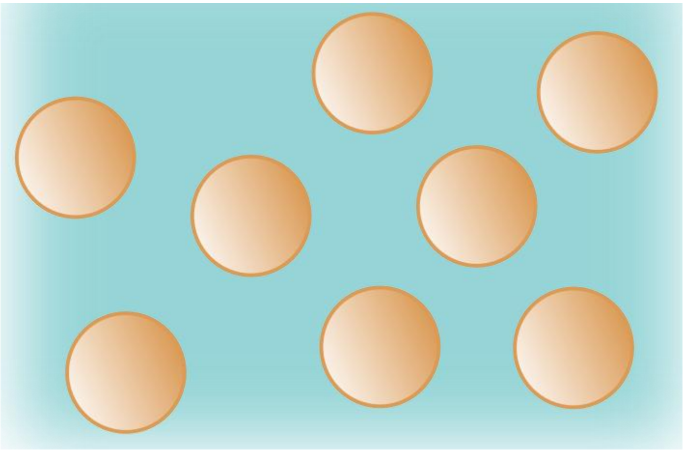
Liquide, particules et confinement

Alice Pelosse, Les Gustins 2024

Granular suspensions



Particles in a liquid

Colloidal/**granular** suspensions

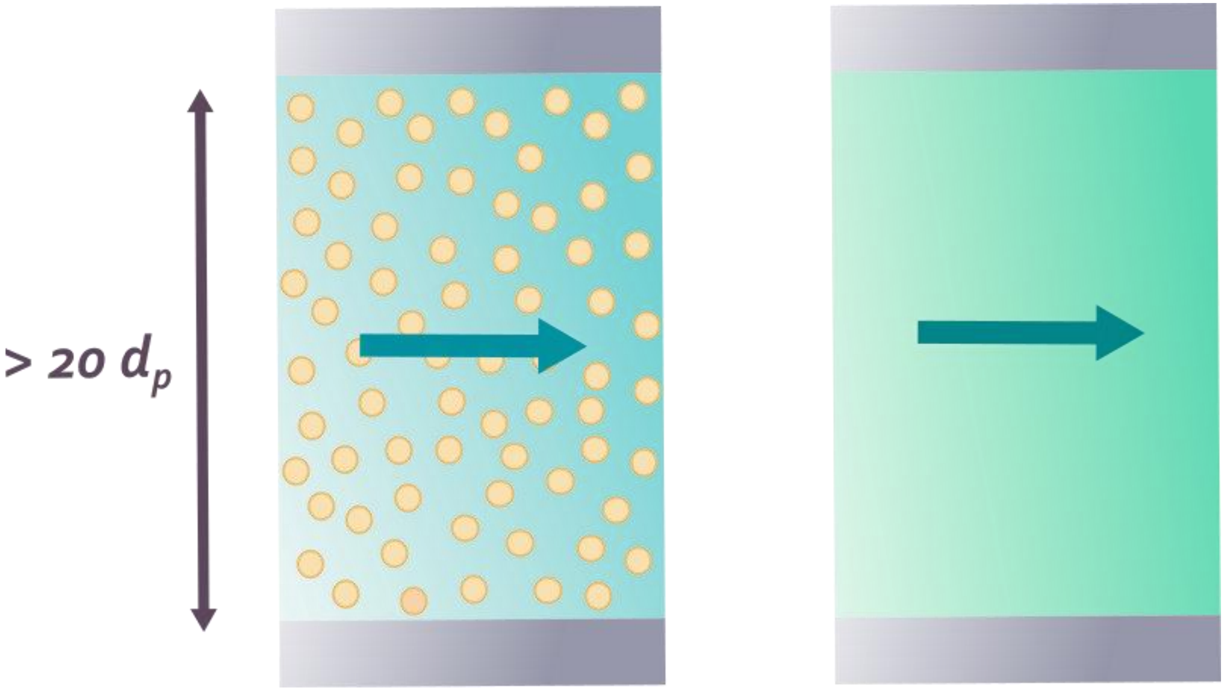
~~Brownian motion~~, ~~electrostatic interactions~~

$$a > 1\,\mathrm{um}$$

- Blood, concrete, sediment transports, debris flows …

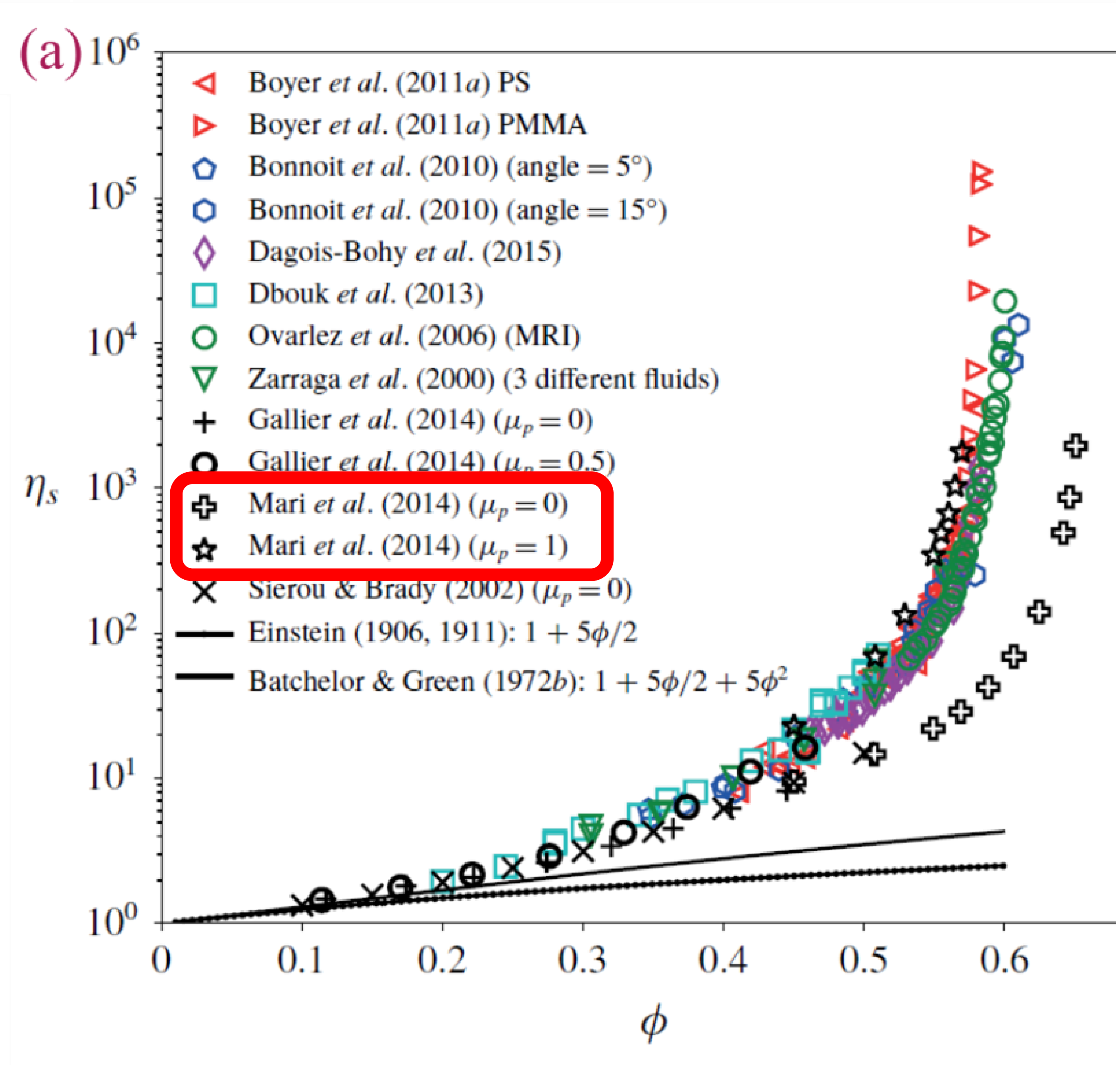
Complex system → continuous approach

- Particles in the liquid = additional dissipation
  - Hydrodynamics
  - Contacts = friction
- Effective viscosity



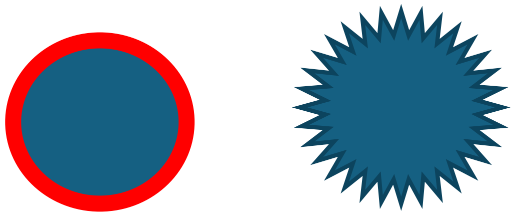
Bulk viscosity

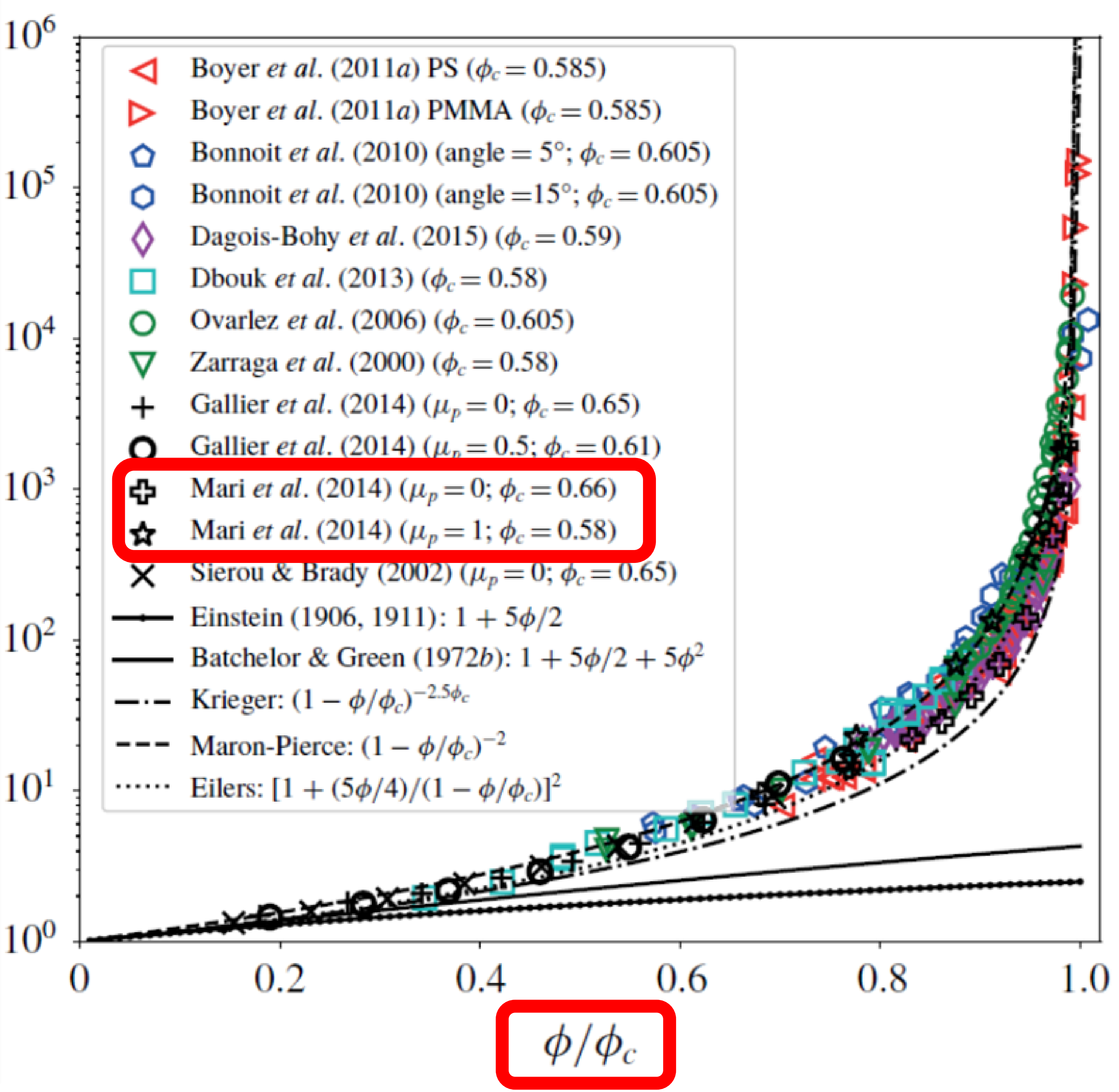
- Particle volume fraction ϕ
- Jamming
- Other parameters?
  - Particle size?
  - Particle density?
  - Particle roughness?



Friction matters a lot close to the jamming transition

- Chemistry of the surfaces
- Particle roughness

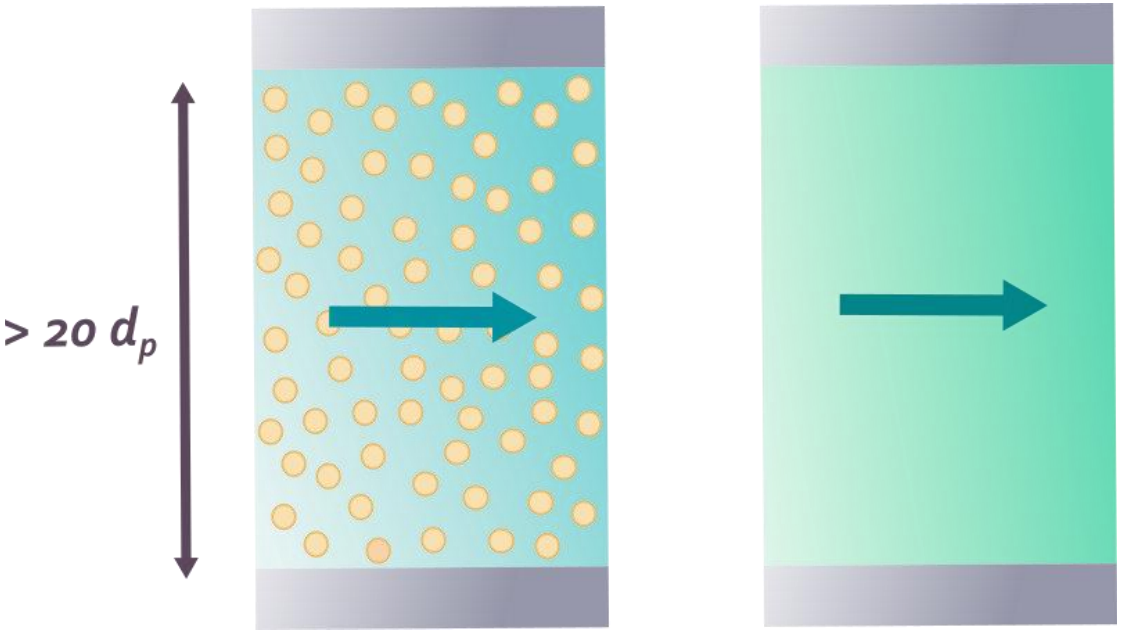




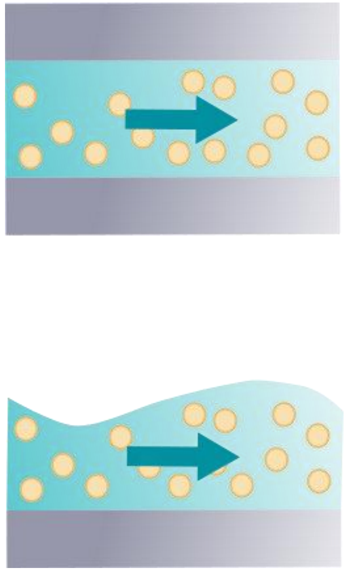
Friction matters a lot close to the jamming transition

→ Friction sets the maximum compaction

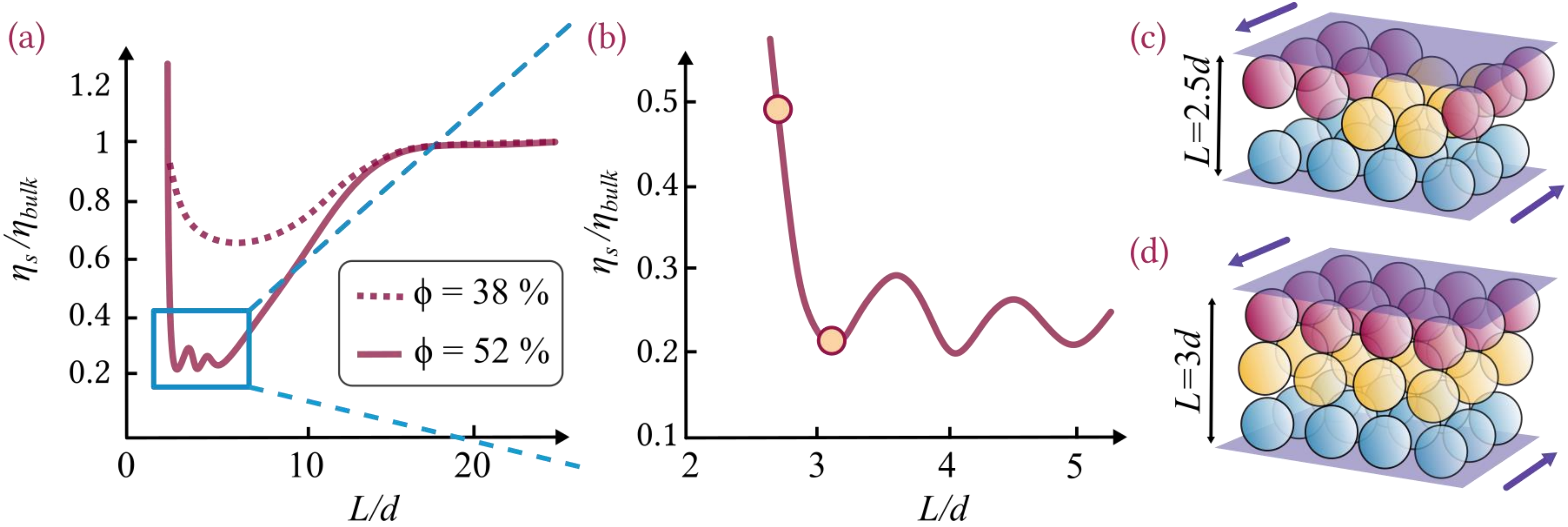
Confinement and viscosity



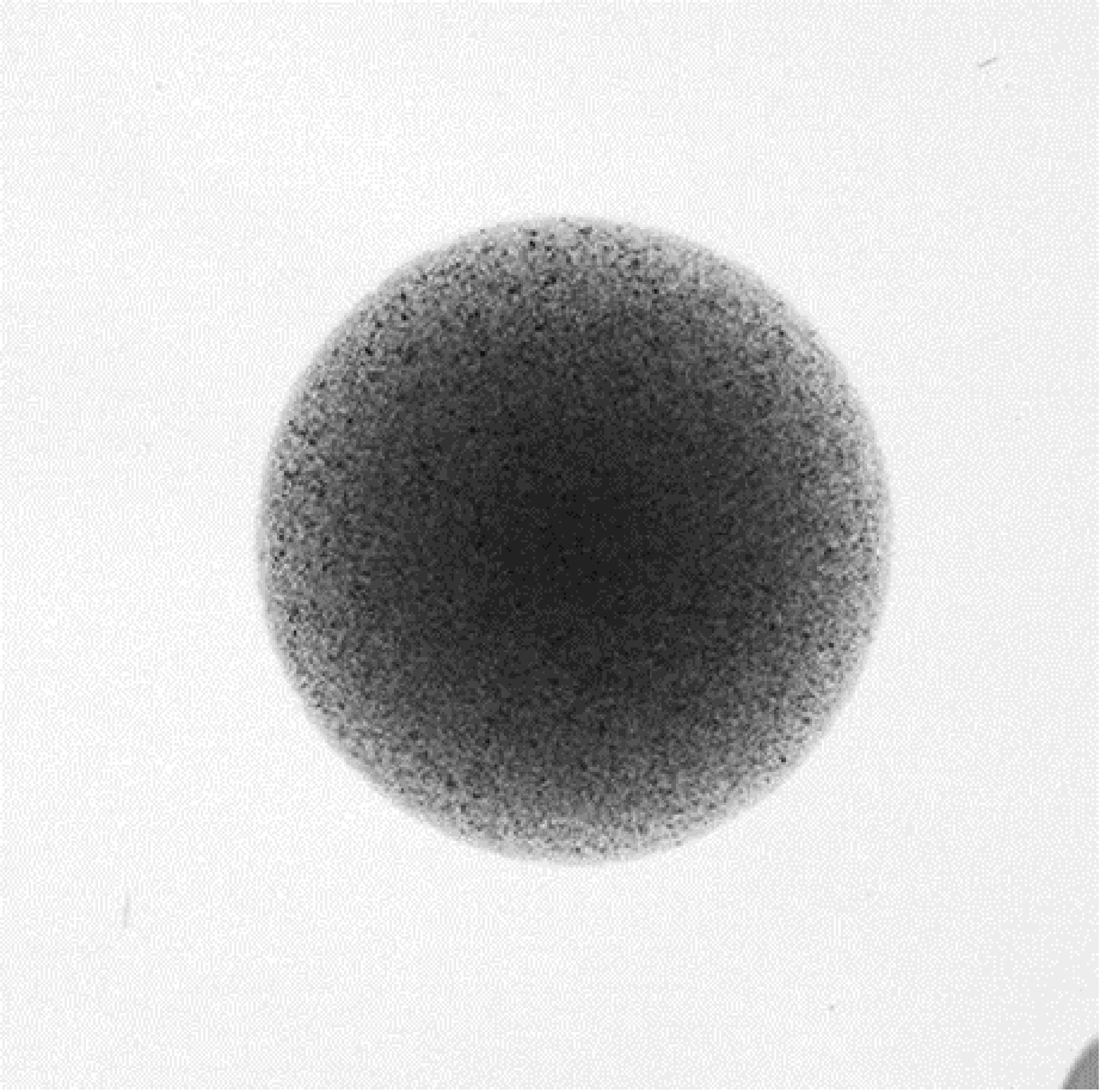
?

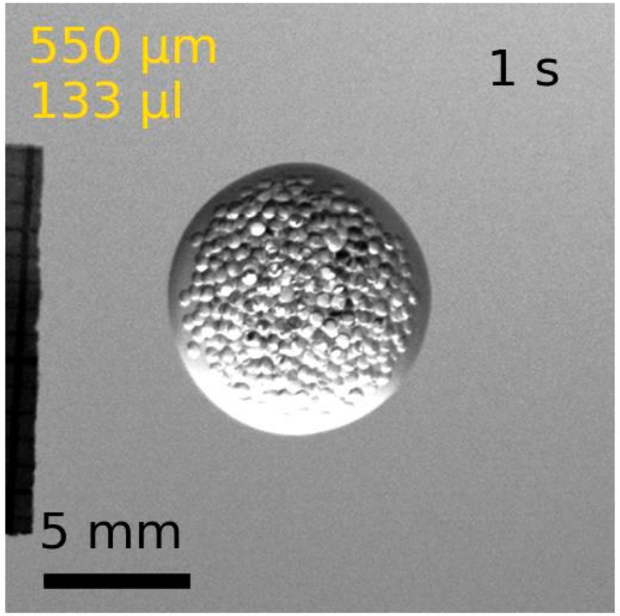


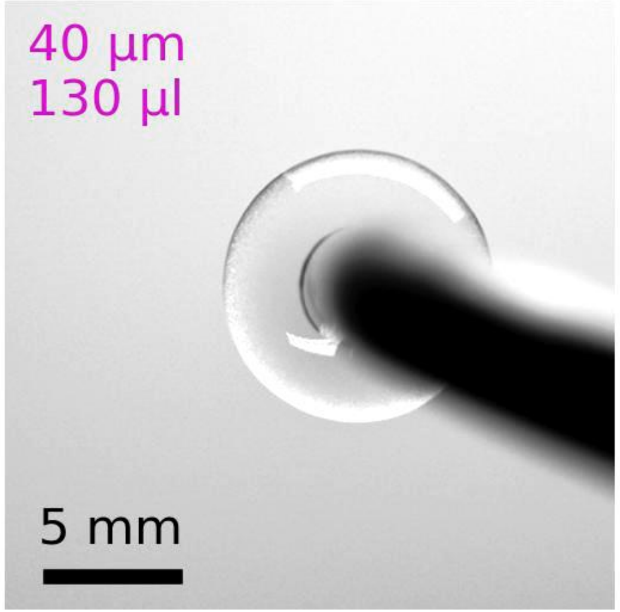
Effective viscosity of a confined suspension



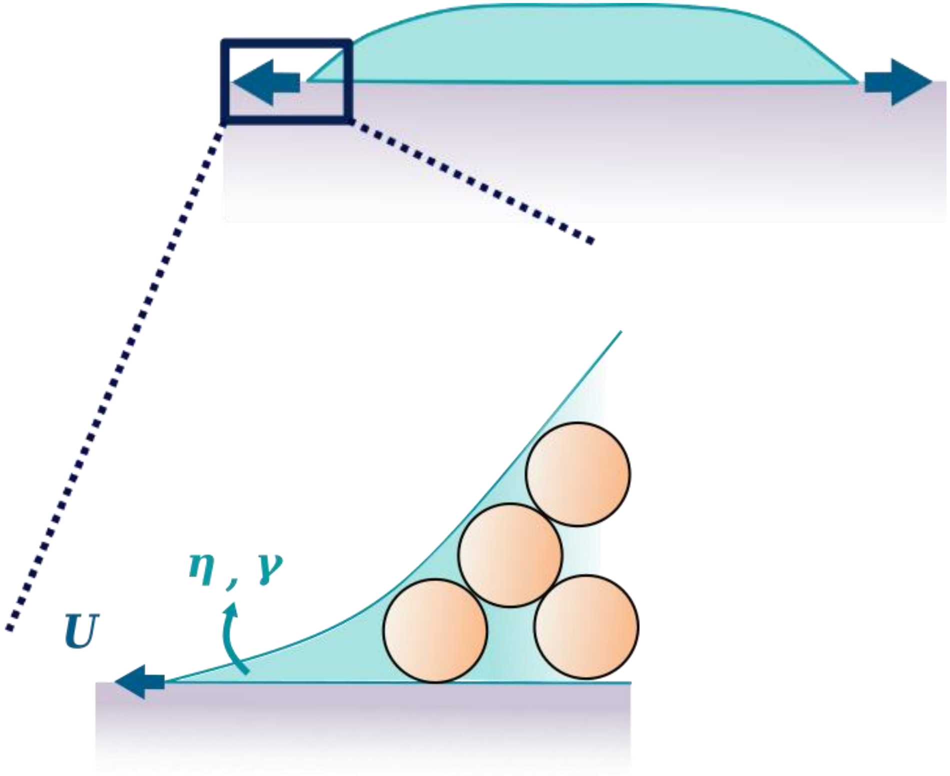
Confinement imposed by flat solid walls
Non-monotonic behavior of the effective viscosity
→ Wall effect, ordering

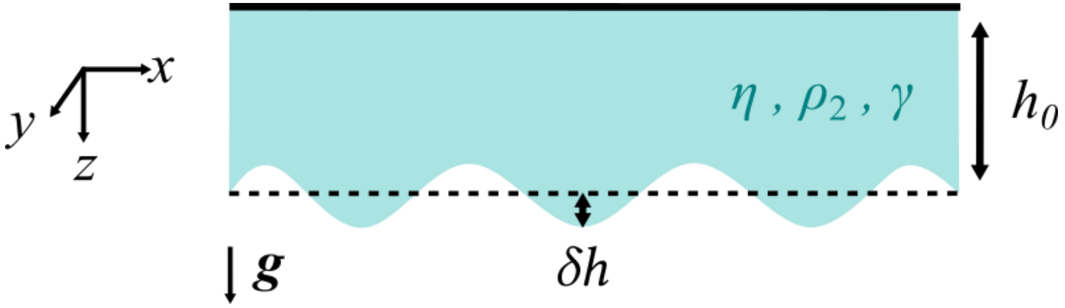


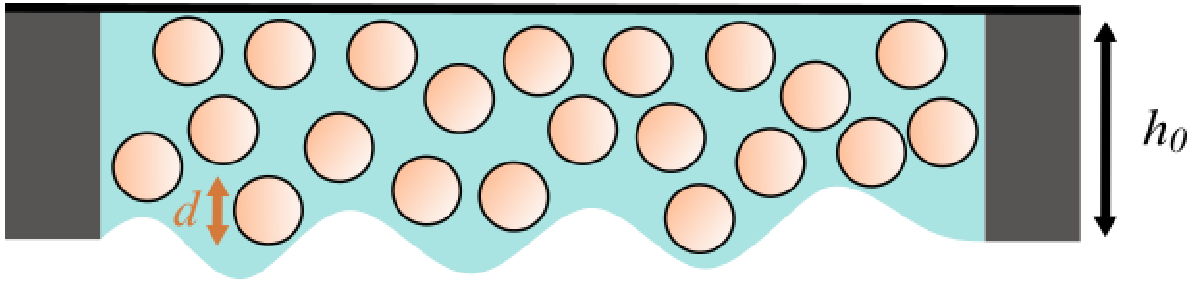

550 µm
133 µl
1 s
5 mm


40 µm
130 µl
5 mm

Soft confinement = free interface

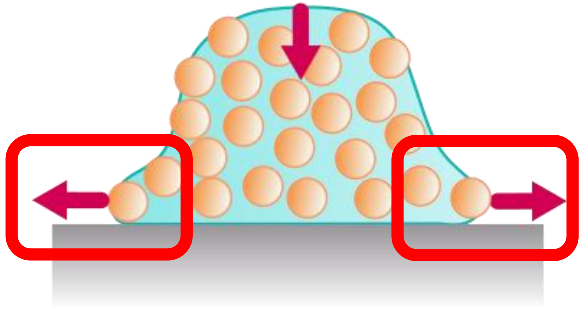






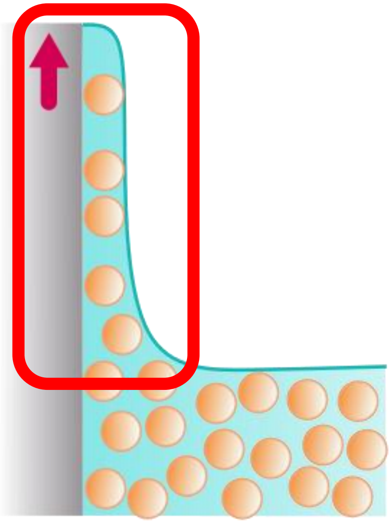
Capillary phenomena and particles

Drop impact



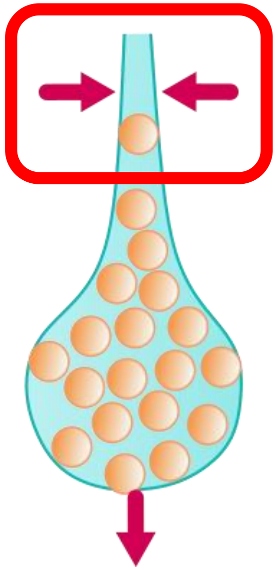
High inertia

Dip coating

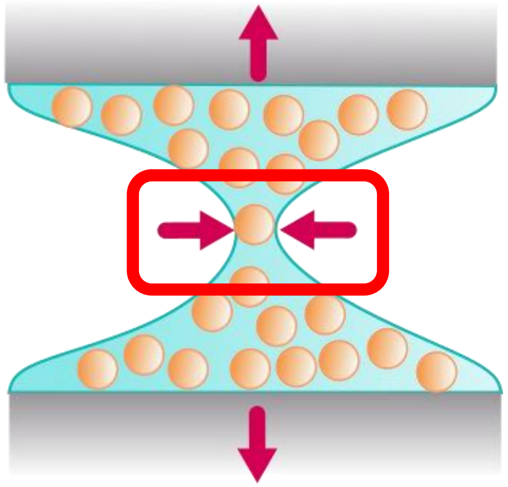


Forced wetting

Pinch-off
of a drop



Pinch-off
of a thread



1D instability

Fast Imaging Technique to Study Drop Impact Dynamics of Non-Newtonian Fluids
Qin Xu , Ivo Peters , Sam Wilken , Eric Brown , Heinrich Jaeger

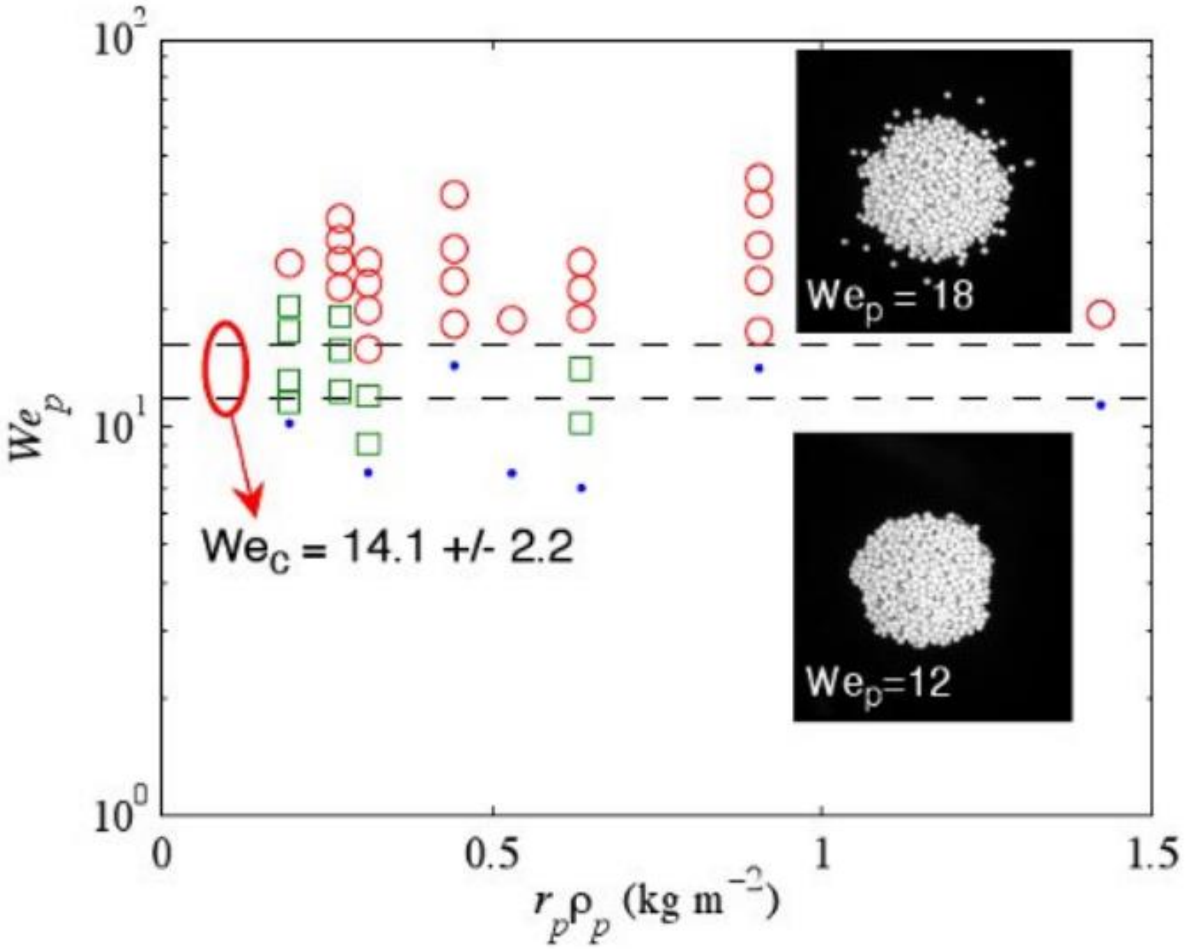
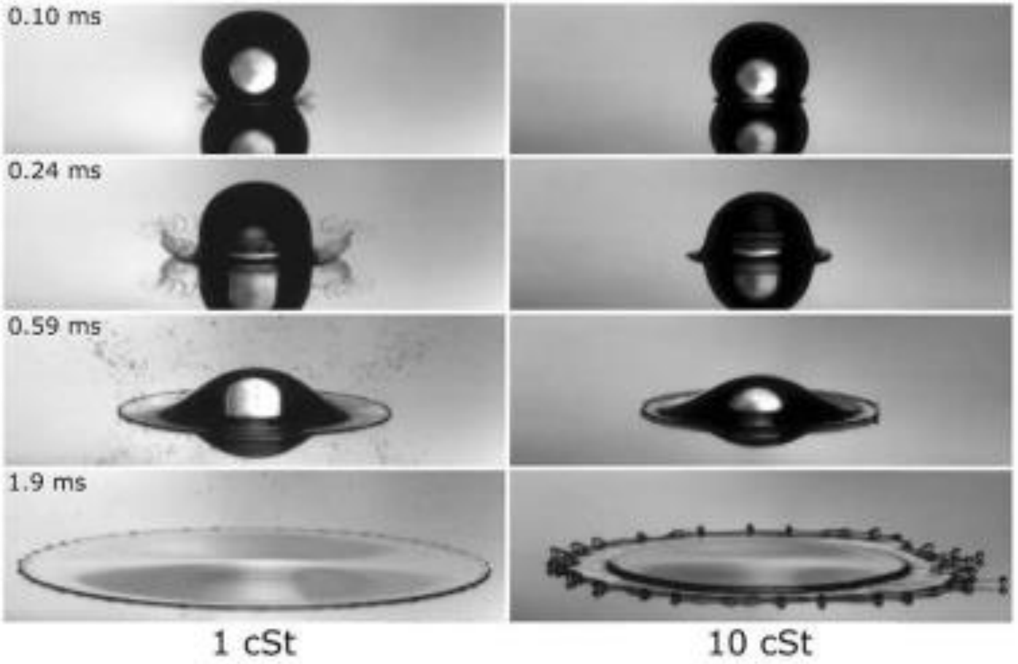
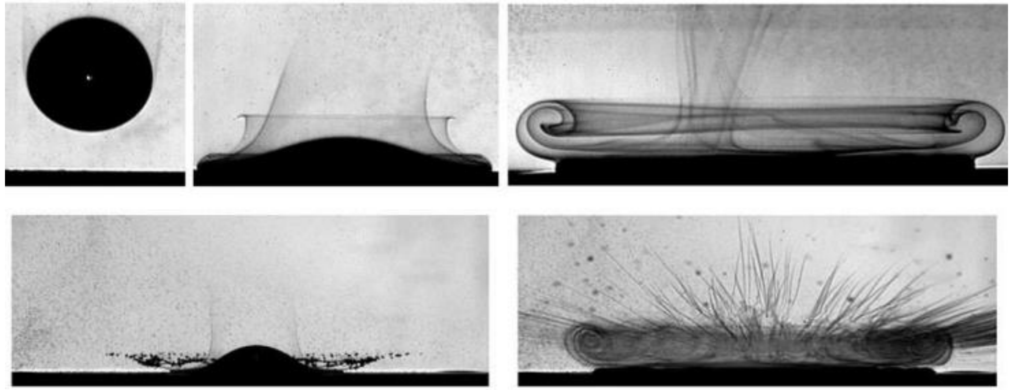


Figure 5. Splash onset Weber number We_p as a function of particle radius r_p and density ρ_p. The red hollow circles are the cases where splash is always found, and the solid blue dots correspond to the situation when no splash is found in 10 successive repeats. The open green squares indicate the scenarios when both splash and no splash are observed in the 10 repeats. The inset plots are typical images of splashing and nonsplashing cases. Please click here to view a larger version of this figure.



Thin film formation during splashing of viscous liquids
Michelle M. Driscoll, Cacey S. Stevens, and Sidney R. Nagel



Seeing the invisible—Air vortices around a splashing drop
Irmgard Bischofberger; Kelly W. Mauser; Sidney R. Nagel

Impact of granular drops

J. O. Marston, M. M. Mansoor, and S. T. Thoroddsen

We investigate the spreading and splashing of granular drops during impact with a solid target. The granular drops are formed from roughly spherical balls of sand mixed with water, which is used as a binder to hold the ball together during free-fall. We measure the instantaneous **spread diameter** for different impact speeds and find that the normalized spread diameter *d/D* grows as (*tV/D*)1/2. The **speeds of the grains ejected during the "splash"** are measured and they rarely exceed twice that of the impact speed.

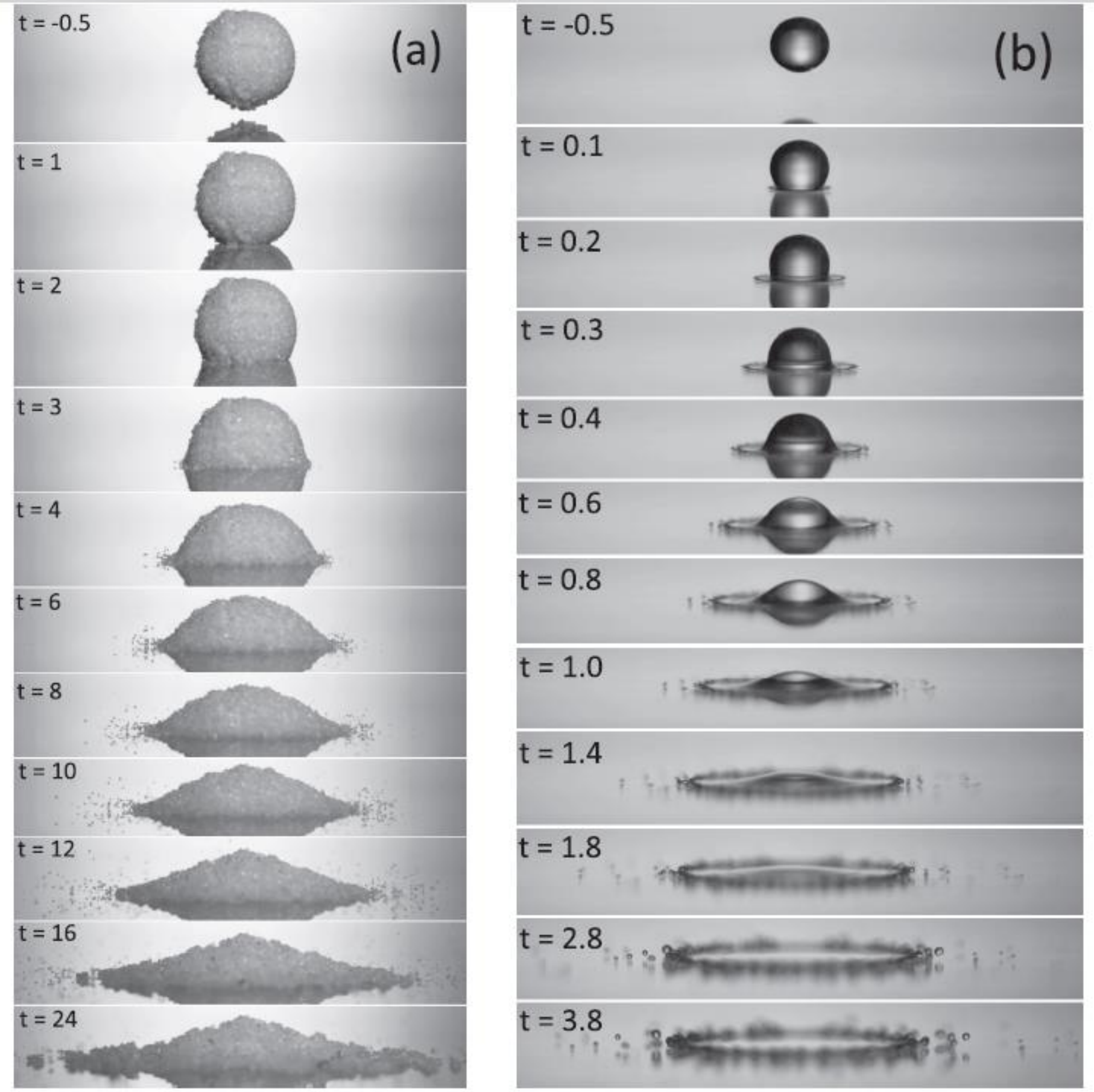
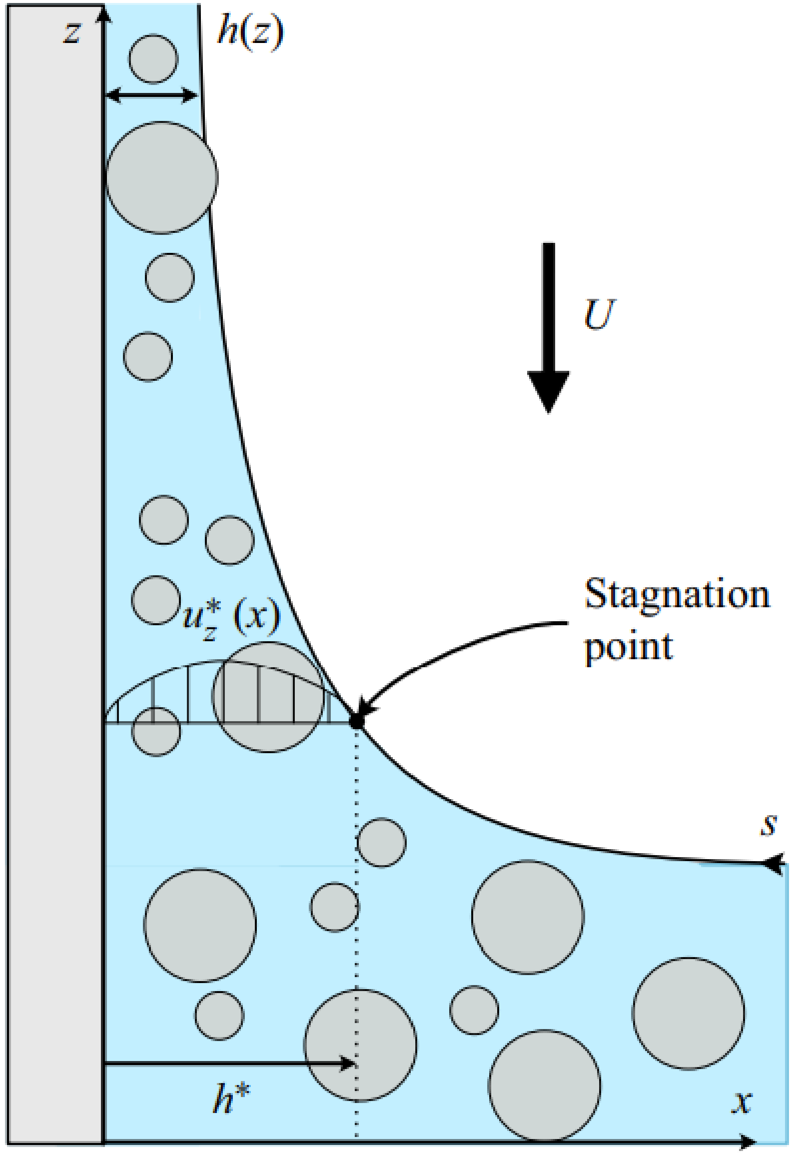
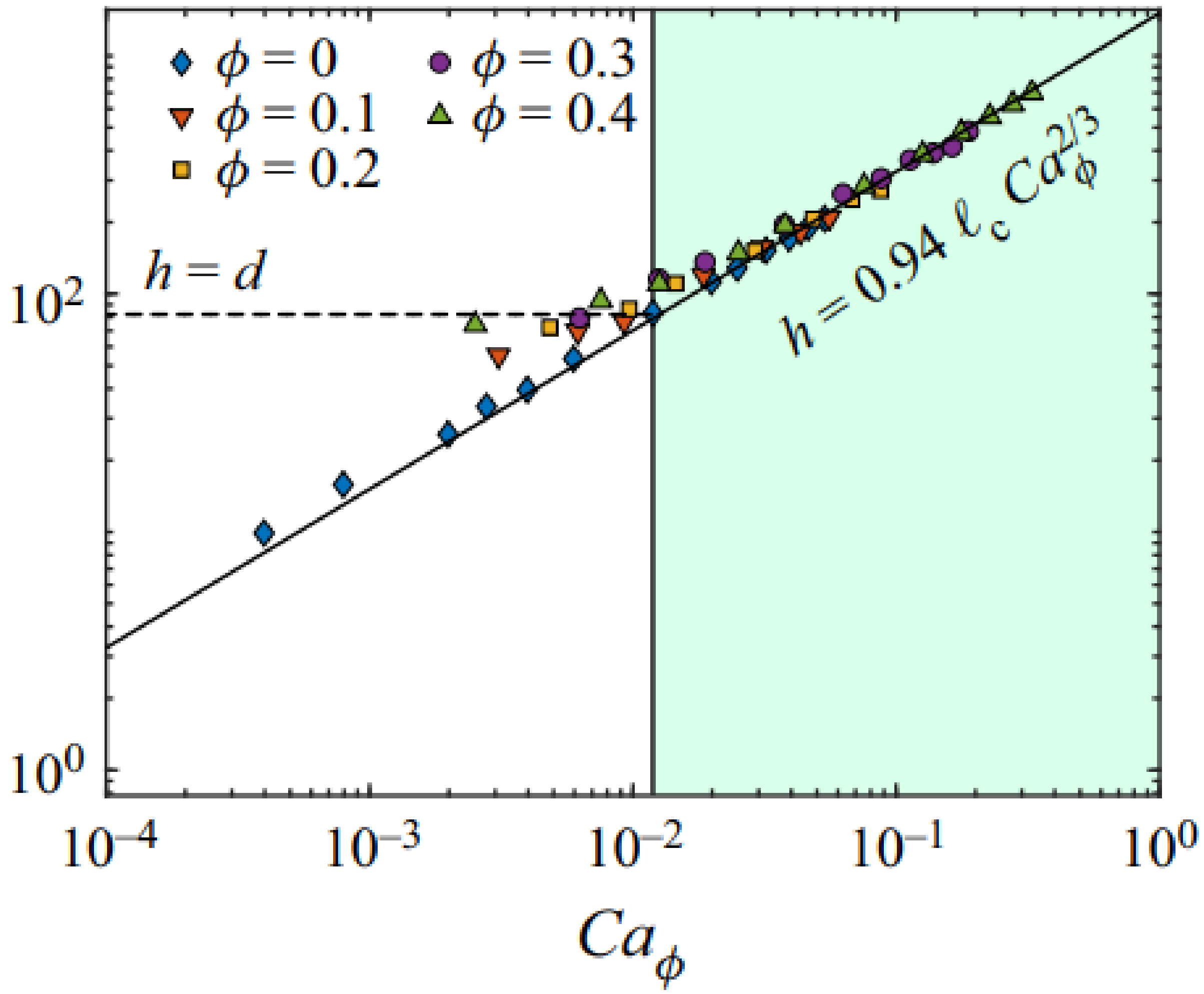
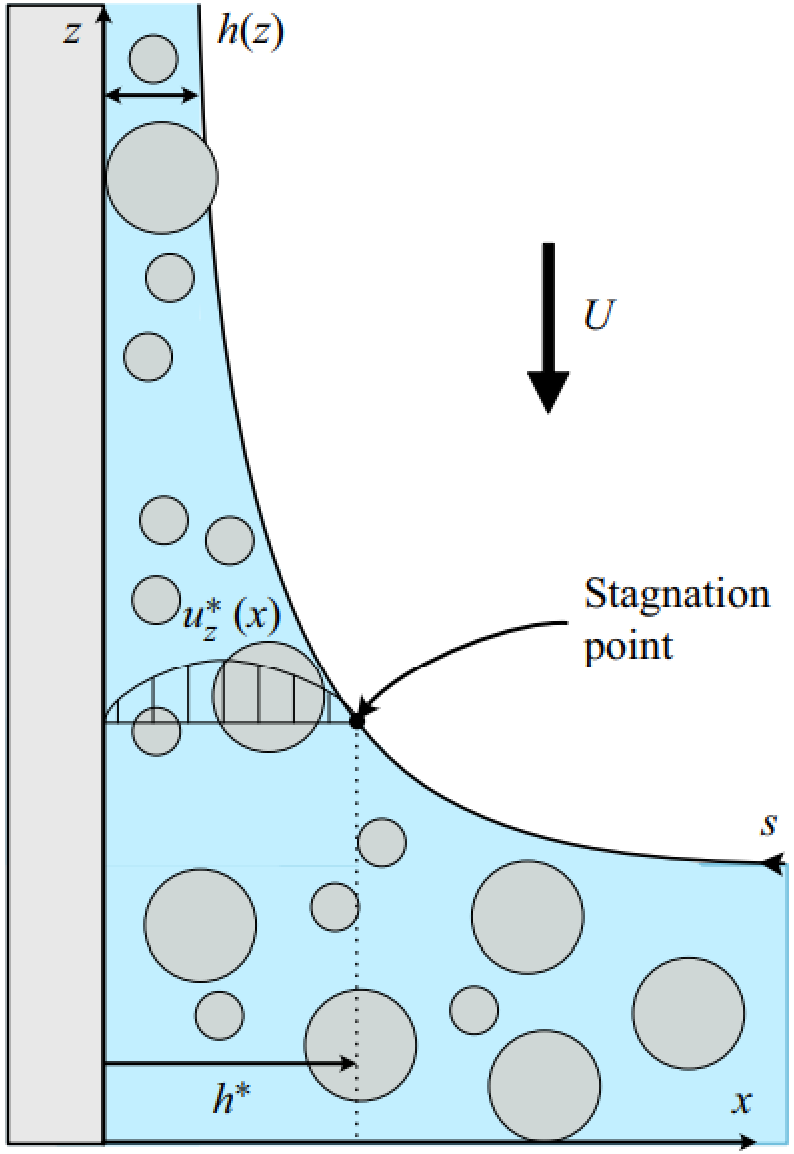


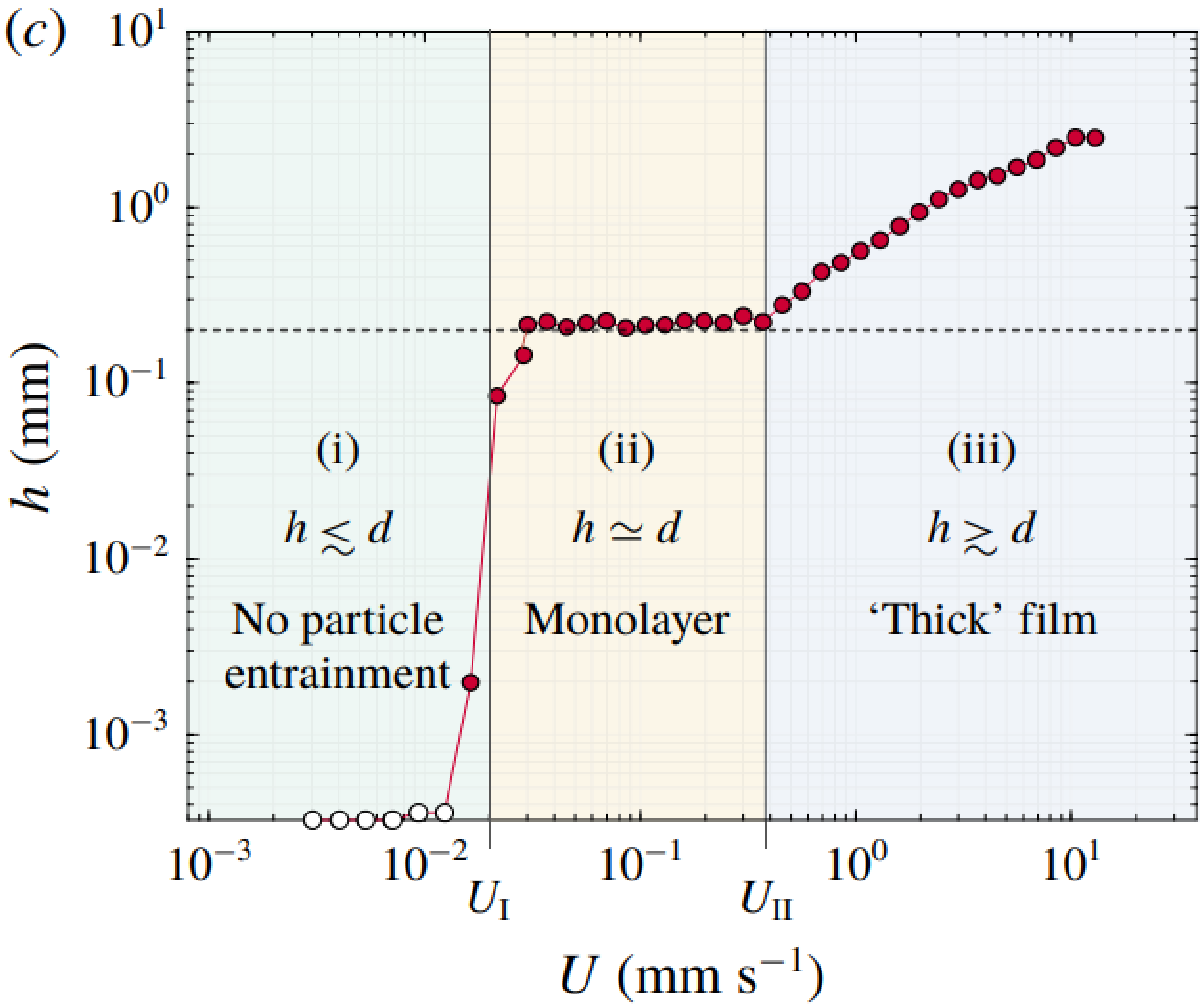
FIG. 1. Impact of (a) a 26 mm granular drop onto a thick glass plate and (b) a 3.6 mm water droplet onto a hydrophobic glass plate. The times shown are in milliseconds. The impact speed in both cases is $V \approx 2.6$ m/s.





Dip coating of bidisperse particulate suspensions
Deok-Hoon Jeong, Michael Ka Ho Lee, Virgile Thiévenaz,
Martin Z. Bazant and Alban Sauret





Dip-coating with a particulate suspension
Sergio Palma and Henri Lhuissier

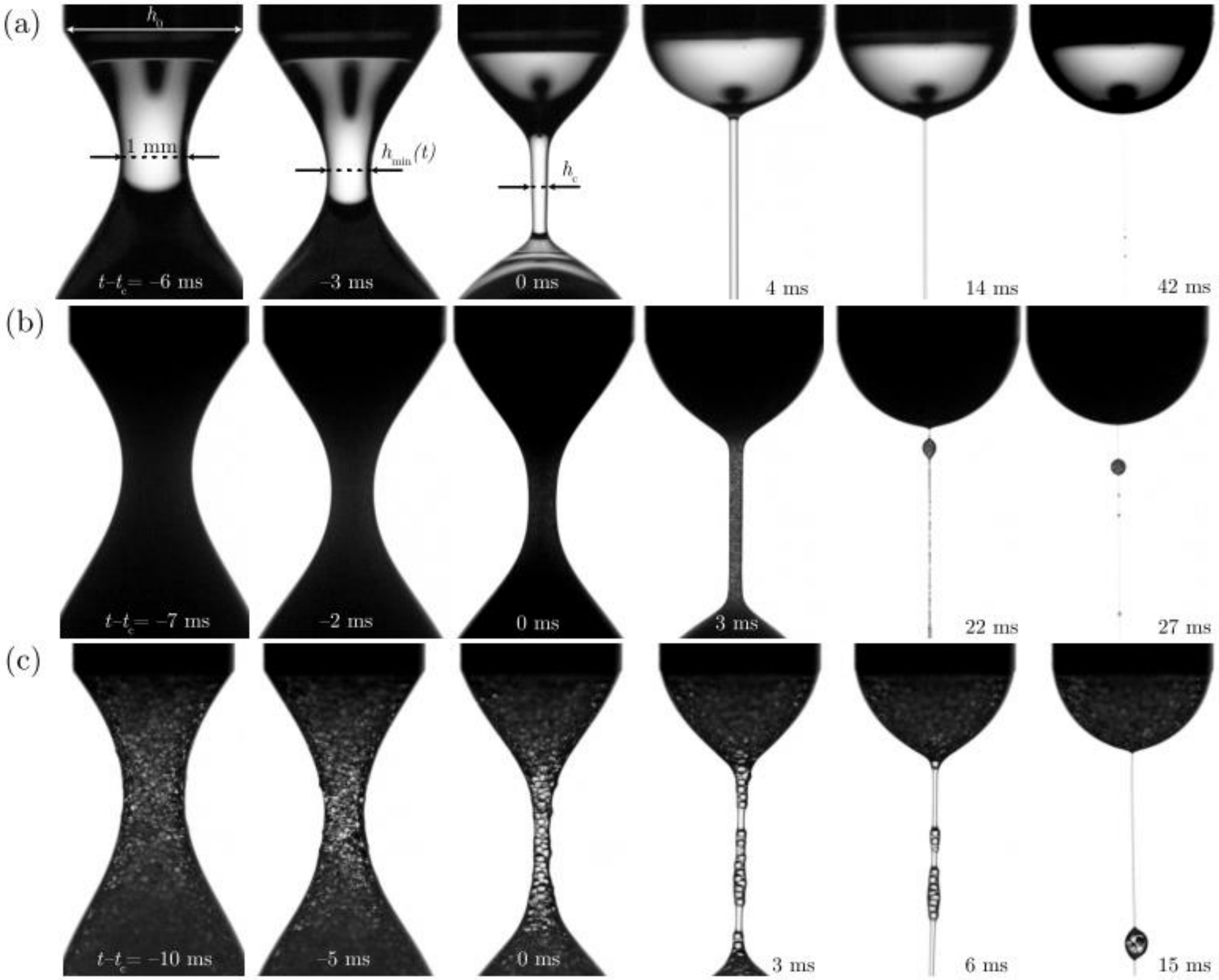
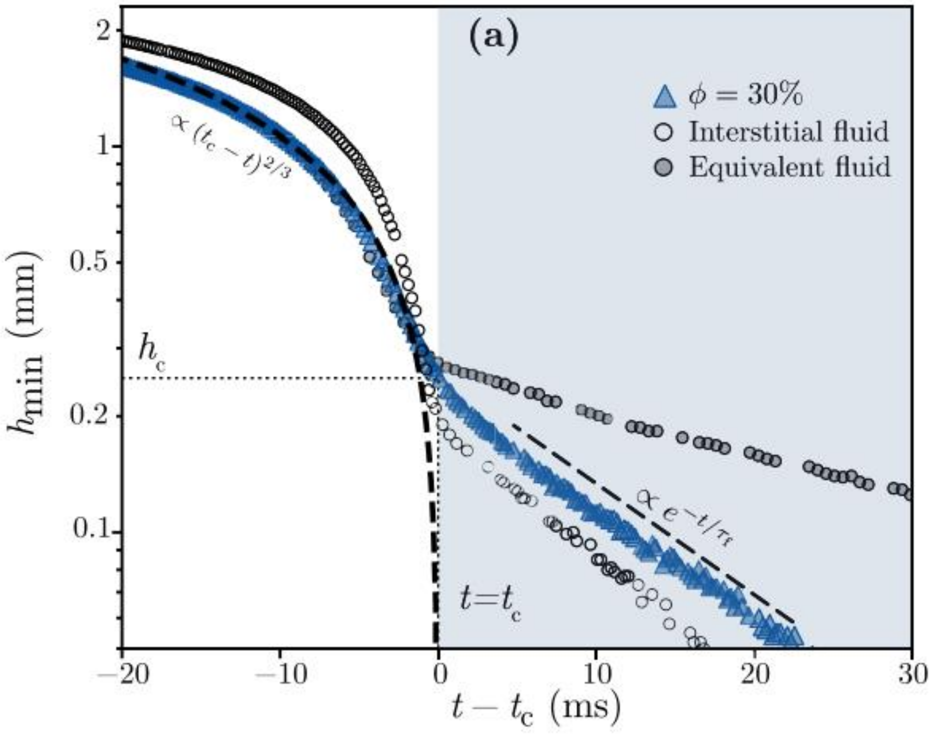
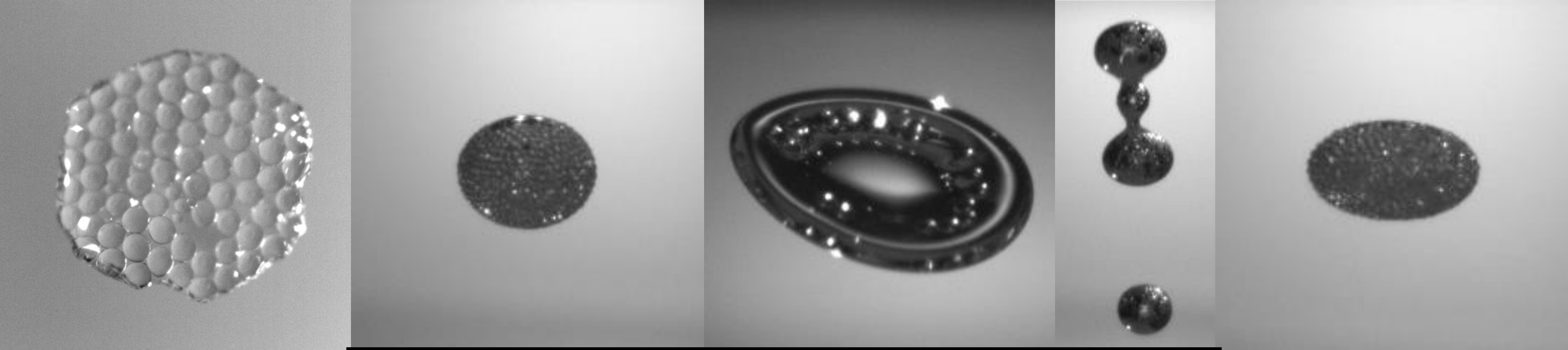
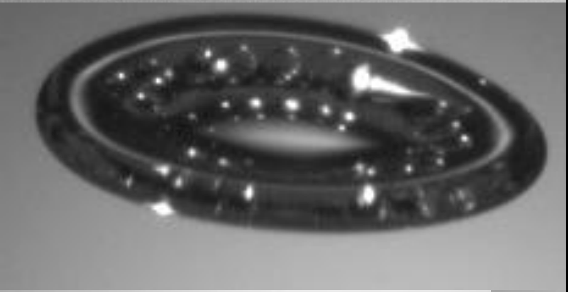


FIG. 1. Detachment of drops of a viscoelastic liquid (74% water, 25% glycerol, 1% PEO300) with and without particles. In the first picture of each row, the neck width is 1 mm. The time stamps display the time to the viscoelastic transition $t - t_c$. (a) Polymer solution only, (b) $\phi = 40\%$ of particles of diameter $d = 20\ \mu$m, and (c) $\phi = 40\%$ of particles of diameter $d = 140\ \mu$m.

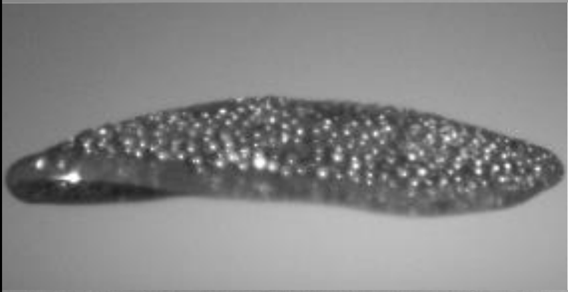


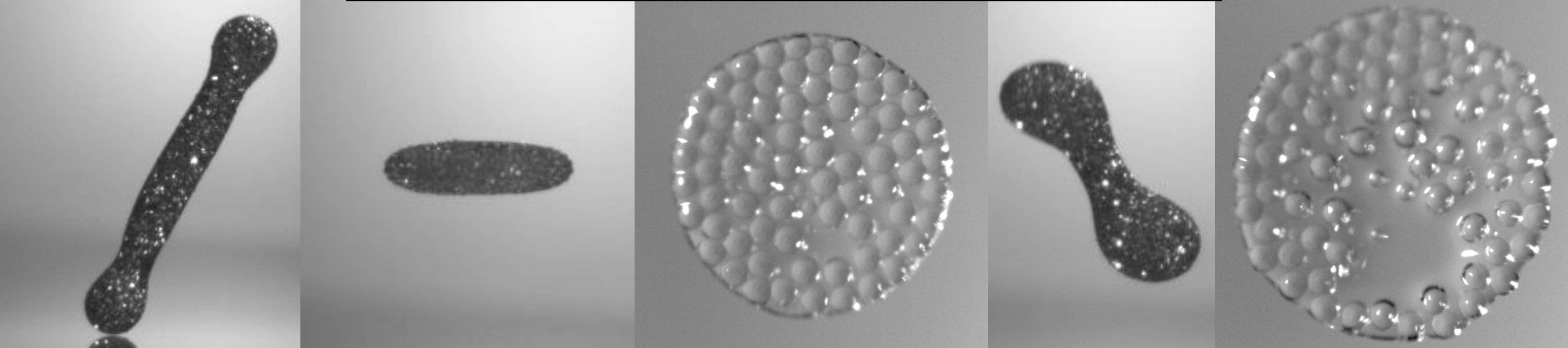




Lévitation acoustique

Gouttes, particules et suspensions





Published: 26 October 2015

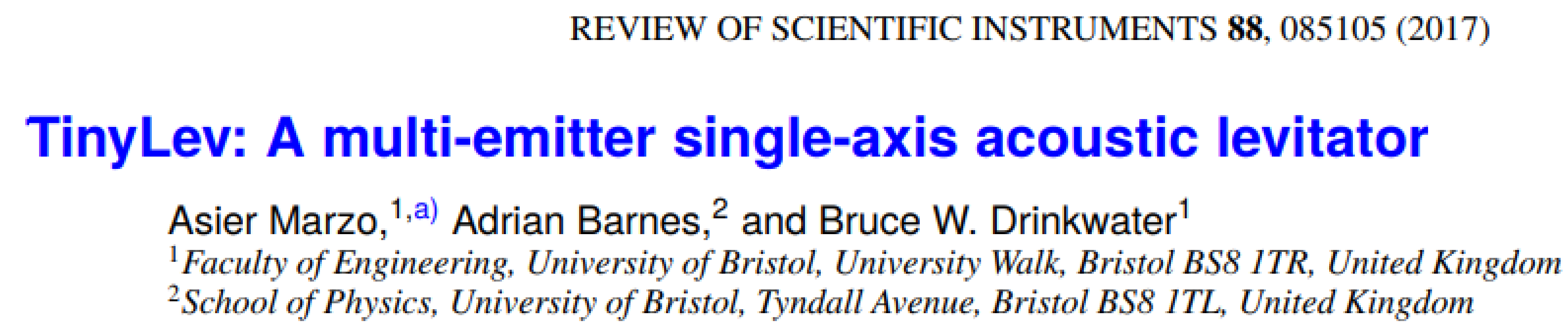
Mechanics of fire ant aggregations

Michael Tennenbaum, Zhongyang Liu, David Hu & Alberto Fernandez-Nieves

Nature Materials **15**, 54–59 (2016) | Cite this article

11k Accesses | **72** Citations | **328** Altmetric | Metrics

Acoustic levitation

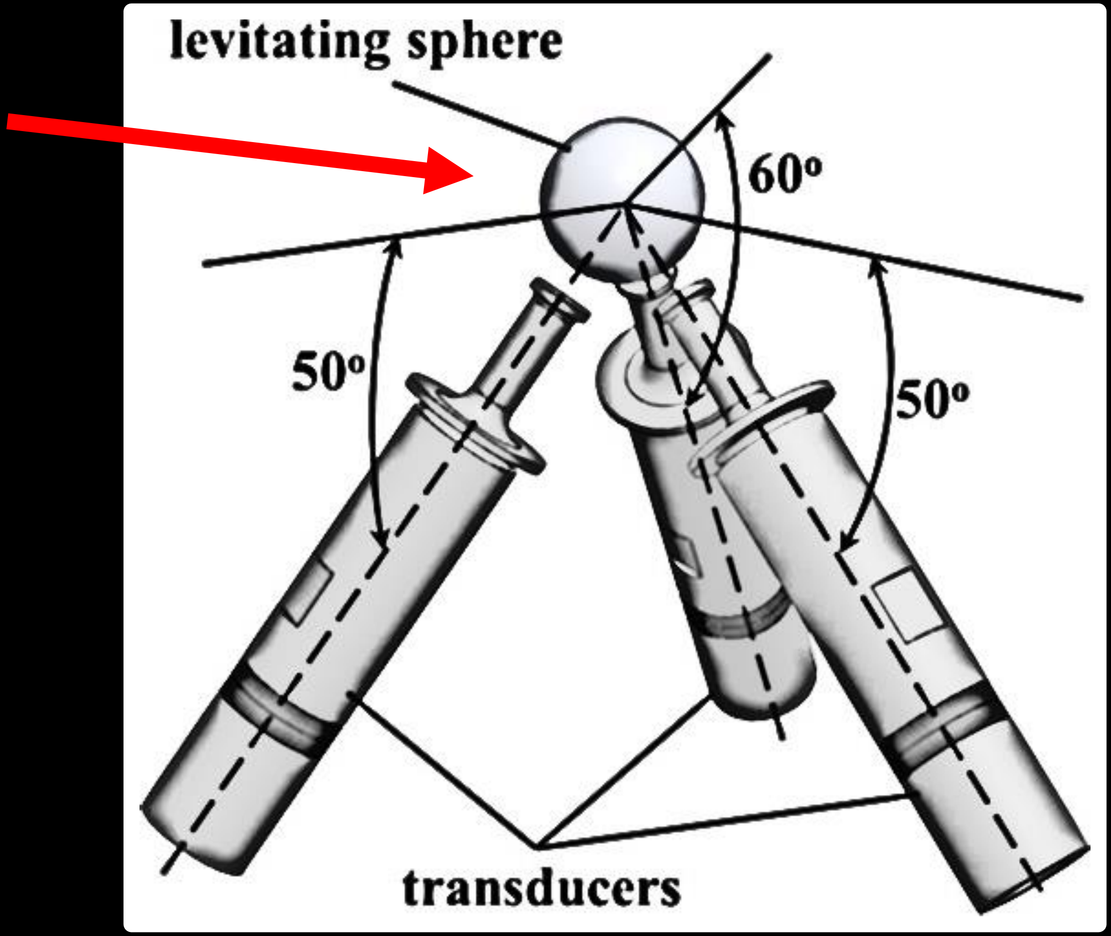


REVIEW OF SCIENTIFIC INSTRUMENTS **88**, 085105 (2017)

TinyLev: A multi-emitter single-axis acoustic levitator

Asier Marzo,[1,a] Adrian Barnes,[2] and Bruce W. Drinkwater[1]
[1] *Faculty of Engineering, University of Bristol, University Walk, Bristol BS8 1TR, United Kingdom*
[2] *School of Physics, University of Bristol, Tyndall Avenue, Bristol BS8 1TL, United Kingdom*

Acoustic levitation: upper size limit

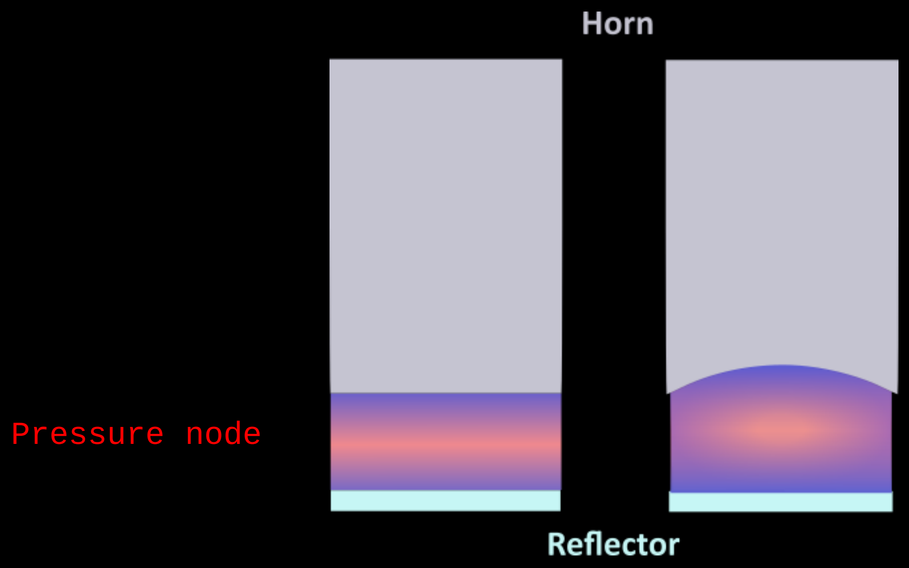


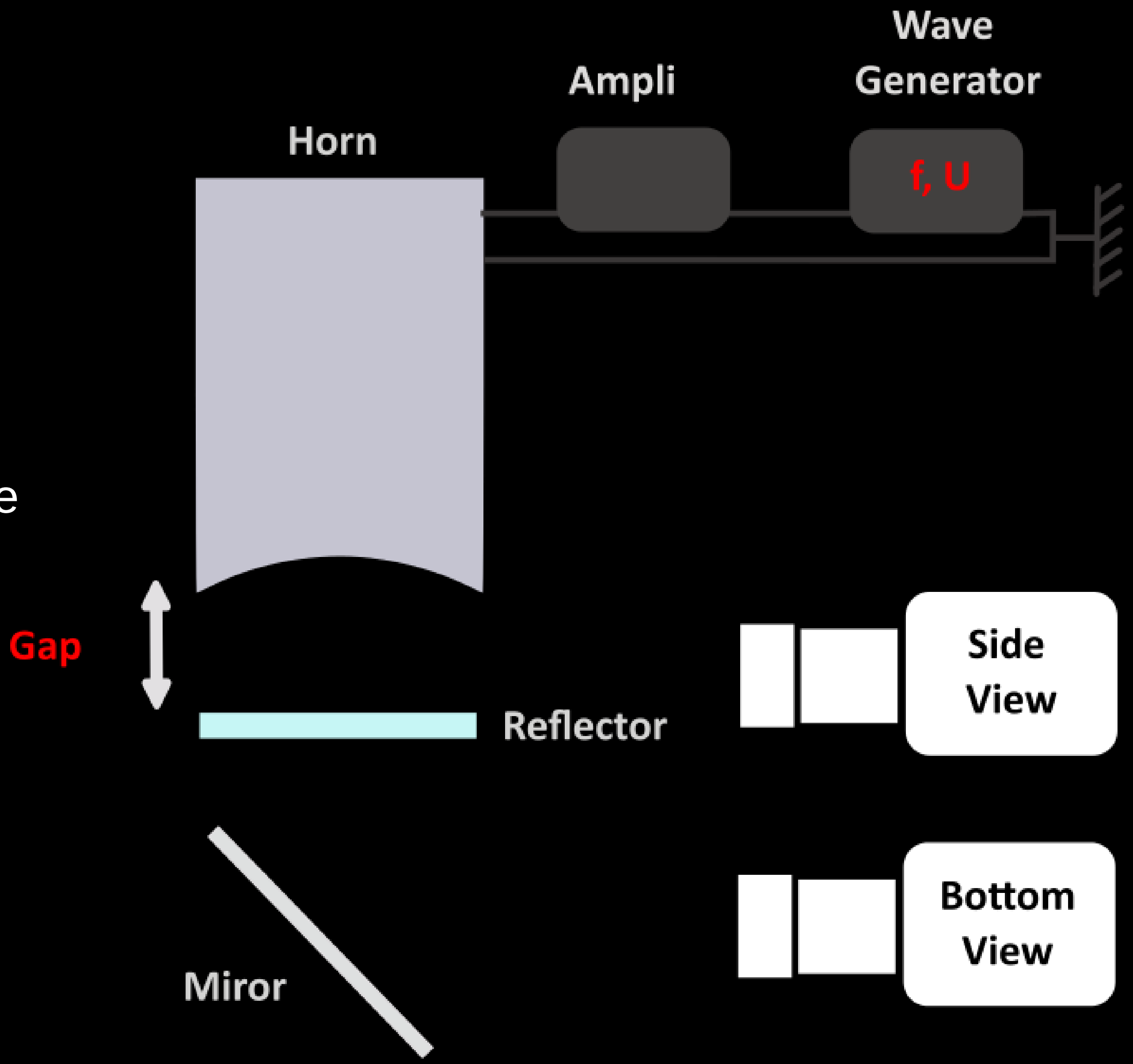
expanded polystyrene sphere of 50 mm in diameter, (1.46 g) corresponding to 3.6 times the sound wavelength

Andrade, M. A., Bernassau, A. L., & Adamowski, J. C. (2016). Acoustic levitation of a large solid sphere. *Applied Physics Letters*, *109*(4).

Apparatus

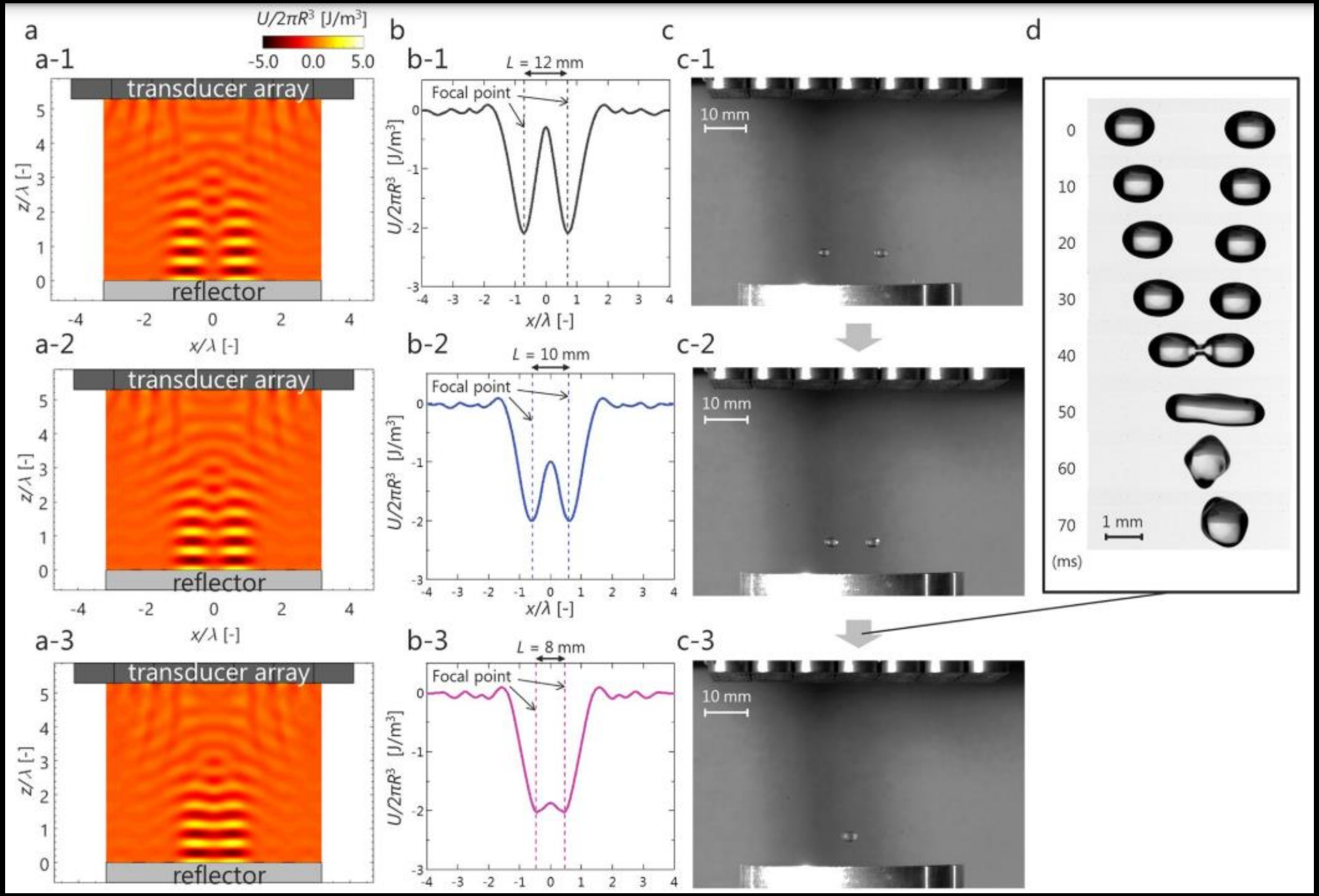
- Horn $f \simeq 34800\,\mathrm{Hz}$
- Input voltage U
- Acoustic frequency $\simeq 34800\,\mathrm{Hz}$
- Gap height $\gtrsim 5\,\mathrm{mm}$ → resonance





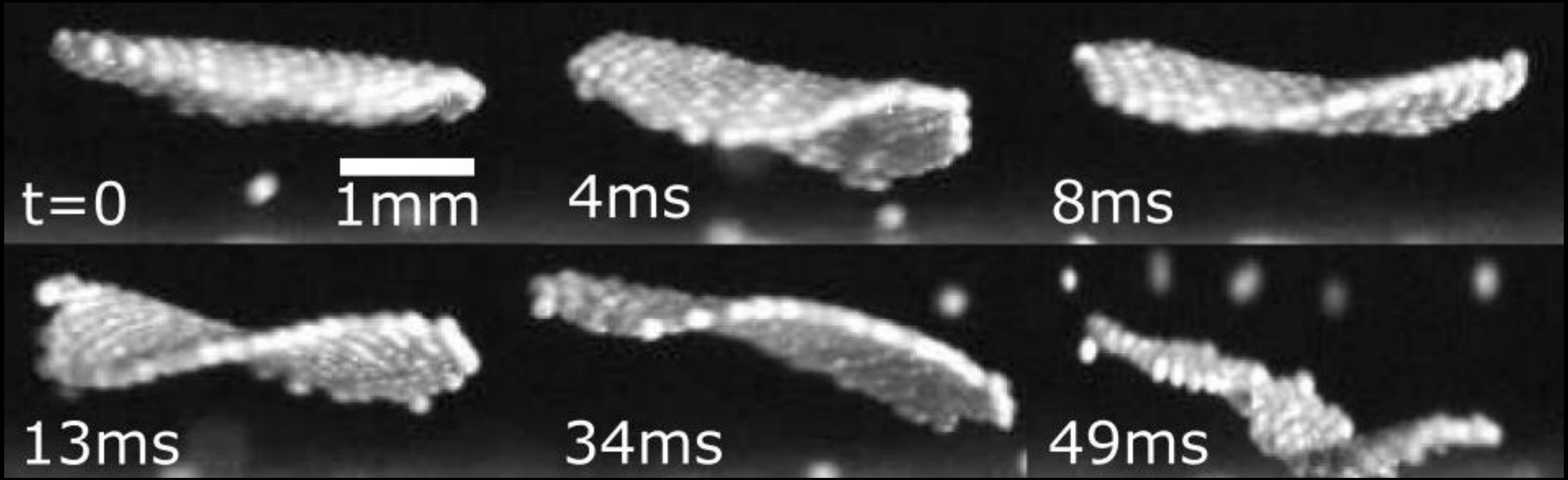
Container-less liquid reactors

- Coalescence: droplet manipulation
- Mixing: oscillations



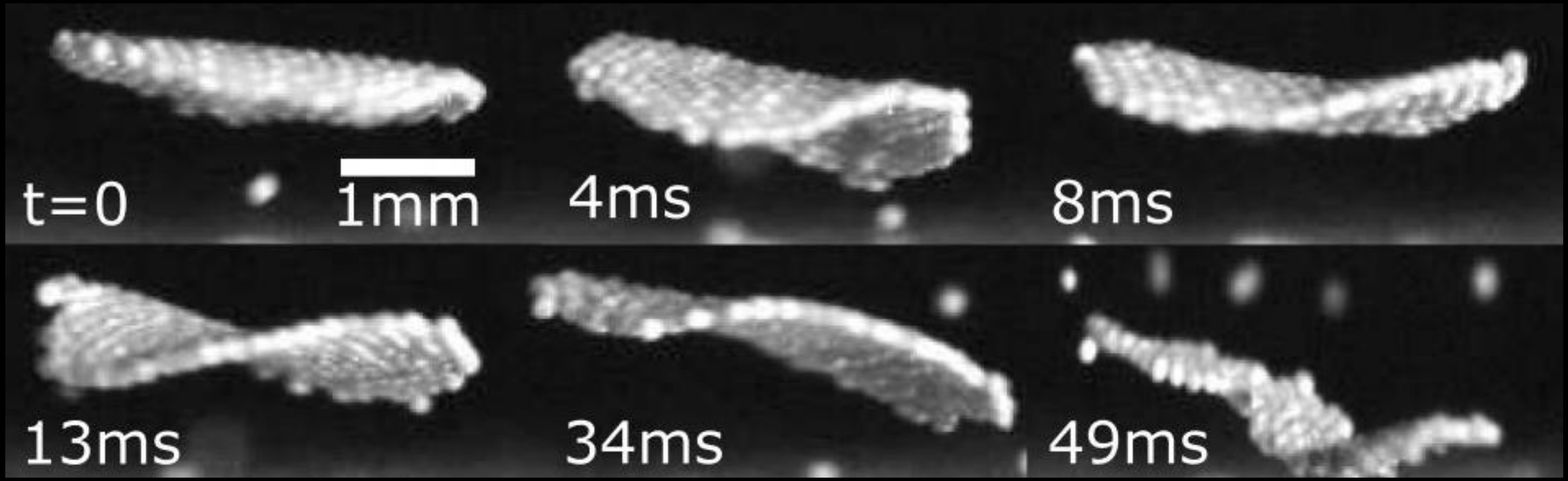
Watanabe, Ayumu, Koji Hasegawa, and Yutaka Abe. "Contactless fluid manipulation in air: Droplet coalescence and active mixing by acoustic levitation." Scientific reports 8.1 (2018): 10221.

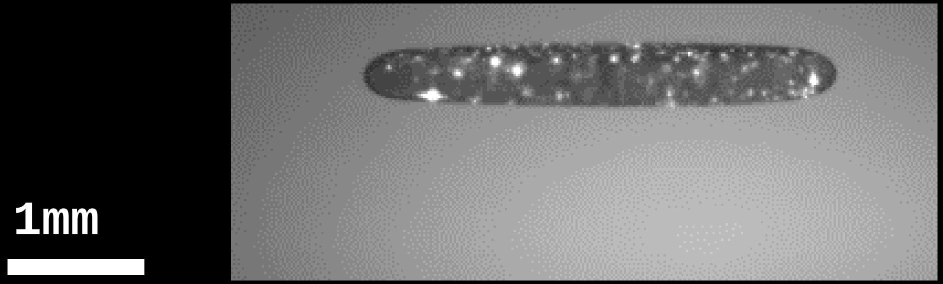
Dry grain raft size…



Lim, M. X., VanSaders, B., Souslov, A., & Jaeger, H. M. (2022). Mechanical properties of acoustically levitated granular rafts. *Physical Review X*, *12*(2), 021017.

Seems similar or a bit smaller than observations with liquids



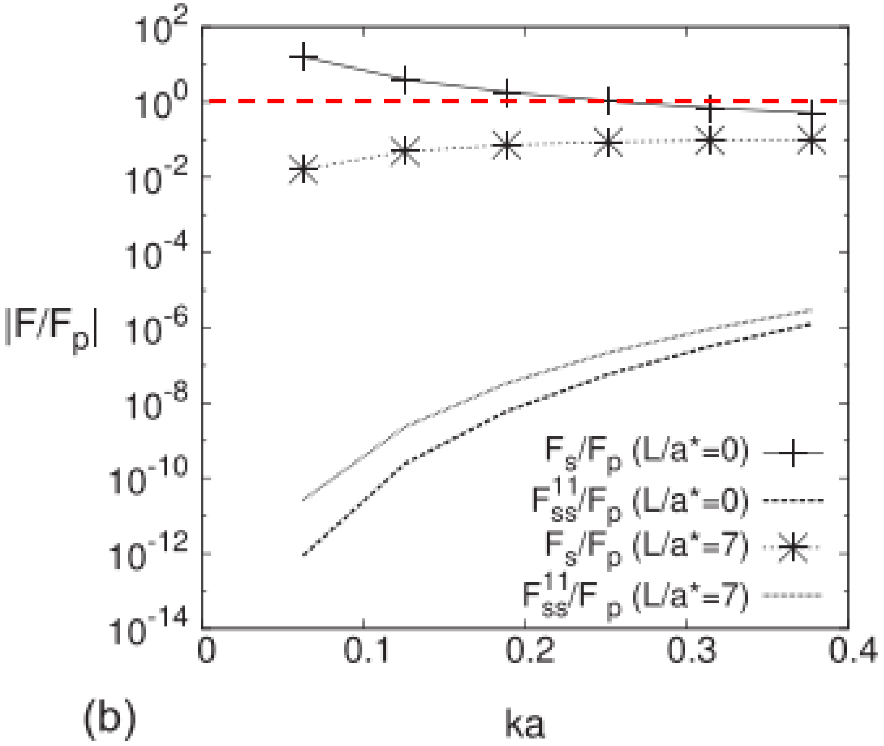


140um PS in PEG3900

Volume: ~ 2.3 mm3
Diameter: 3.4-4.7 mm
Thickness: 360-170 um

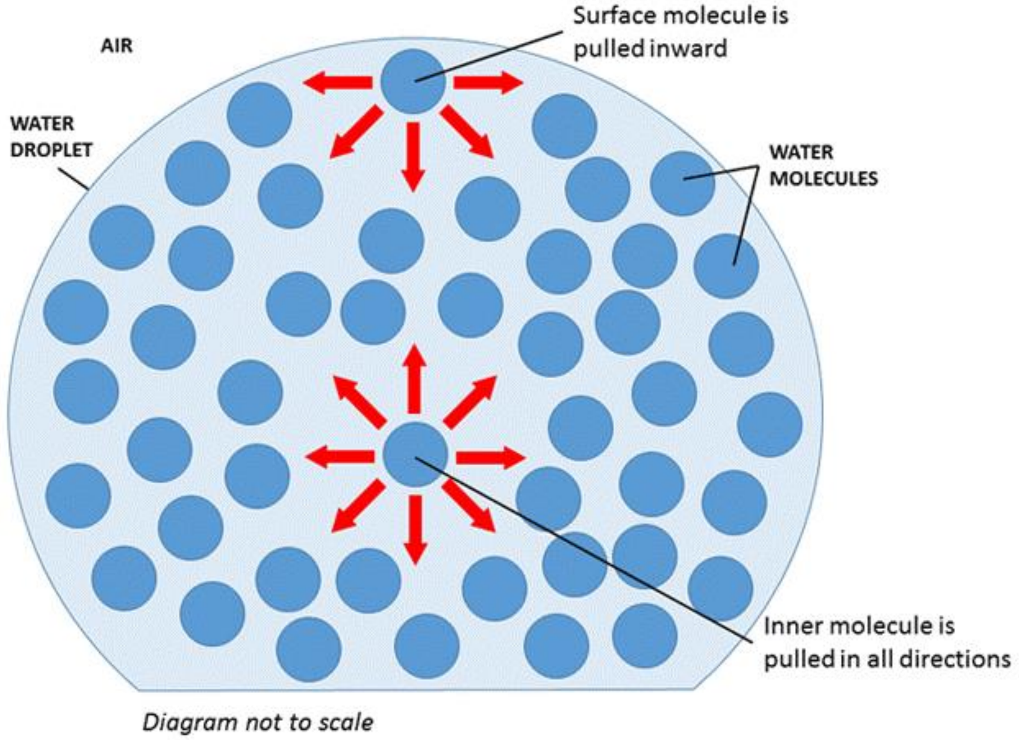
Dry granular vs fluid droplet

Attractive scattering, raft size



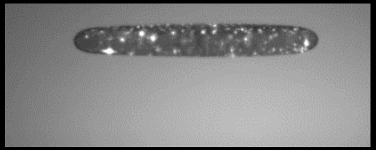
Sepehrirahnama, S., Lim, K. M., & Chau, F. S. (2015). Numerical study of interparticle radiation force acting on rigid spheres in a standing wave. *The Journal of the Acoustical Society of America*, *137*(5), 2614-2622.

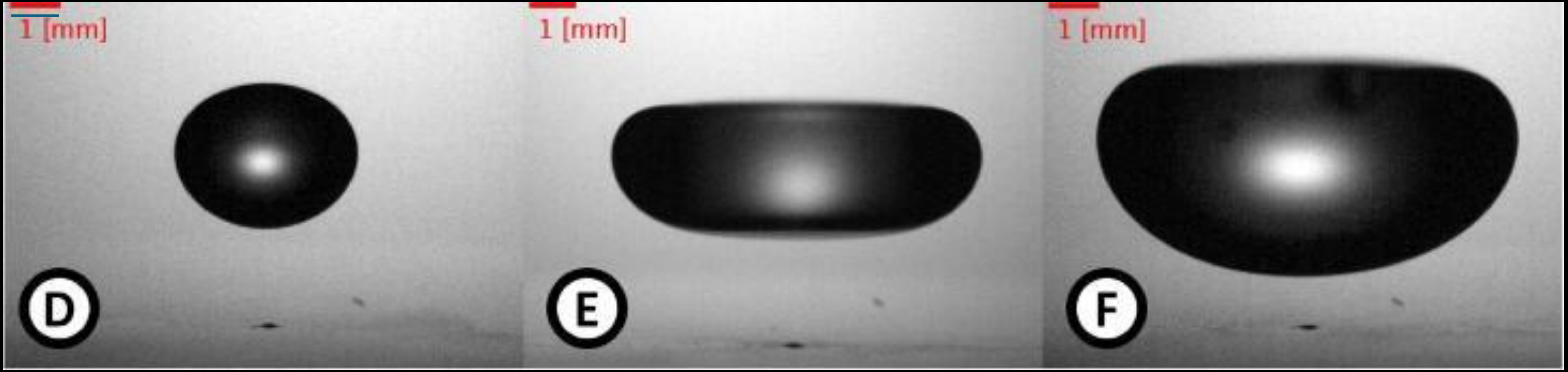
Surface tension, drop size



https://www.sciencebuddies.org/

And beyond





Stable levitation of drops of various sizes at different sound pressure levels
D) volume: (19.39±0.06)[μl] and SPL: 160.7[dB].
E) volume: (108±5)[μl] and SPL: 165[dB].
F) volume: (166±2)[μl] and SPL: 164.4[dB].

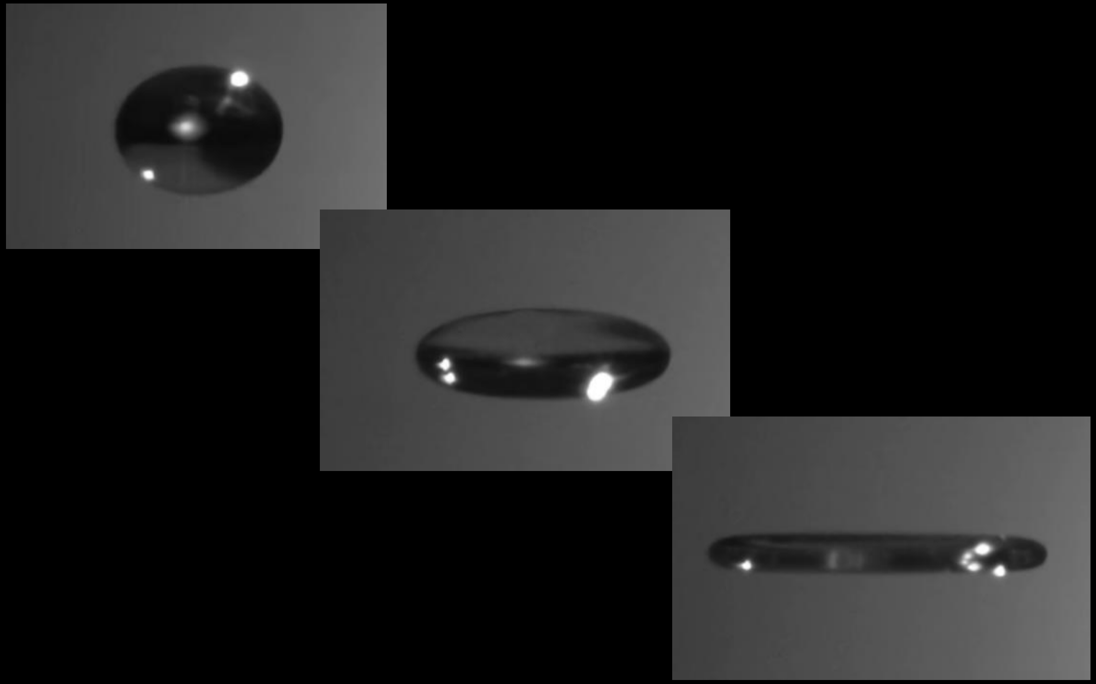
Cancino-Jaque, E., Meneses-Diaz, J., Vargas-Hernández, Y., & Gaete-Garretón, L. (2023). On the dynamics of a big drop in acoustic levitation. Ultrasonics Sonochemistry, 101, 106705

Dry granular vs fluid droplet

Swarm & raft

40um beads, decreasing gap

Sphere, ellipsoid & pancake



PEG3900, 34700 → 34760 Hz 10 Vpp

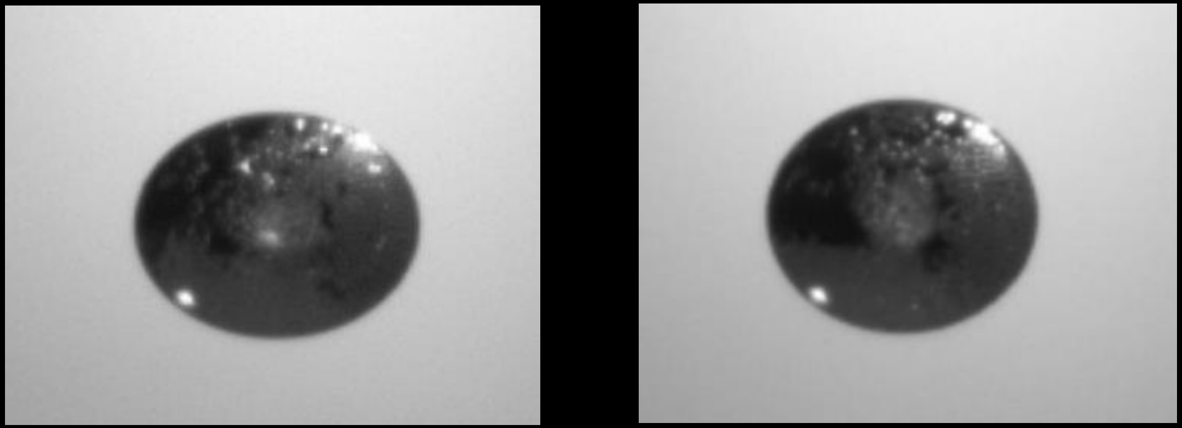
Dry granular vs fluid droplet

Exchange with environment

Pinning on substrates

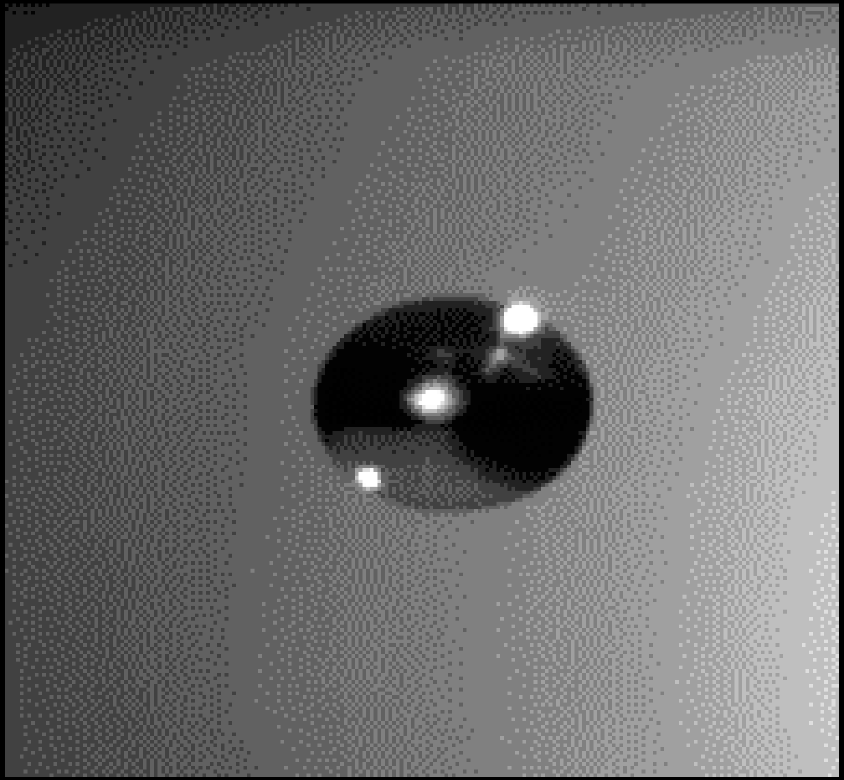
Acoustic pressure

Voltage

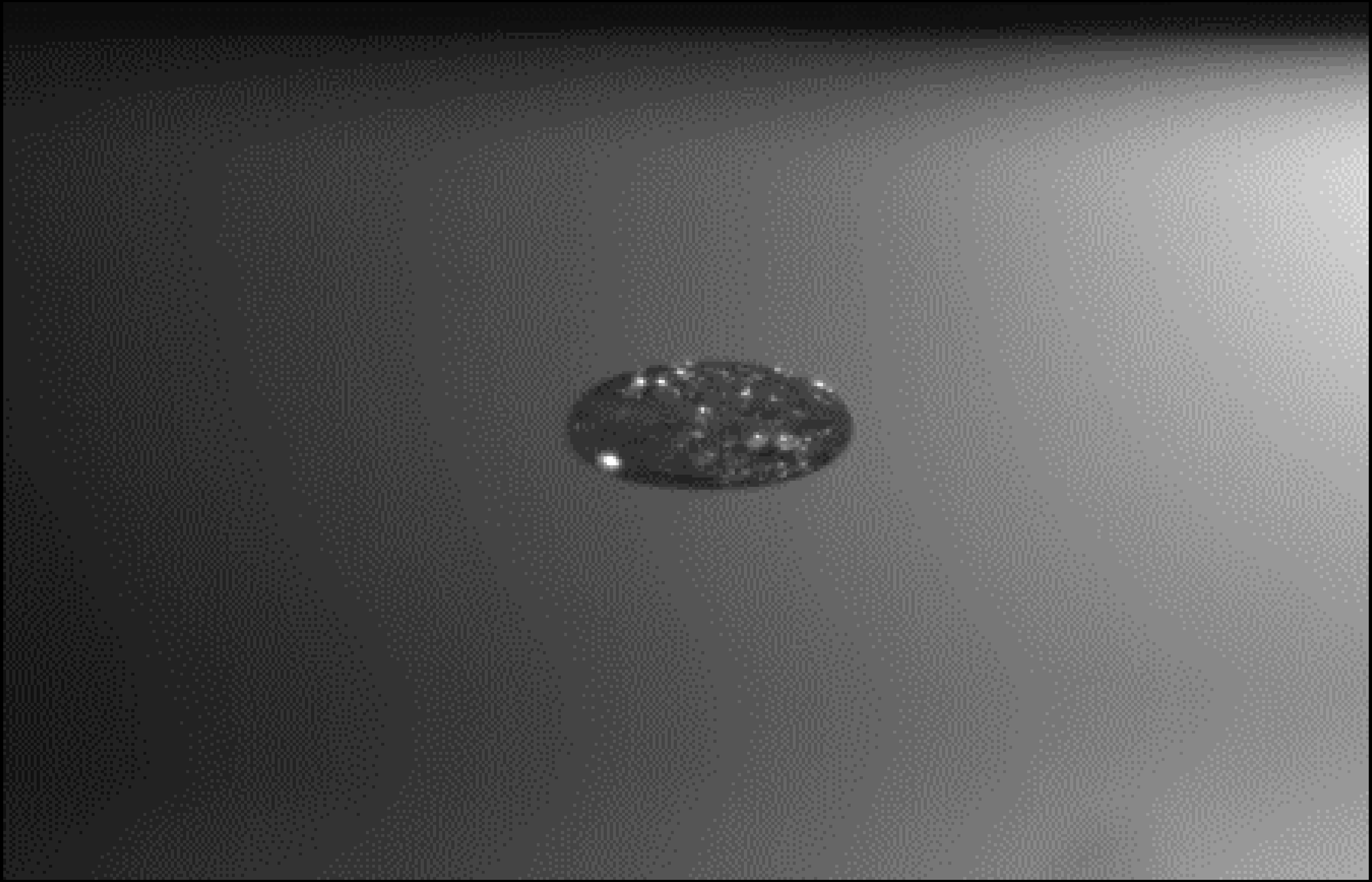


80um PS in water, 34700 Hz from 7 Vpp to 4 Vpp

Frequency



PEG3900, 34700 → 34760 Hz 10 Vpp



140um in PEG200