FLUIDS AND FLOWS

Julia Yeomans: Fluids all around us

Ramin Golestanian: The bacterial viewpoint

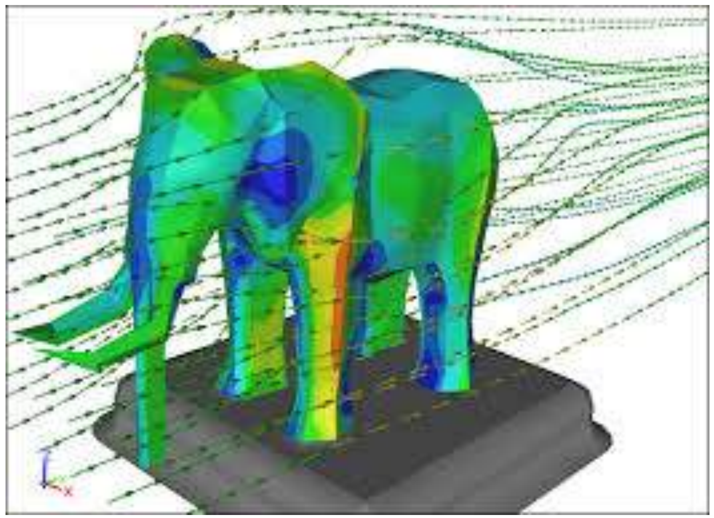
Michael Barnes: Turbulence

The Navier-Stokes equation

$$\rho\{\frac{\partial \mathbf{u}}{\partial t} + (\mathbf{u} \cdot \nabla)\mathbf{u}\} = -\nabla p + \eta \nabla^2 \mathbf{u}$$

$$\rho\{\frac{\partial \mathbf{u}}{\partial t} + (\mathbf{u}\cdot\nabla)\mathbf{u}\} = -\nabla p + \eta\nabla^2\mathbf{u}$$

Computational fluid dynamics:
a success story



$$\rho\{\frac{\partial \mathbf{u}}{\partial t} + (\mathbf{u}\cdot\nabla)\mathbf{u}\} = -\nabla p + \eta\nabla^2\mathbf{u}$$

Inertial term

viscous term

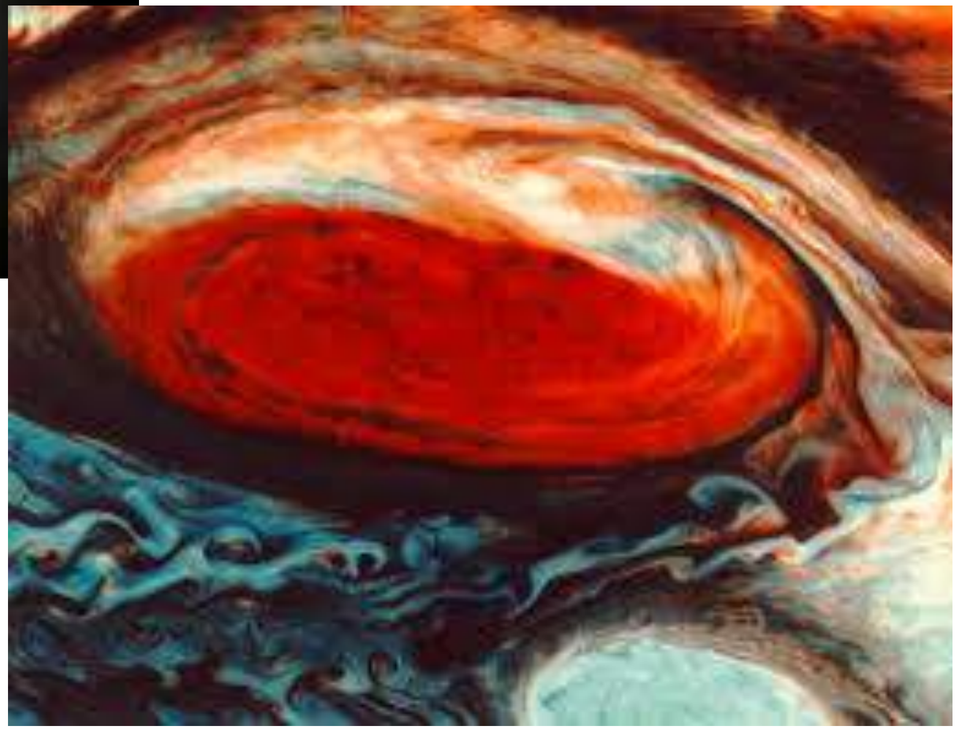
$$\frac{\partial \tilde{\mathbf{u}}}{\partial t} + (\tilde{\mathbf{u}}\cdot\tilde{\nabla})\tilde{\mathbf{u}} = -\frac{\tilde{\nabla}\tilde{p}}{\tilde{\rho}} + \frac{\nu}{LU}\tilde{\nabla}^2\tilde{\mathbf{u}}$$

Reynolds number

$$\boxed{Re = \frac{LU}{\nu}}$$

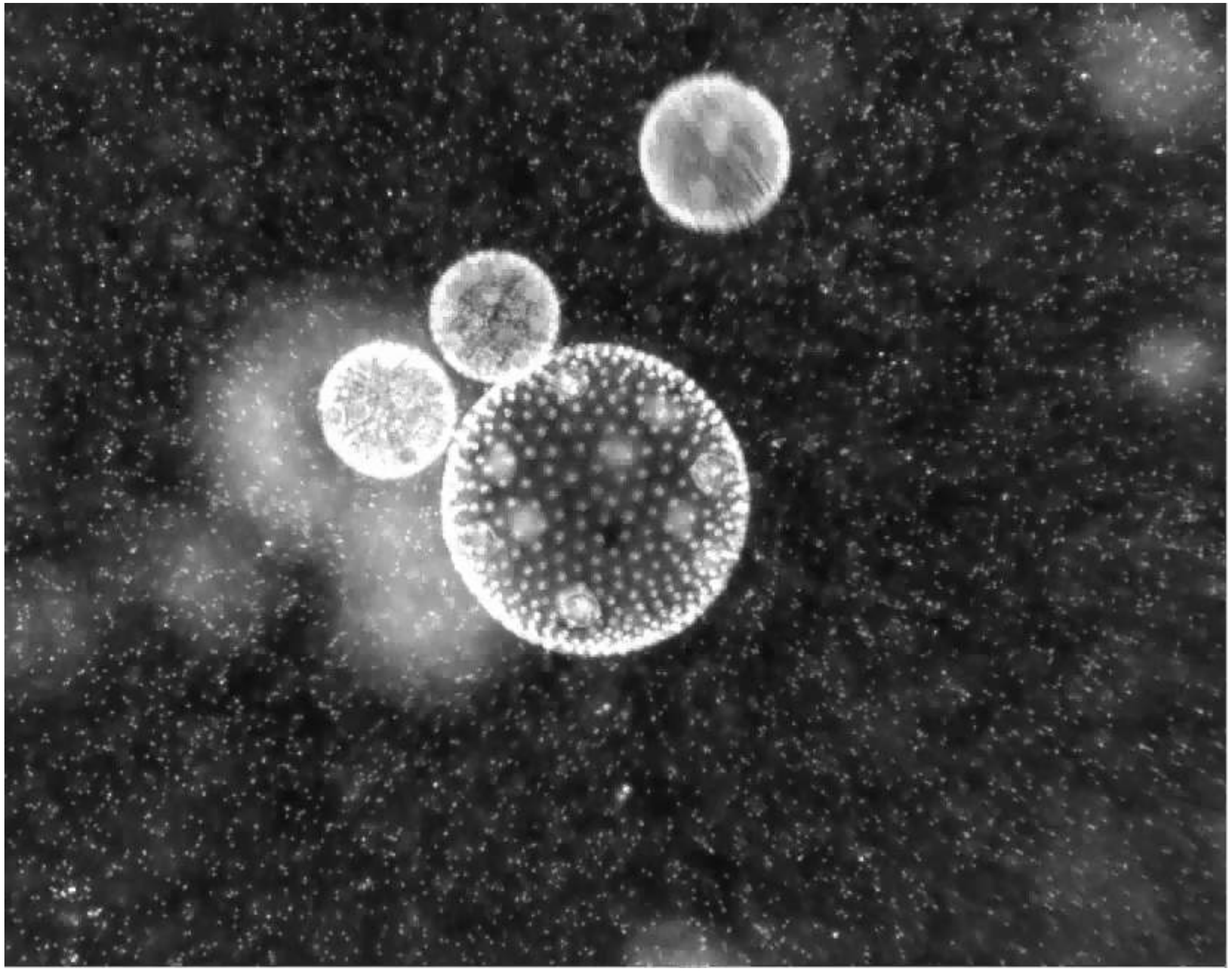
High Reynolds numbers

$$Re = \frac{LU}{\nu}$$



Low Reynolds numbers

$$Re = \frac{LU}{\nu}$$



Goldstein group, Cambridge

A day in the life of a fluid dynamicist

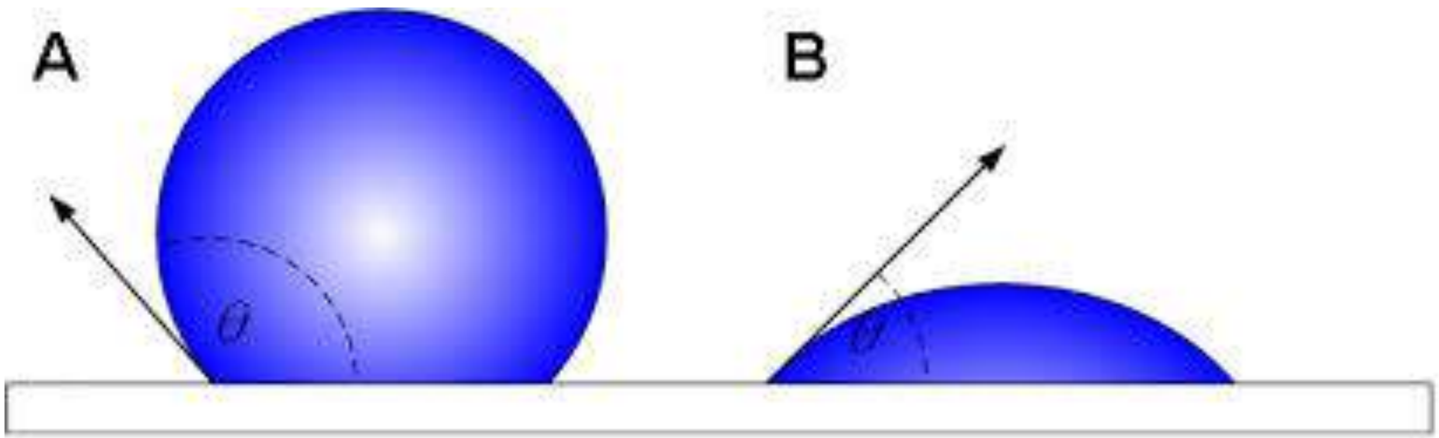
https://gfm.aps.org/meetings/dfd-2015/55ec9a5d69702d060d570100

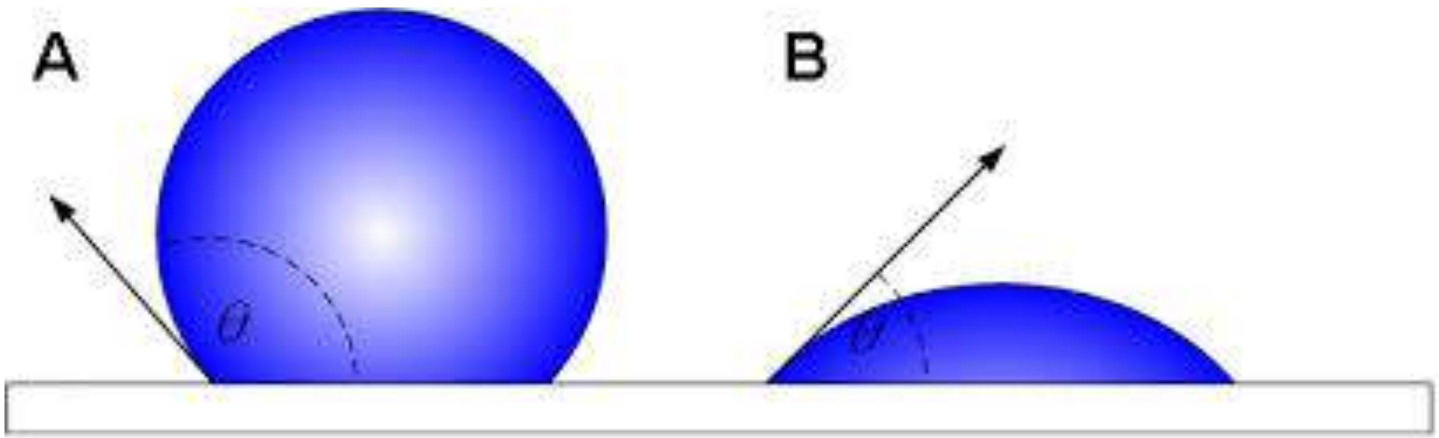
1. Superhydrophobic surfaces

2. Pancake bouncing

3. Vorticity


Roll to centre


A
B
θ
θ


A
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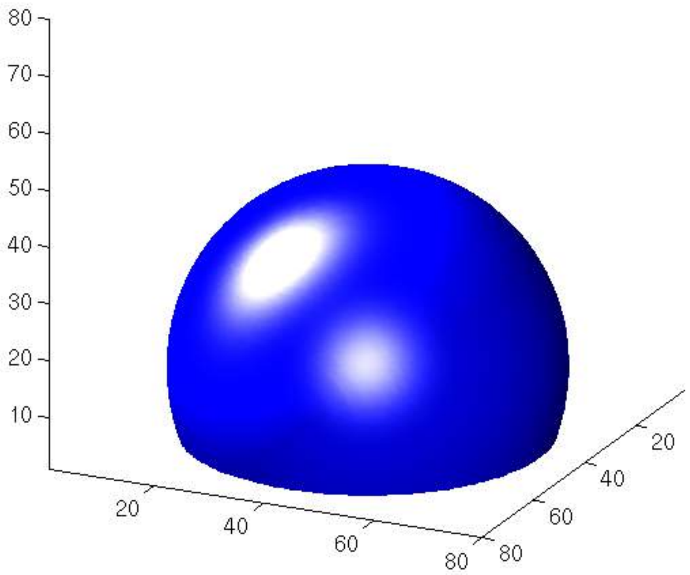
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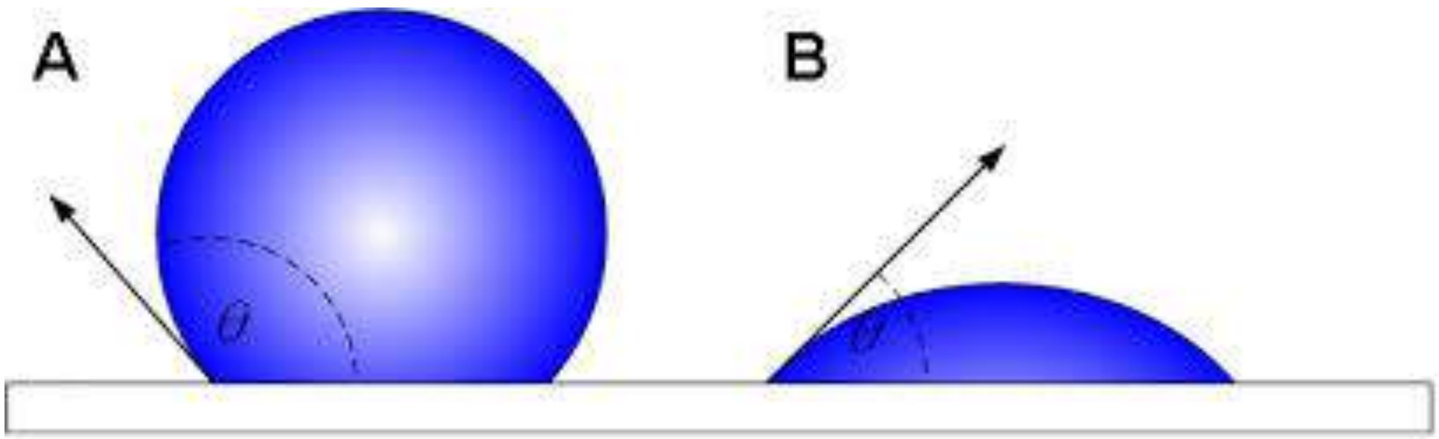
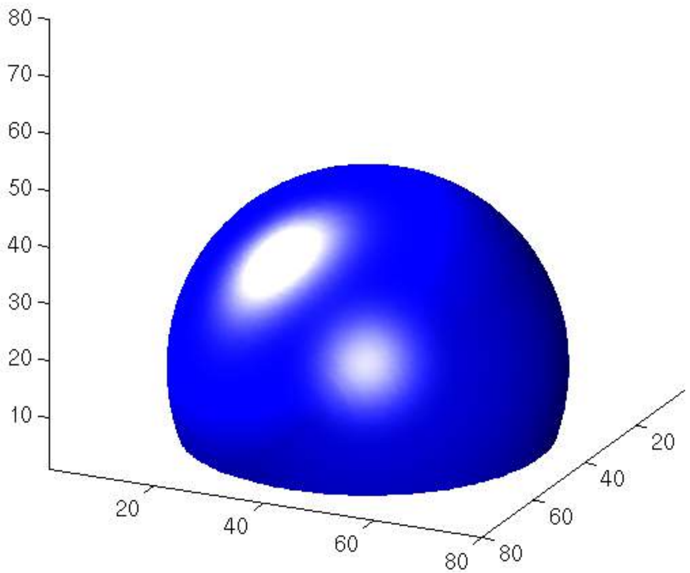

A
B
θ
θ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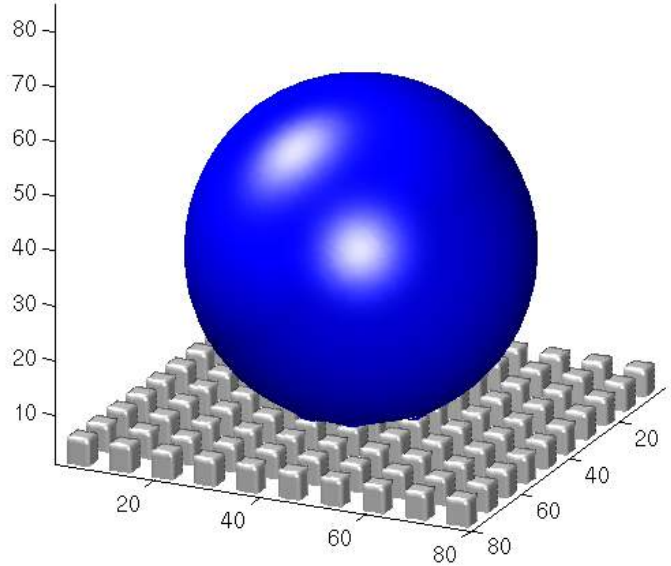
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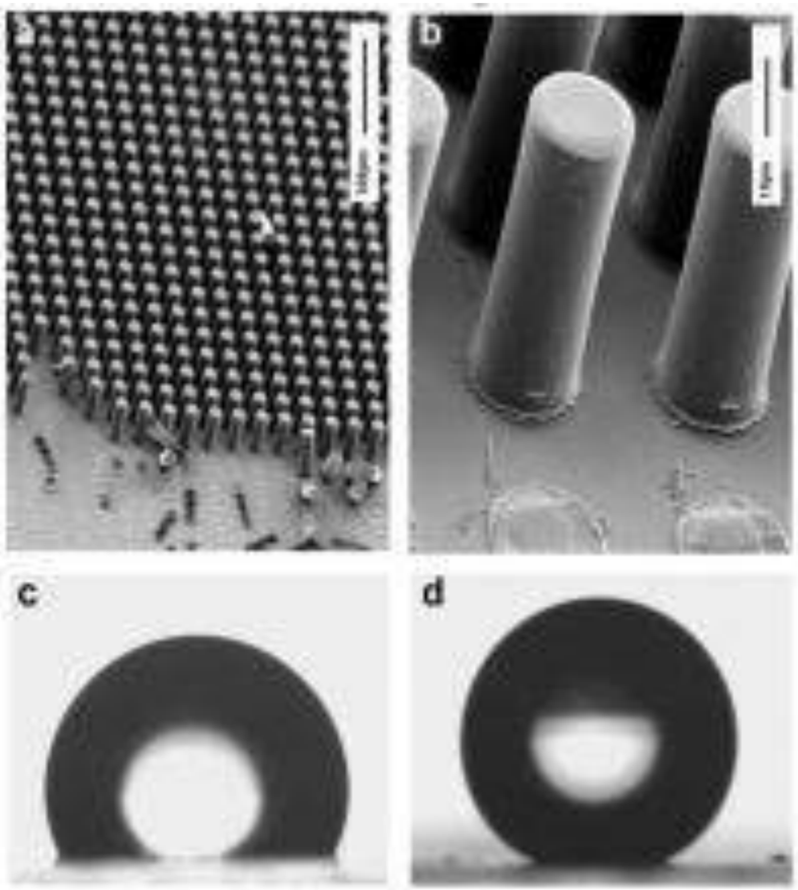
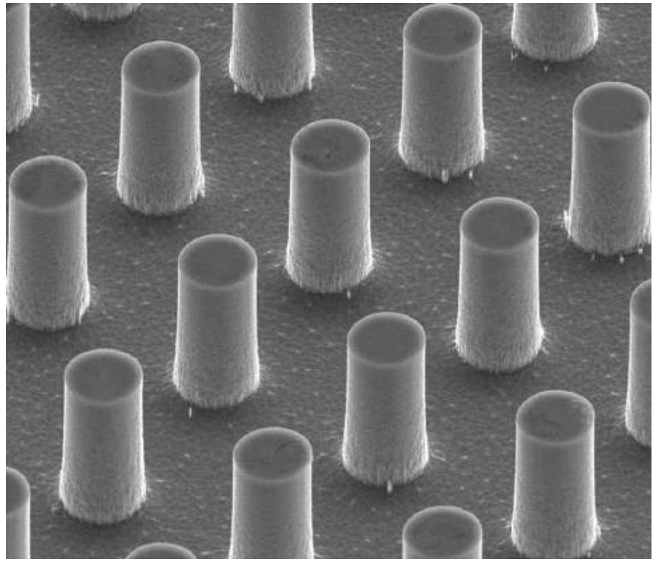
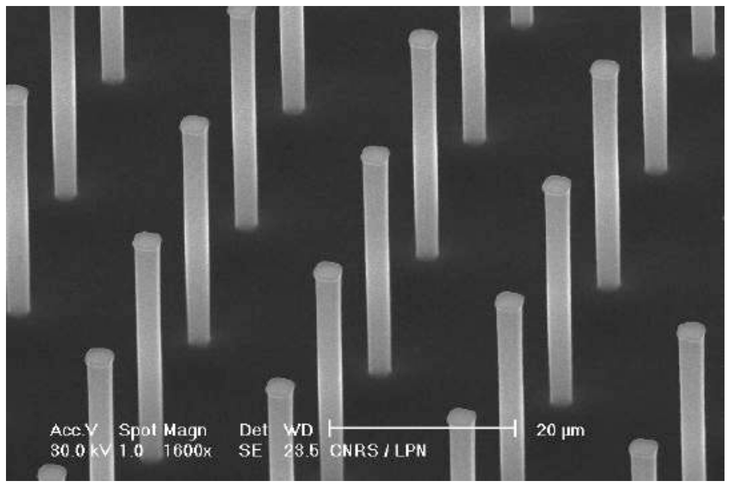
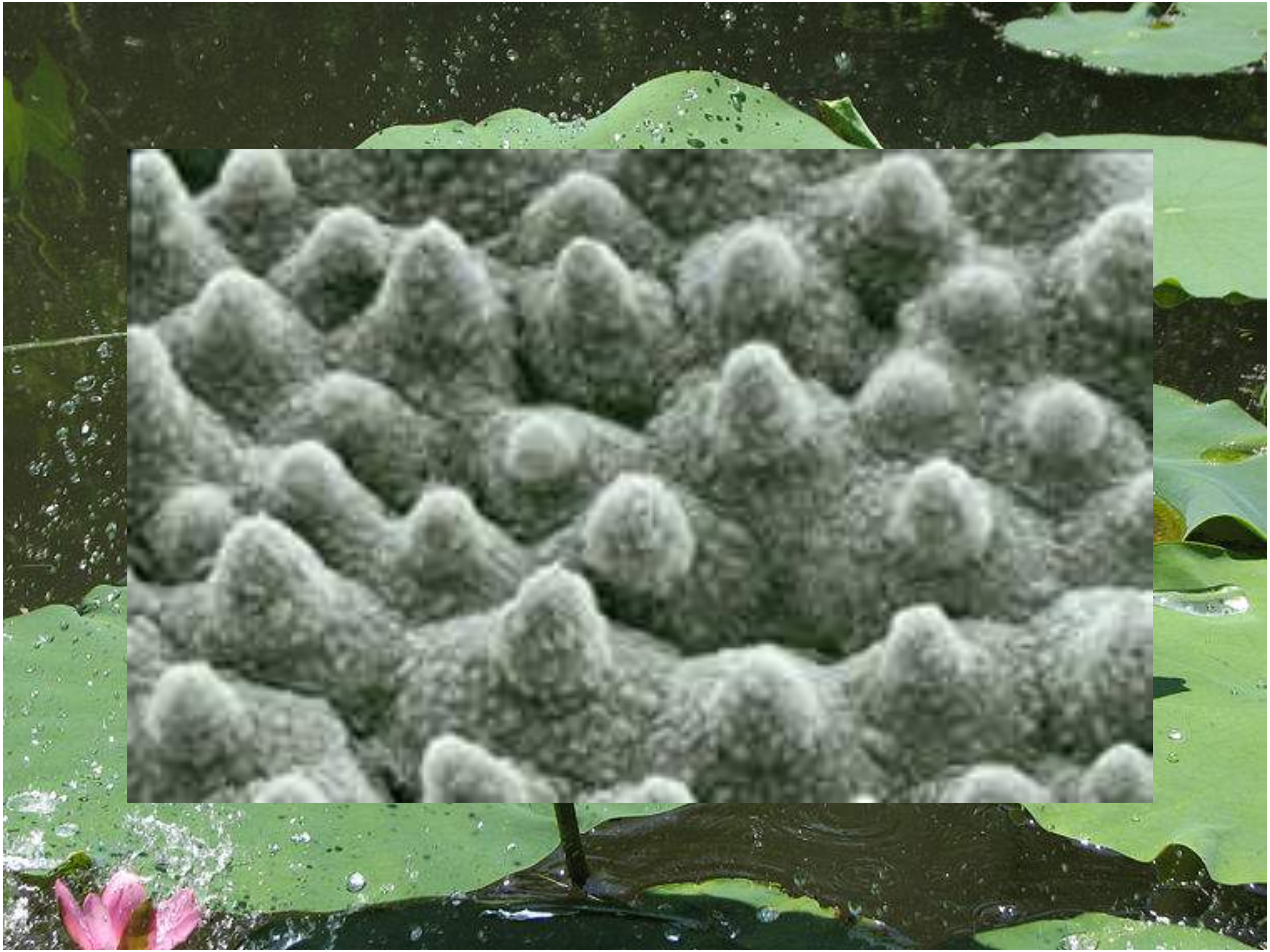


soft matter group
Nottingham Trent
University





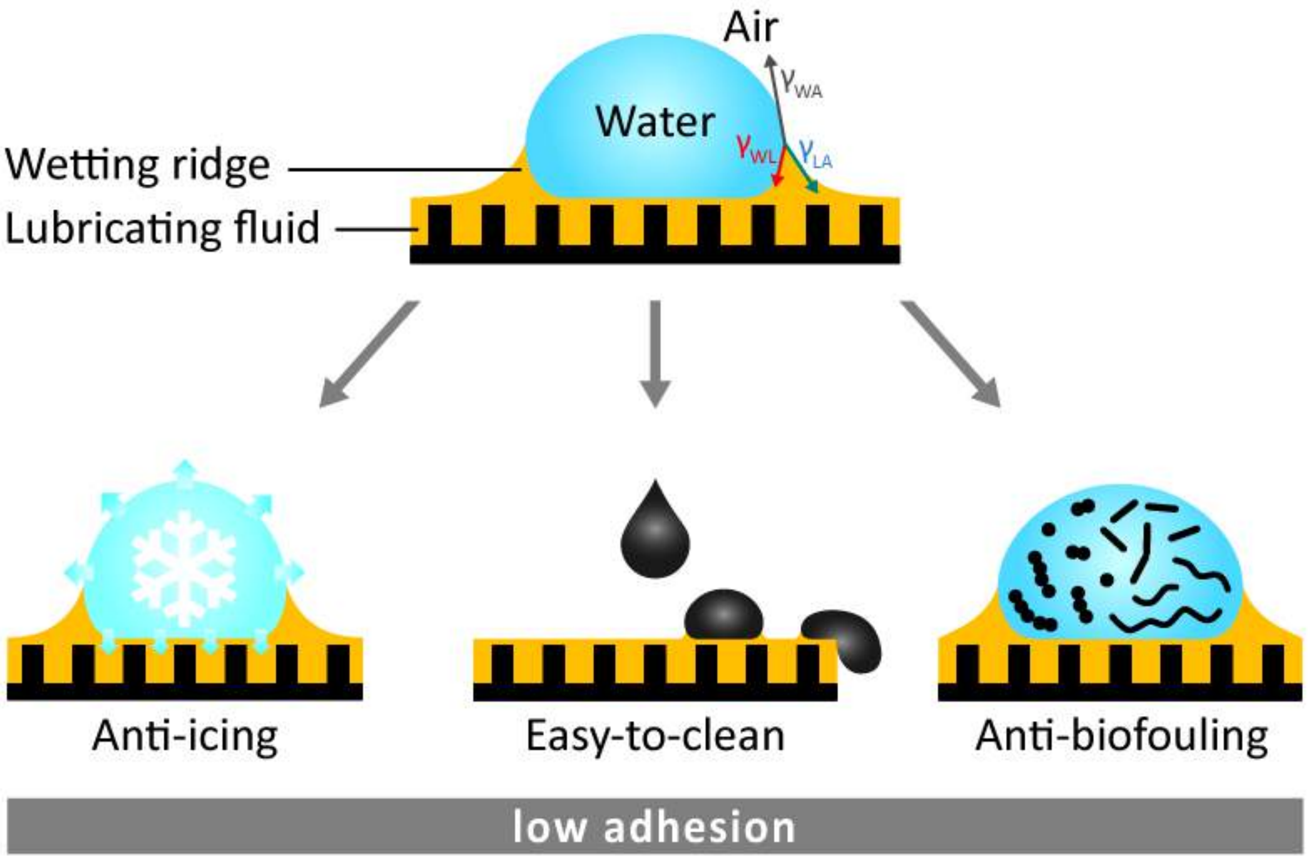
Davide Quere, Mathilde Reyssat




www.natureraincoats.org


www.natureraincoats.org

Lubricant impregnated slippery surface



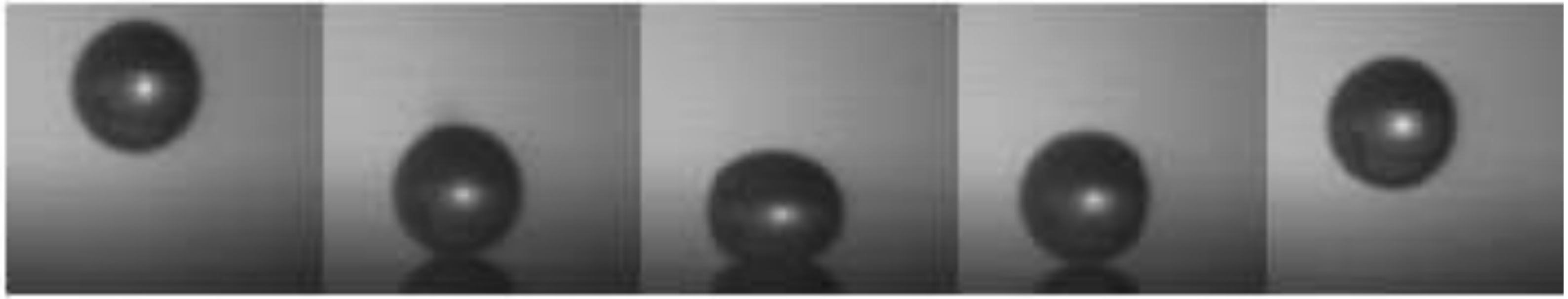
1. Superhydrophobic surfaces
2. Pancake bouncing
3. Vorticity

Weber number

balancing inertia and surface tension

$$We = \frac{r_0 v_0^2 \rho}{\gamma}$$

We=0.07

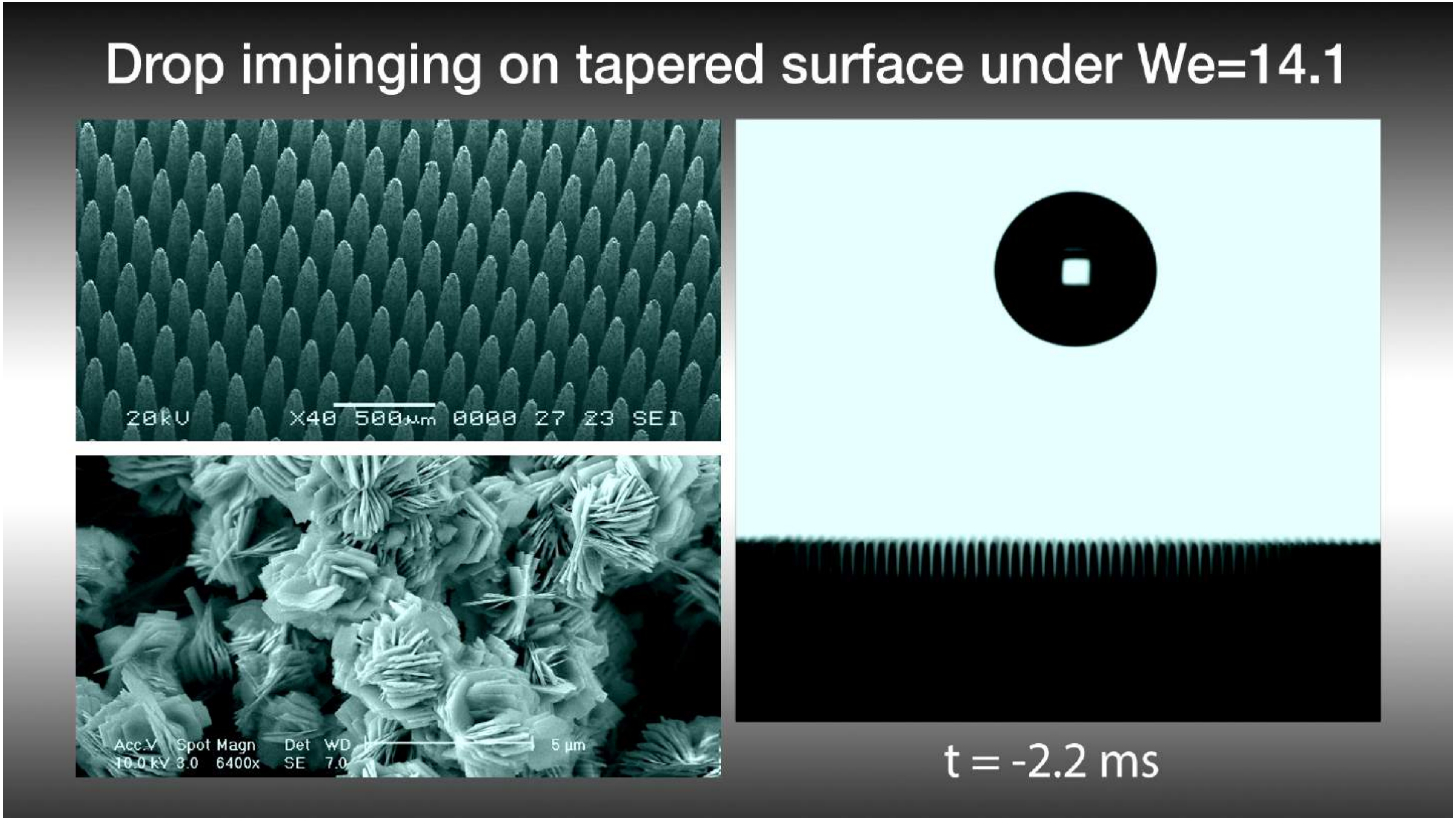


We=12

spreading time

$$t_{max} \sim \sqrt{\frac{\rho r_0^3}{\gamma}}$$

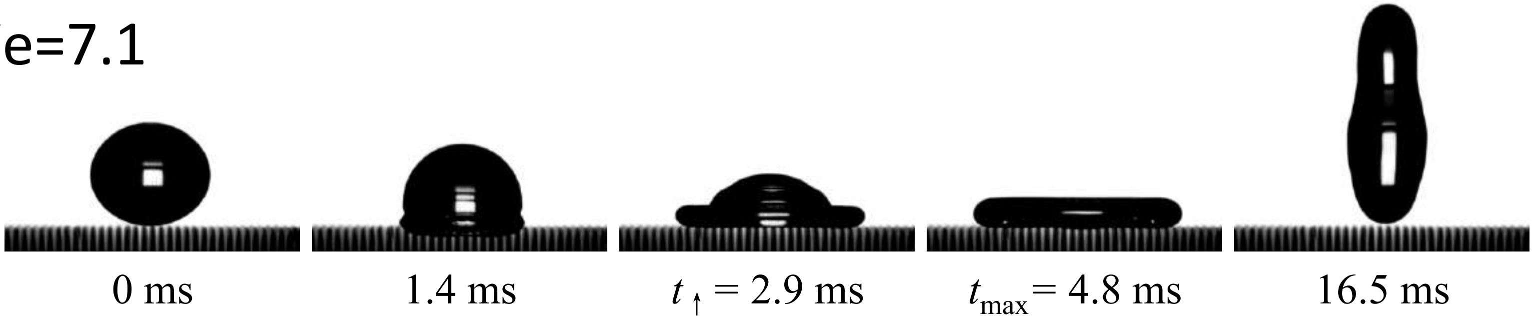
independent of impact velocity



Drop impinging on tapered surface under We=14.1
20kV X40 500µm 0000 27 23 SEI
Acc.V Spot Magn Det WD
10.0 kV 3.0 6400x SE 7.0
5 µm
t = -2.2 ms

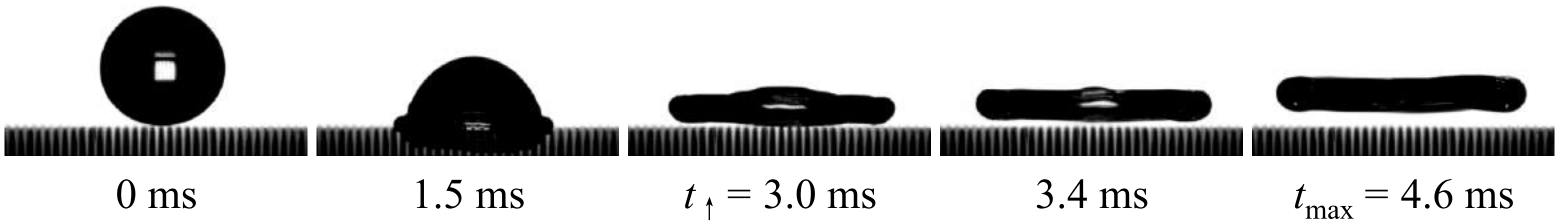
Impact on tapered posts

We=7.1



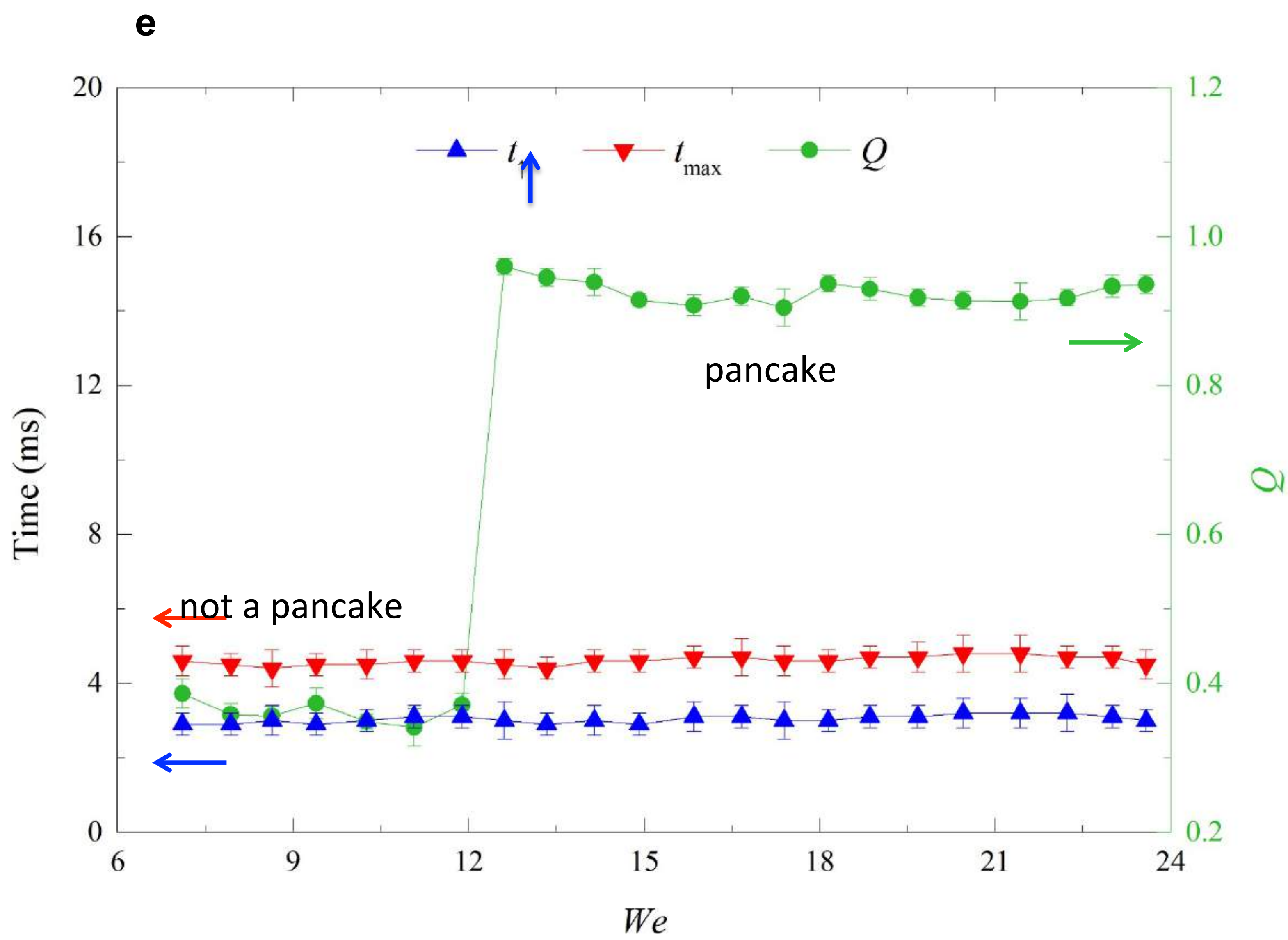
Normal bouncing on a superhydrophobic surface: very little friction so drops spread, retract and then bounce

We=14.1



Pancake bouncing: drop spreads, and then jumps as a pancake without retracting

Impact on tapered posts: experiments



Estimating the timescales: tapered posts

$$F \sim -2\pi R\gamma \cos\theta_Y n \qquad\qquad R = \beta z$$

capillary force proportional to distance from surface so simple harmonic motion

$$t_{\uparrow} \sim \sqrt{\frac{w^2 r_0 \rho}{\beta\gamma\cos\theta_Y}}$$

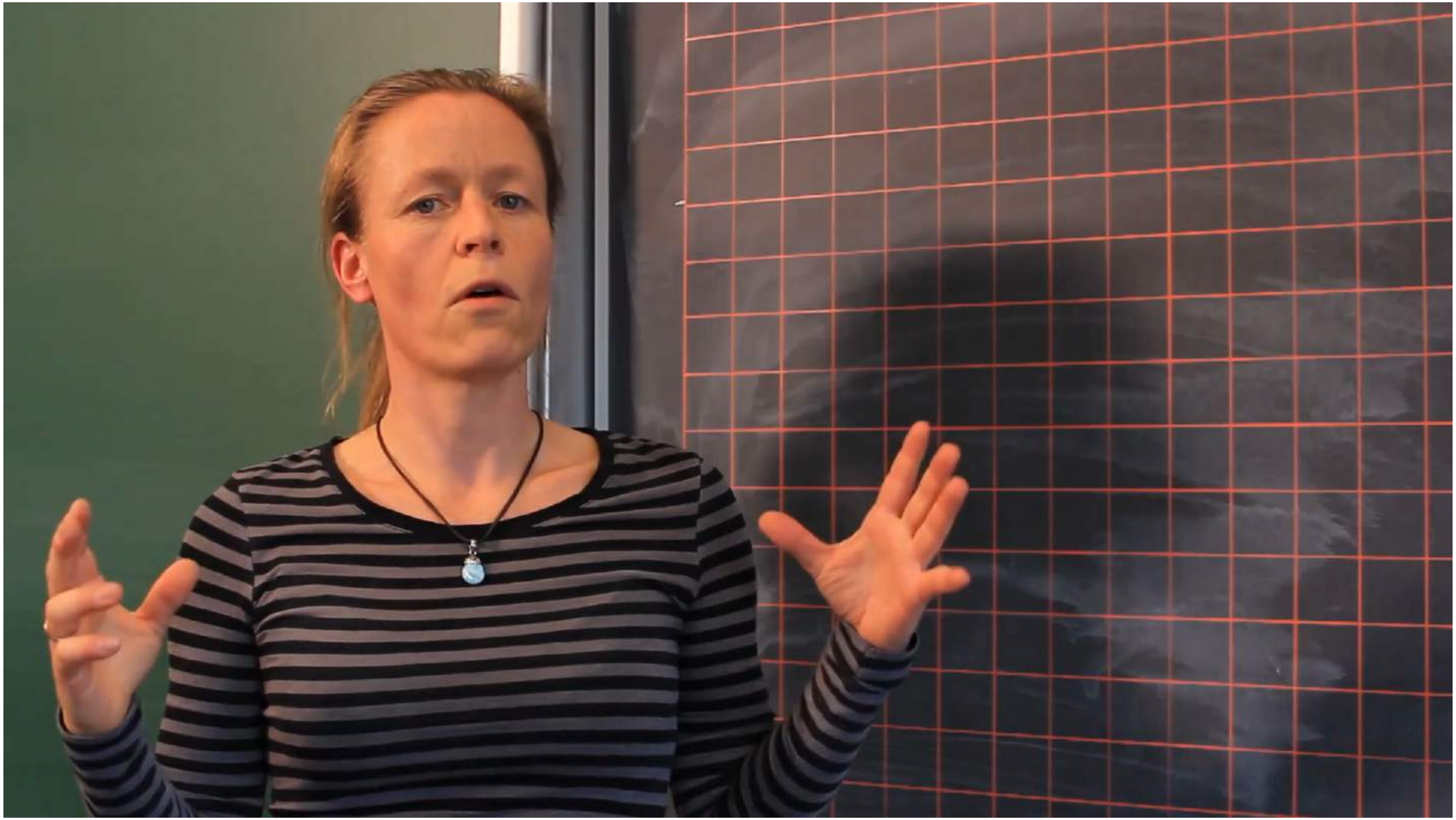
lateral spreading approx simple harmonic motion

$$t_{max} \sim \sqrt{\frac{\rho}{\gamma} r_0^3}$$

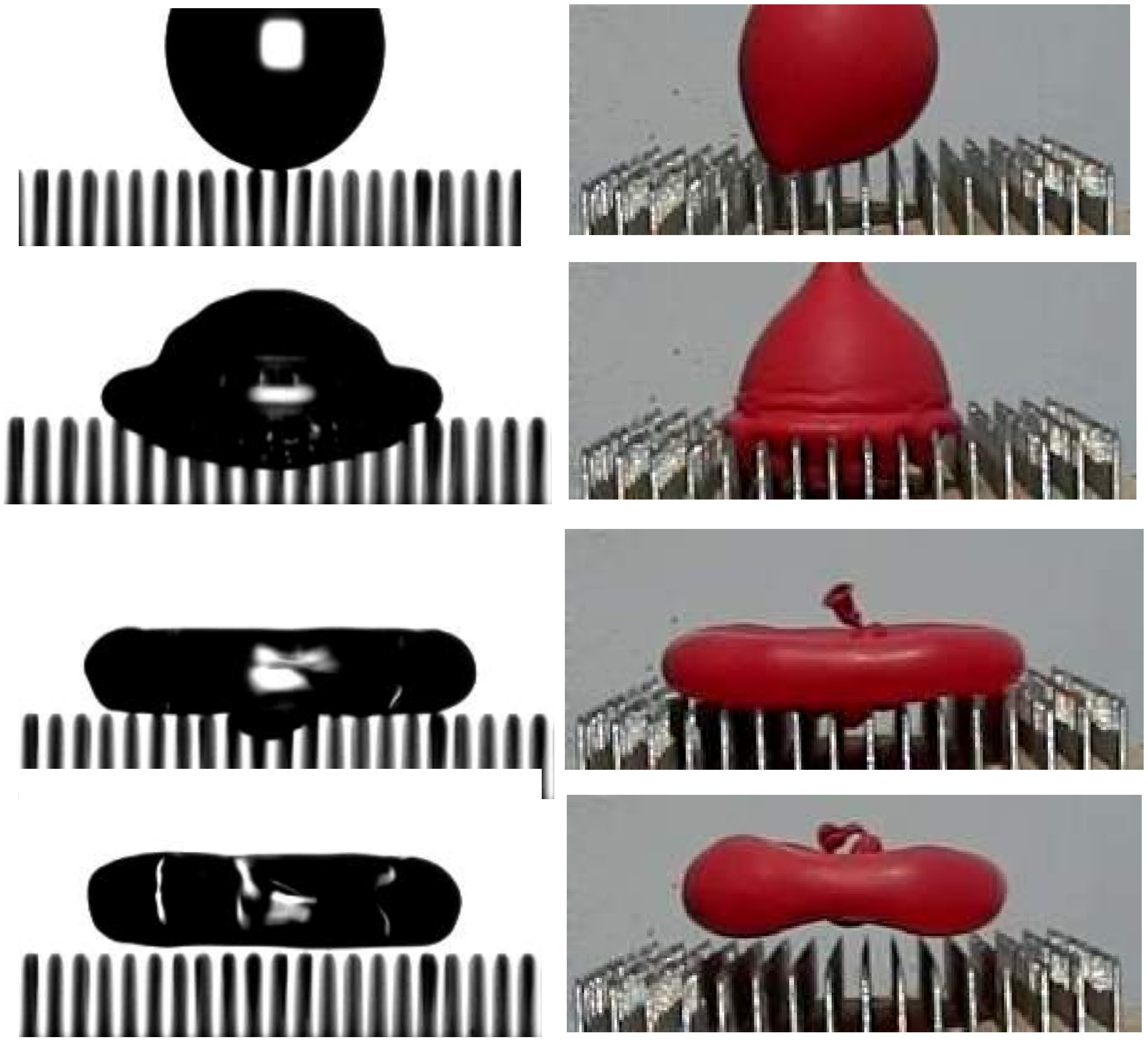
$$k = \frac{t_{\uparrow}}{t_{max}} \sim \frac{w^2}{\beta \cos \theta_Y r_0^2} \sim 1$$

Why has pancake bouncing not been seen before?

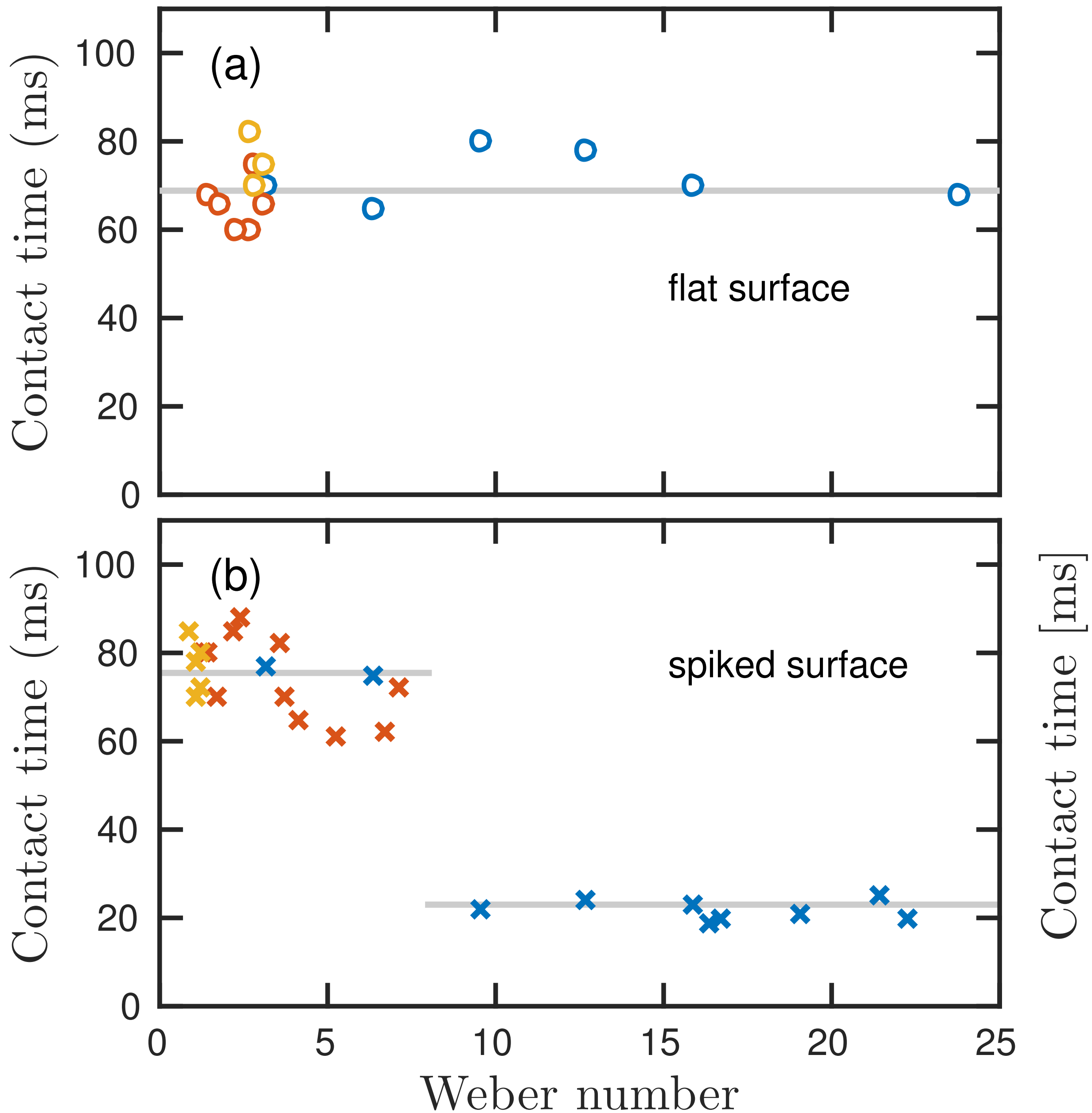
Tina Hecksher   Balloons on Nails: a 2nd semester project at Roskilde University



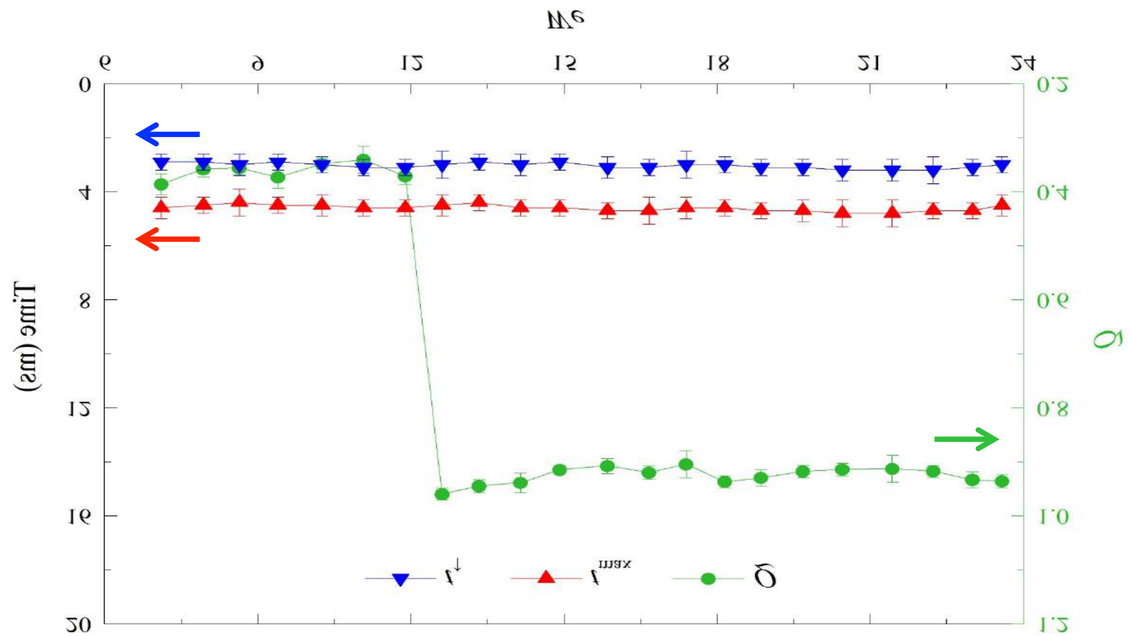
Tina Hecksher Balloons on Nails: a 2nd semester project at Roskilde University, Denmark

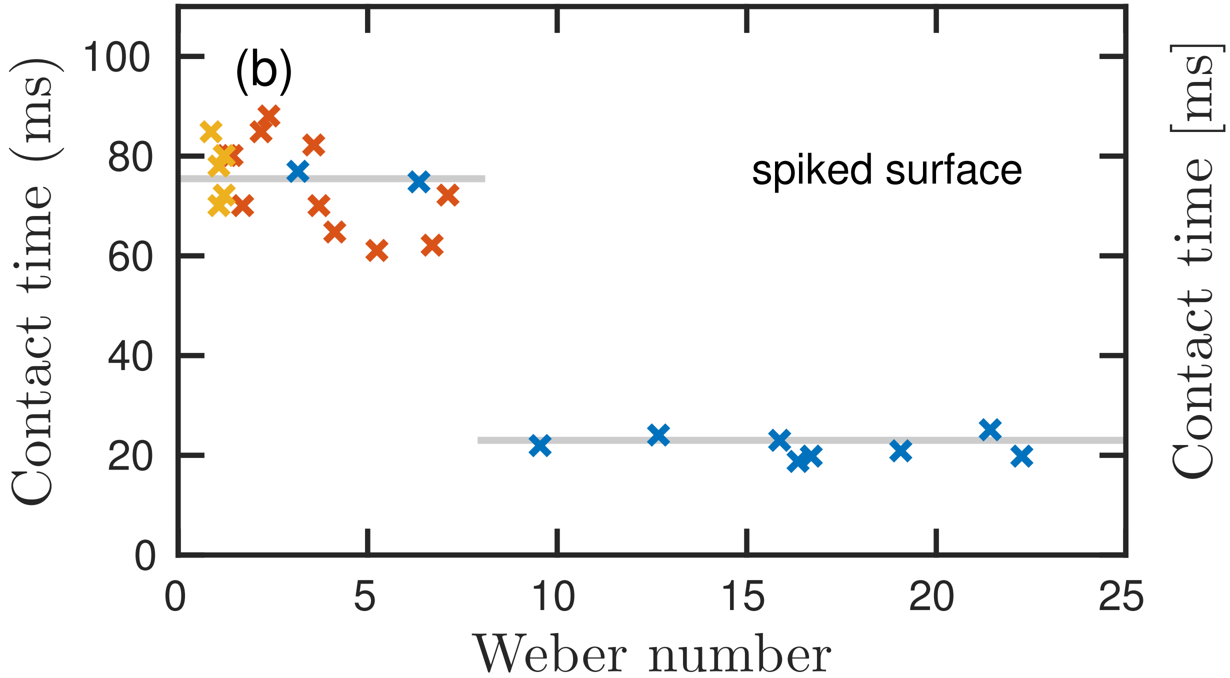


(a) (b)



(a)
flat surface
(b)
spiked surface
Contact time (ms)
Contact time (ms)
Contact time [ms]
Weber number
100
80
60
40
20
0
0
5
10
15
20
25





(b)
spiked surface
Contact time (ms)
Contact time [ms]
Weber number
0
20
40
60
80
100
0
5
10
15
20
25

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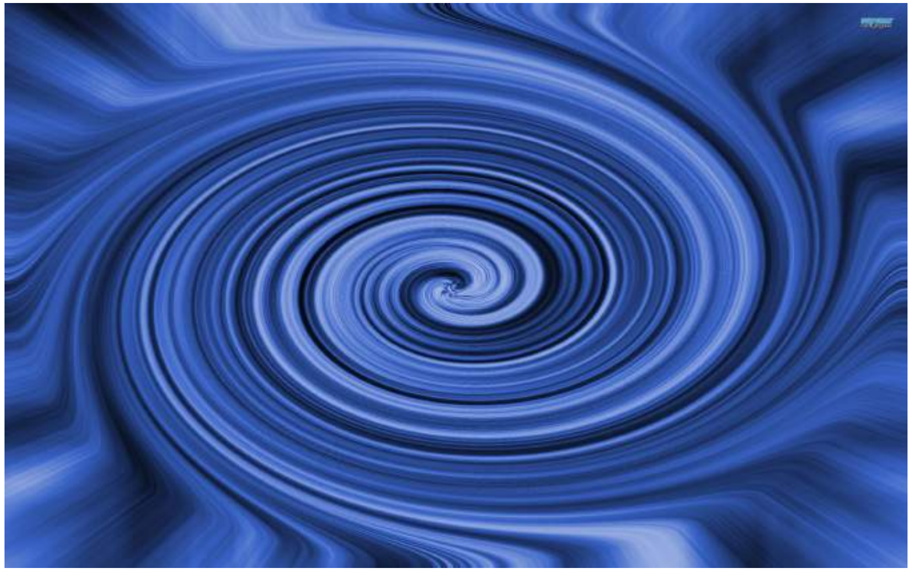


http://www.wimp.com/extraordinary-toroidal-vortices-produced-by-dolphins-humpback-whales-and-volcanoes/

Kutta-Joukovski theorem

$$L = -\rho u_0 \Gamma.$$

lift circulation

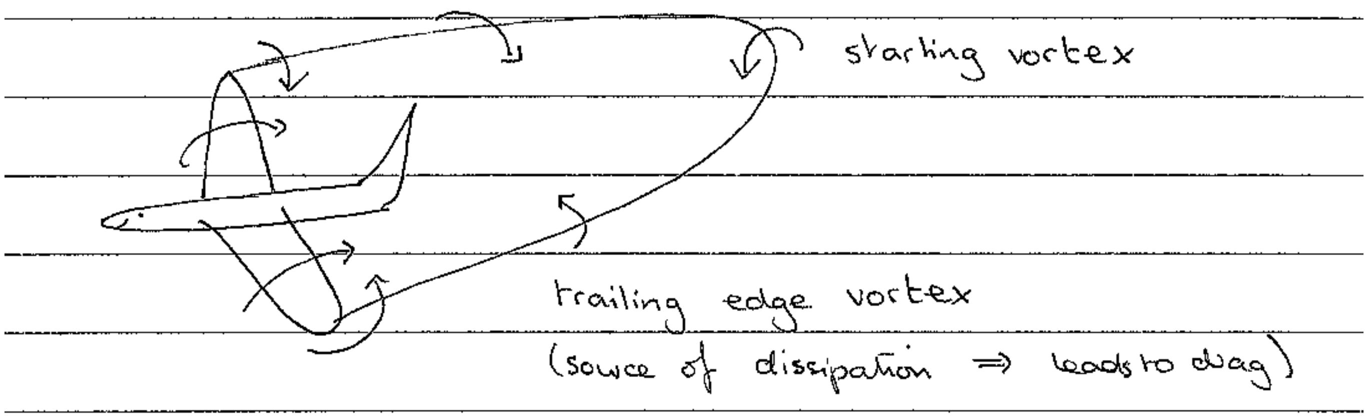
$$\Gamma = \oint_{C(t)} \mathbf{u} \cdot d\boldsymbol{\ell}$$

Kutta-Joukovski theorem

$$L = -\rho u_0 \Gamma.$$

lift circulation

$$\Gamma = \oint_{C(t)} \mathbf{u} \cdot d\boldsymbol{\ell}$$



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