ESR 2 Report

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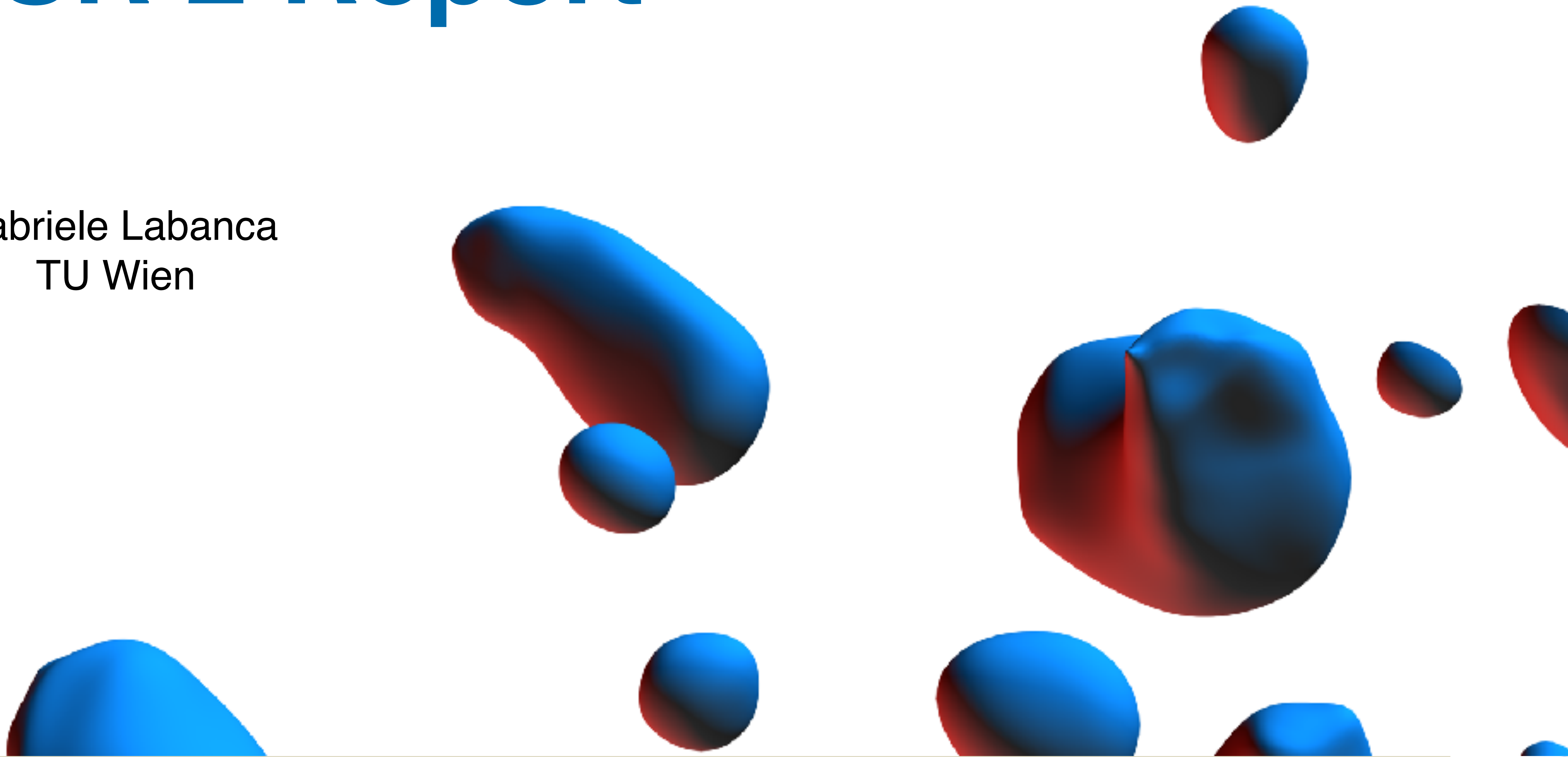
TU Wien



Vienna
11 Feb 2020

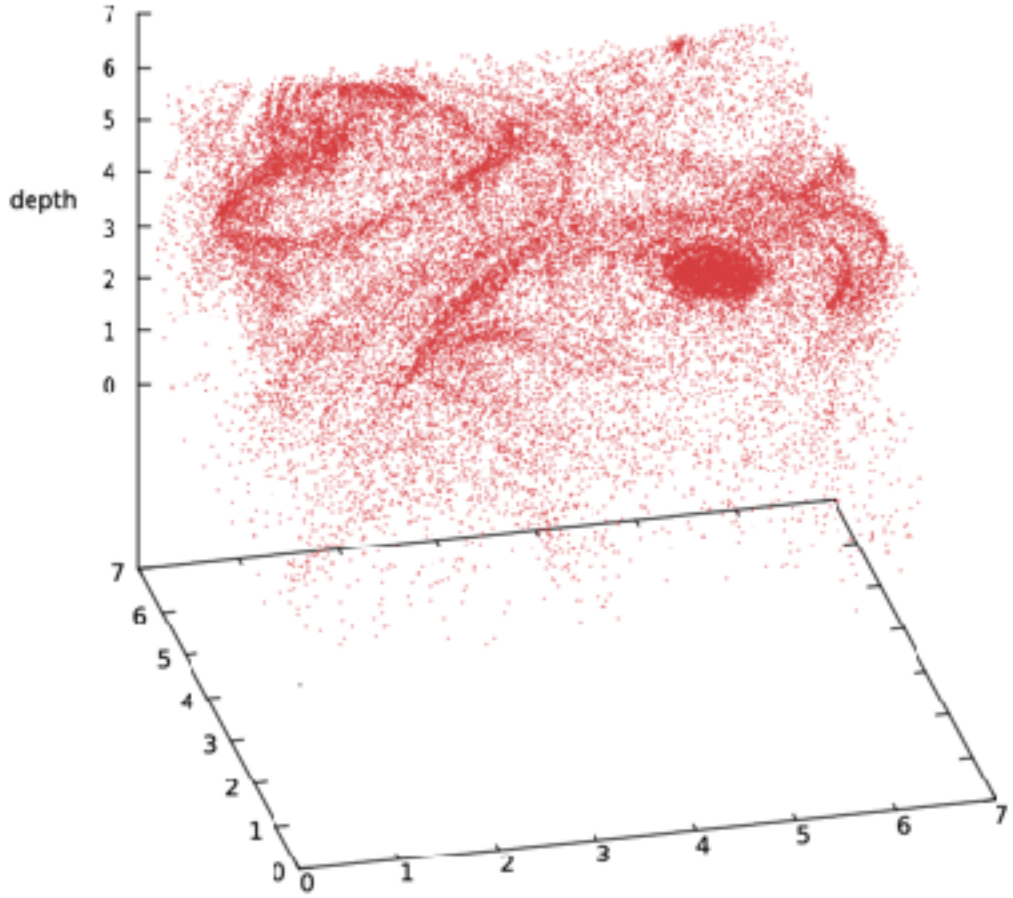
Background

Degree in Physics
Bachelor’s (**Padova**) and Master’s (**Torino**)

Study of **Plankton** spatial distribution in turbulence

$$\partial_t n + v\partial_z n = D\partial_z^2 n + (\lambda f - \mu)n$$

Pseudo-spectral, parallel, Lagrangian code



Courses and training

Bologna, CINECA, Debugging and Optimisation in High Performance Computing

Vienna, VSC, Parallelisation with MPI; Shared memory parallelisation with OpenMP

Udine, CISM, Advances in Dispersed Multi-Phase Flows: from Measuring to Modeling

Bologna, CINECA, Advanced school on parallel computing (February)

University of Innsbruck, GPU programming with CUDA (March)

http://www.hpc.cineca.it/news/marconi100-new-accelerated-gpu-cluster

Chicago, Argonne National Laboratory,
Training program on extreme-scale computing (July)

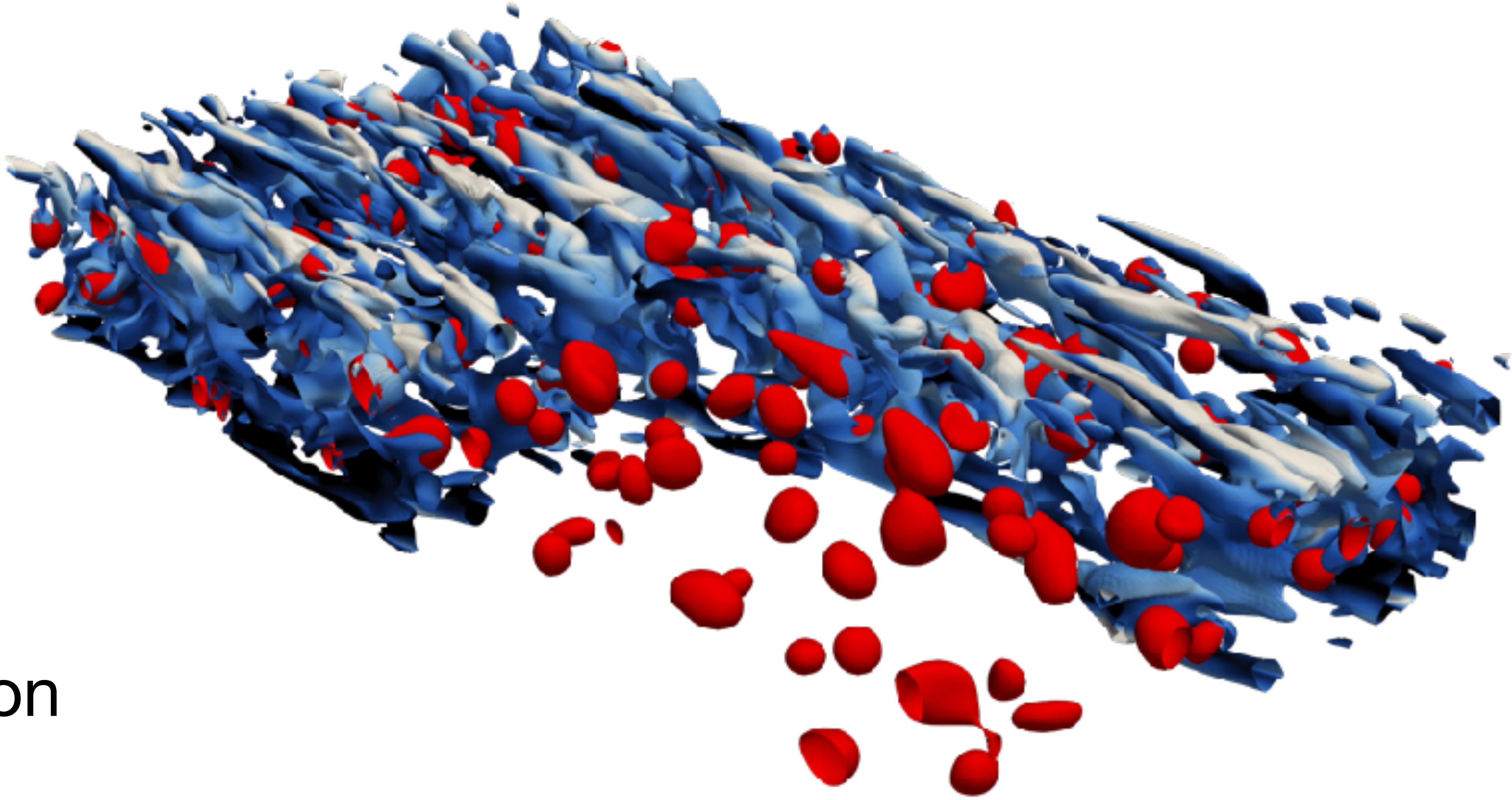
Networking and divulgation

Torino, ETC, Attendance and staff

Vienna, ERCOFTAC, Phase Field simulations of turbulent bubbly flows

Seattle, American Physical Society meeting, Fluid-dynamics division*,*
Dynamics of large and deformable bubbles in turbulence

Defining the physical problem



Turbulence

$$Re_\tau = \frac{\rho_c u_\tau h}{\eta_c}$$

Surface tension

Weber number
(ratio between inertial
and surface forces)

$$We = \frac{\rho_c u_\tau^2 h}{\sigma}$$

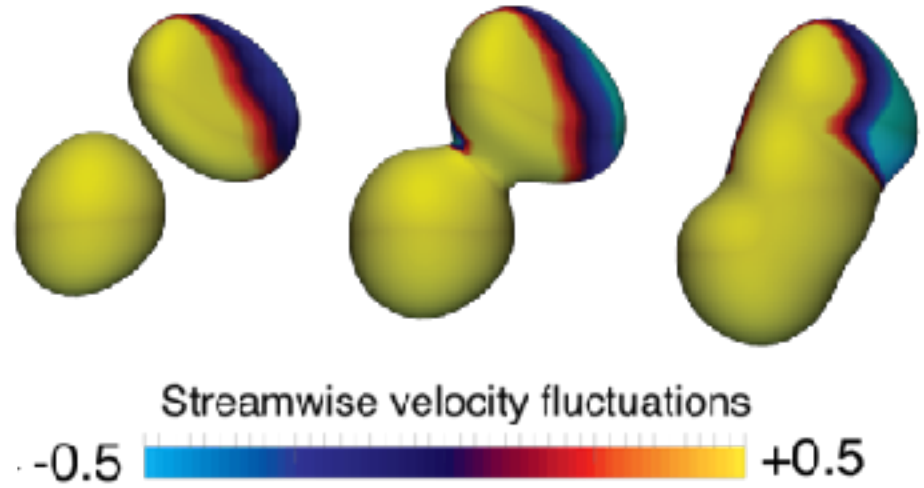
Viscosity ratio

$$\lambda = \frac{\eta_d}{\eta_c}$$

Density ratio

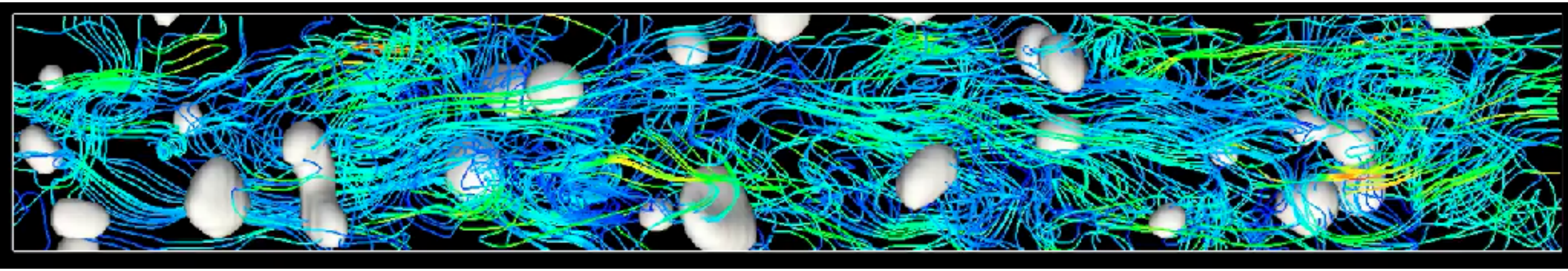
$$\gamma = \frac{\rho_d}{\rho_c}$$

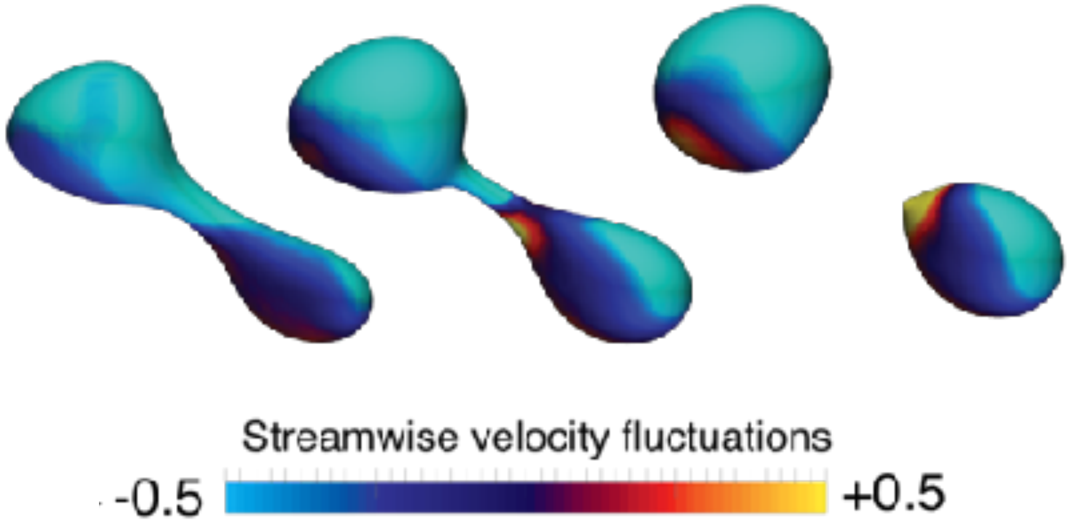
Drop-drop interaction



COALESCENCE

Two drops come close and collide due to turbulence fluctuations. During the collision, a small bridge is initially formed; later, surface tension (which tends to reshape the drop) comes into the picture and complete the coalescence process.





BREAK-UP

A drop is subjected to a sufficient shear stress, such that it is deformed and stretched until the emerging thin liquid bridge is broken (due to surface tension that acts minimising the energy stored at the interface).

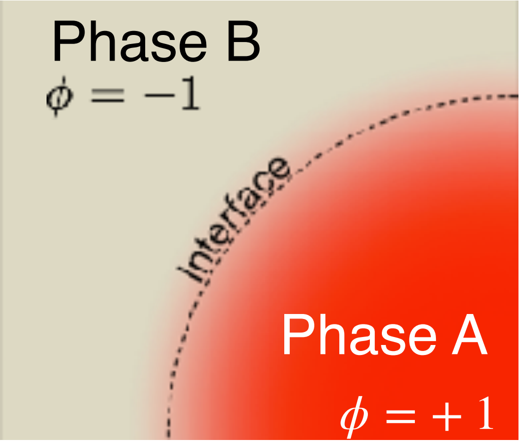
Scarbolo, Bianco, Soldati, Coalescence and breakup of large droplets in turbulent channel flow, PoF (2015)
Roccon et al., Viscosity-modulated breakup and coalescence of large drops in bounded turbulence, PRF (2017)
Soligo, Roccon, Soldati, Breakage, coalescence and size distribution of surfactant-laden droplets in turbulent flow, JFM (2019)

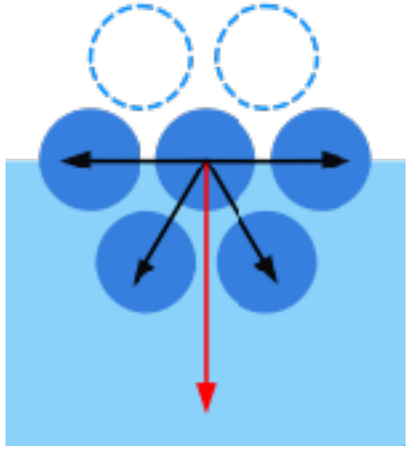
Phase Field Method
Fluid equations

Interface

Cahn-Hilliard

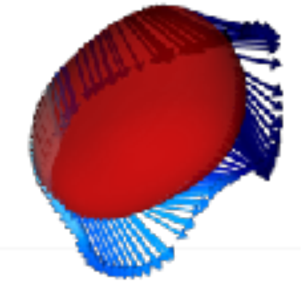
$$\frac{\partial \phi}{\partial t} + \mathbf{u}\cdot\nabla\phi = \frac{1}{Pe_\phi}\nabla^2\mu_\phi$$





Interface forces
(Korteweg tensor)

Flow



Continuity

$$\nabla\cdot\mathbf{u} = 0$$

Navier-Stokes

$$\rho(\phi)\left[\frac{\partial \mathbf{u}}{\partial t} + \mathbf{u}\cdot\nabla\mathbf{u}\right] = -\nabla P + \frac{1}{Re_\tau}\nabla\cdot\left[\eta(\phi)\left(\nabla\mathbf{u} + \nabla\mathbf{u}^T\right)\right] + \frac{3}{\sqrt{8}}\frac{Ch}{We}\nabla\cdot\tau_c$$

Density: $\rho(\phi) = \left[1 + \frac{\gamma - 1}{2}(\phi + 1)\right]$

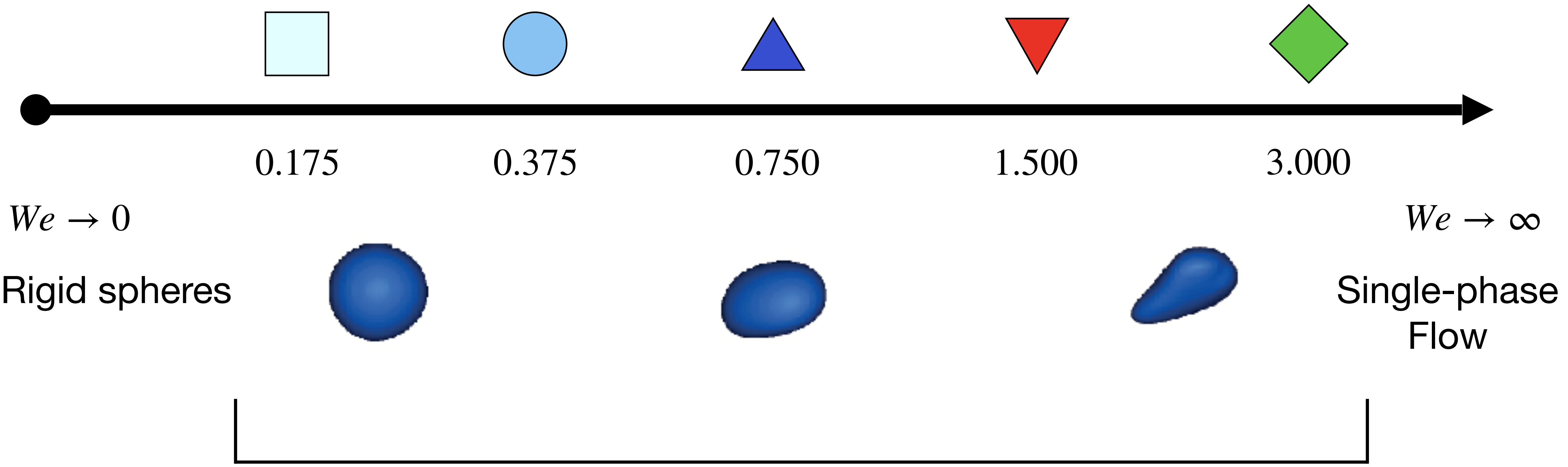
Viscosity: $\eta(\phi) = \left[1 + \frac{\lambda - 1}{2}(\phi + 1)\right]$

Jacqmin, Calculation of Two-Phase Navier–Stokes Flows Using Phase-Field Modelling, JCP (1999)
Badalassi, Ceniceros, Banerjee, Computation of multiphase systems with phase model, JCP (2003)
Ding, Spelt, Shu, Diffuse interface model for incompressible two-phase flows with large density ratios, JCP (2007)
Roccon et al., Viscosity-modulated breakup and coalescence of large drops in bounded turbulence, PRF (2017)

Effect of Weber number

Weber number
(ratio between inertial
and surface forces)

$$We = \frac{\rho_c u_\tau^2 h}{\sigma}$$



$We \to 0$

Rigid spheres

$We \to \infty$

Single-phase Flow

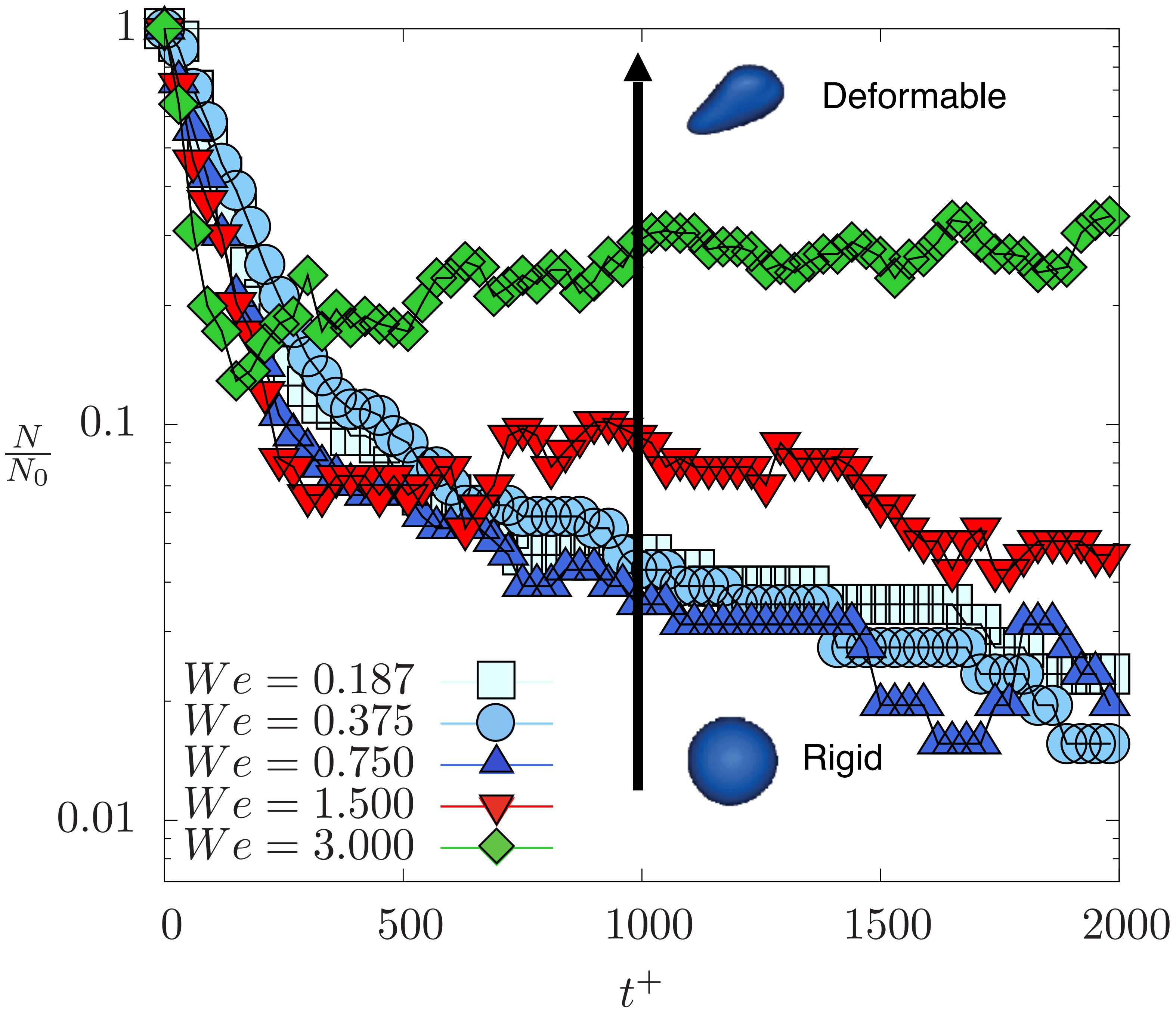
Deformable drops

Number of drops

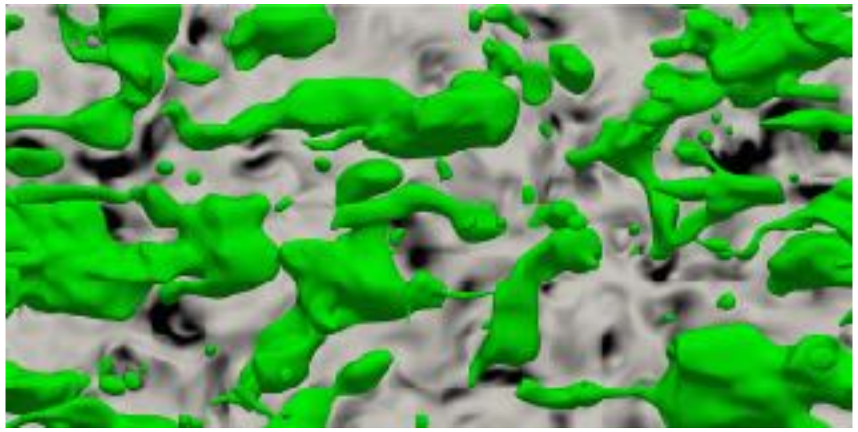
Effect of Weber number

Temporal evolution of the number of drops

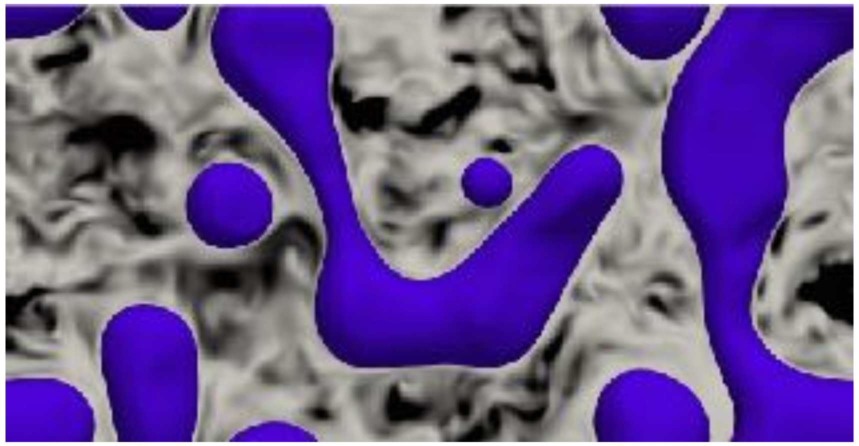
$$We = \frac{\rho_c u_\tau^2 h}{\sigma}$$



Break-up regime



Coalescence regime



Scarbolo, Bianco, Soldati, Coalescence and breakup of large droplets in turbulent channel flow, PoF (2015)
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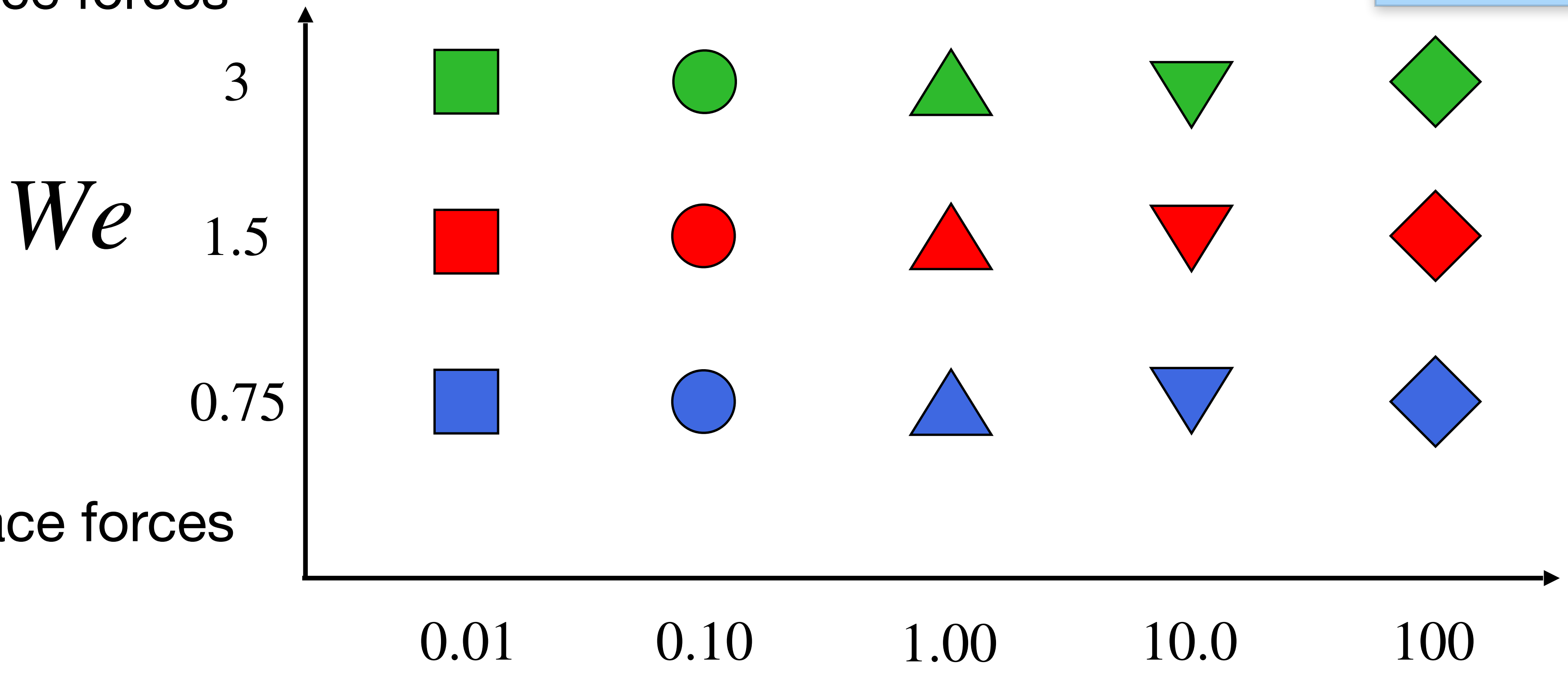
Effect of viscosity ratio and Weber number

More viscous droplets dissipate more effectively the turbulence fluctuations.

Low surface forces



High surface forces

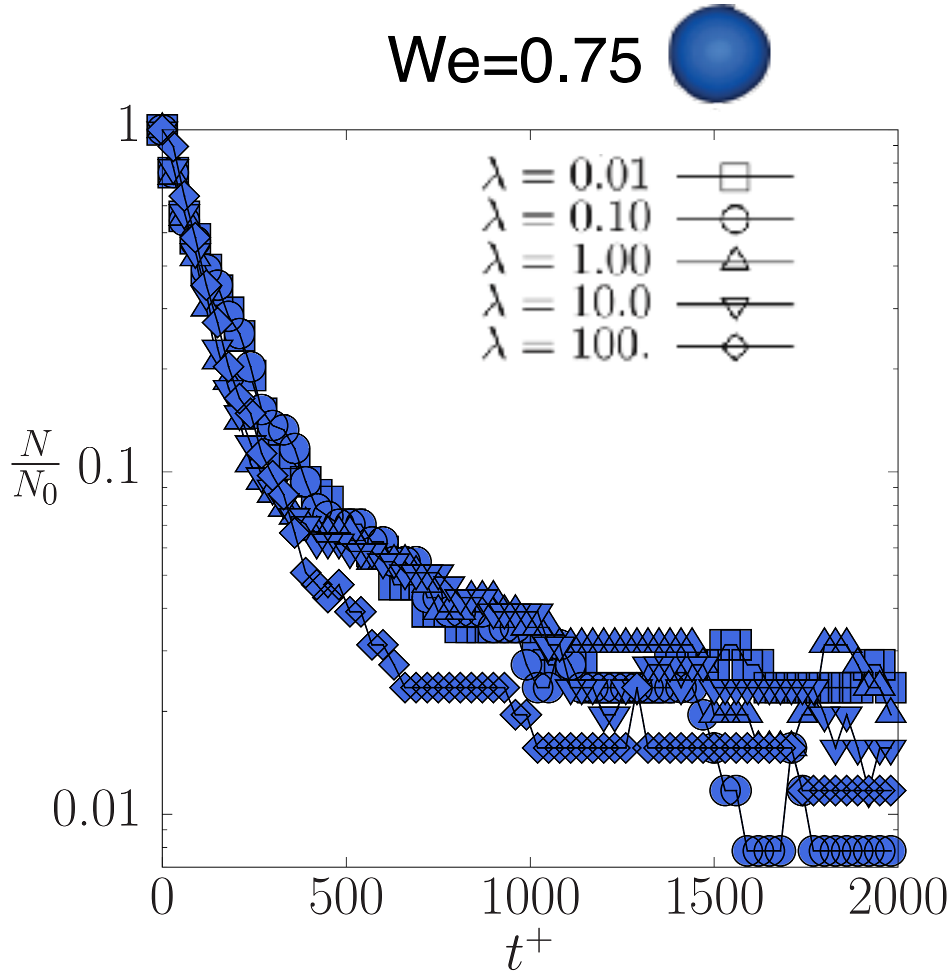
Low drops viscosity λ High drops viscosity

$$\lambda = \frac{\eta_d}{\eta_c}$$

Number of drops

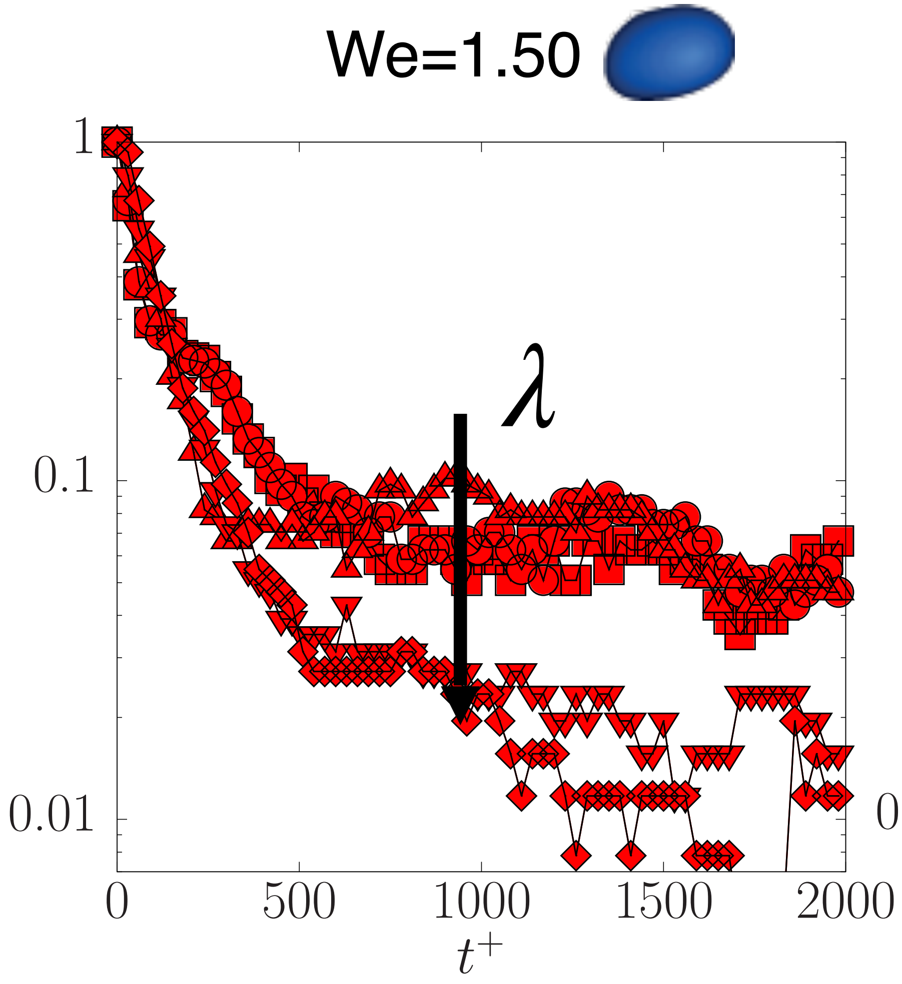
Effect of viscosity ratio and Weber number

We=0.75



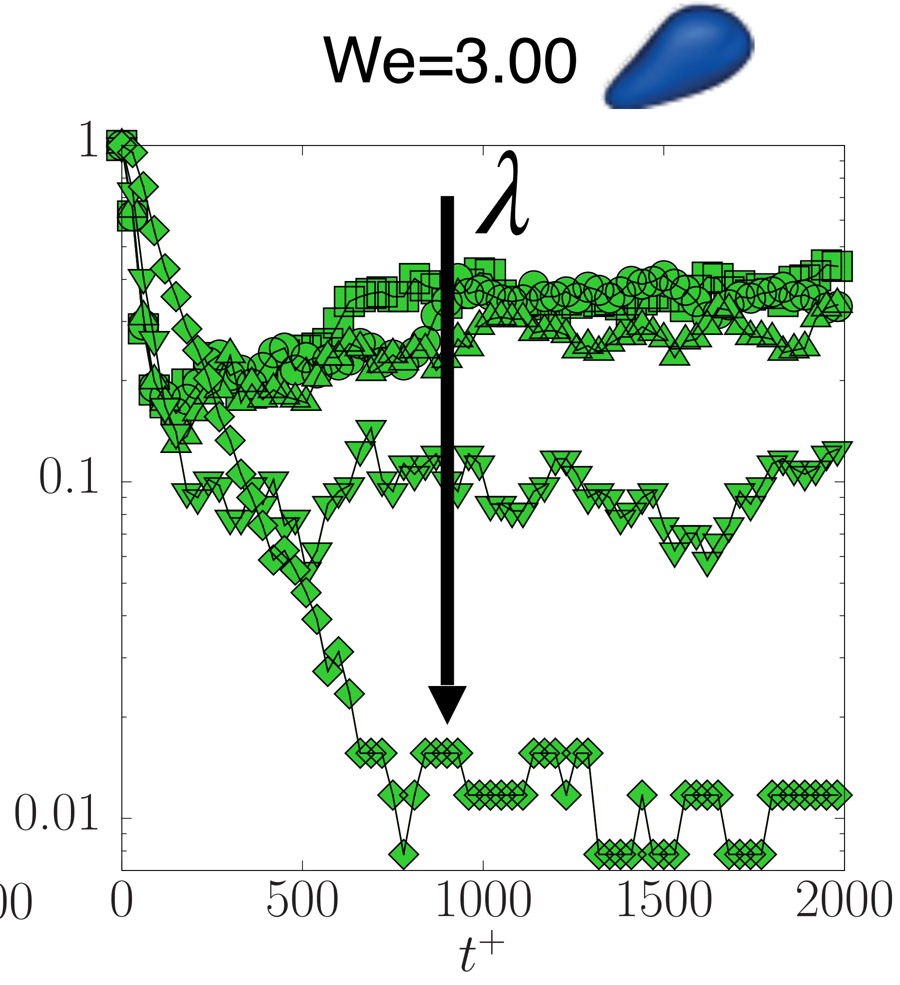
Coalescence Regime $\forall\lambda$

We=1.50



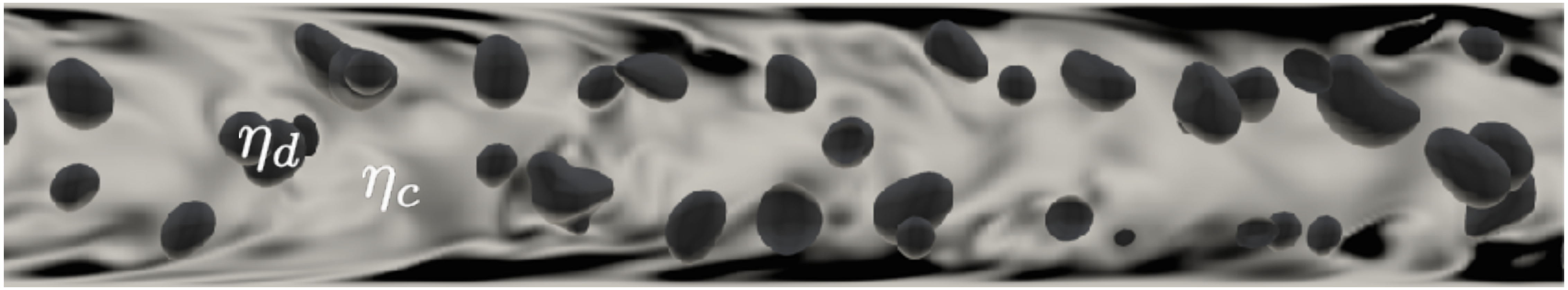
Coalescence Regime $\lambda > 1$

We=3.00



Coalescence Regime $\lambda > 10$

$$\lambda = \frac{\eta_d}{\eta_c}$$



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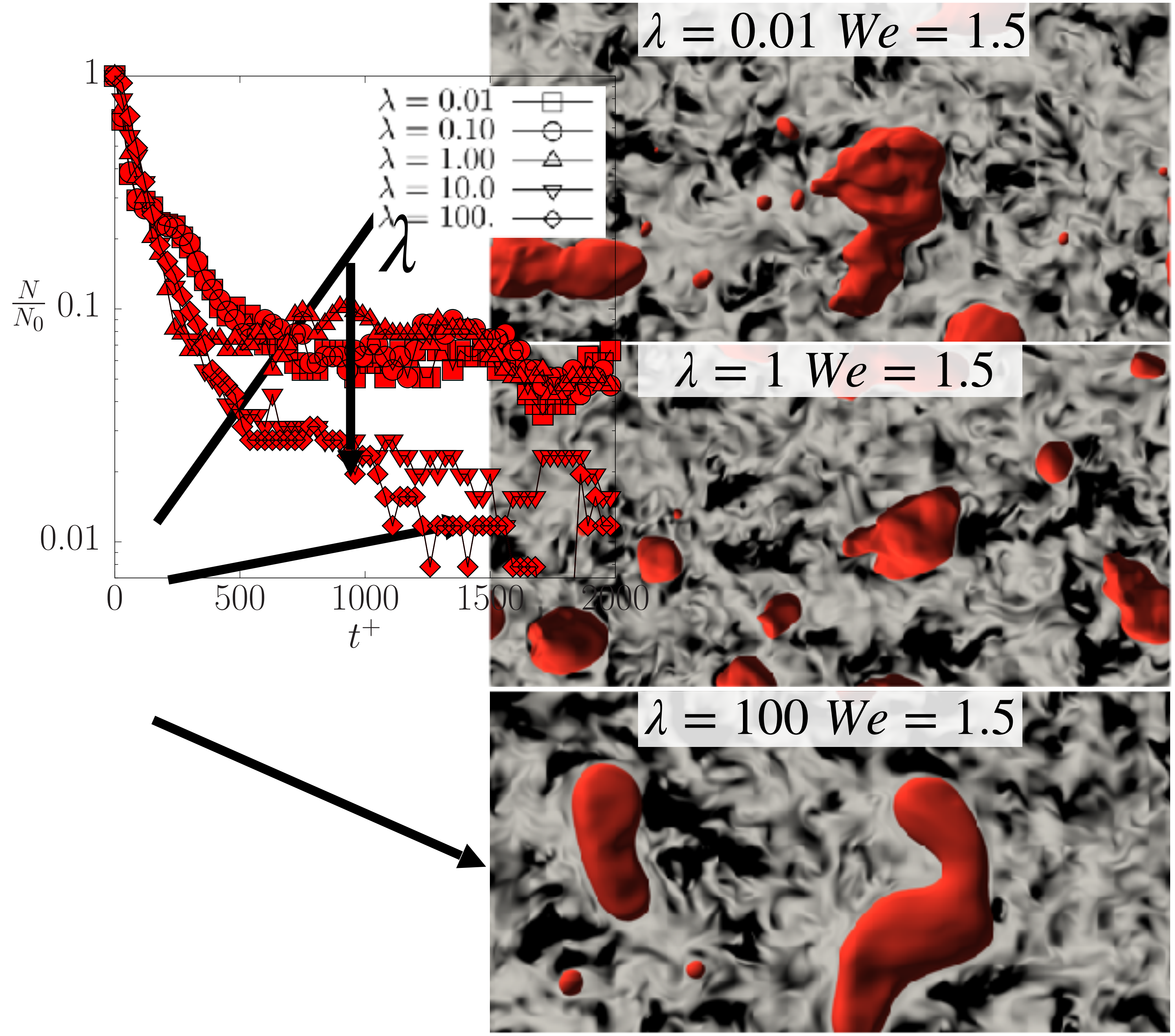
Number of drops

Effect of viscosity ratio and Weber number



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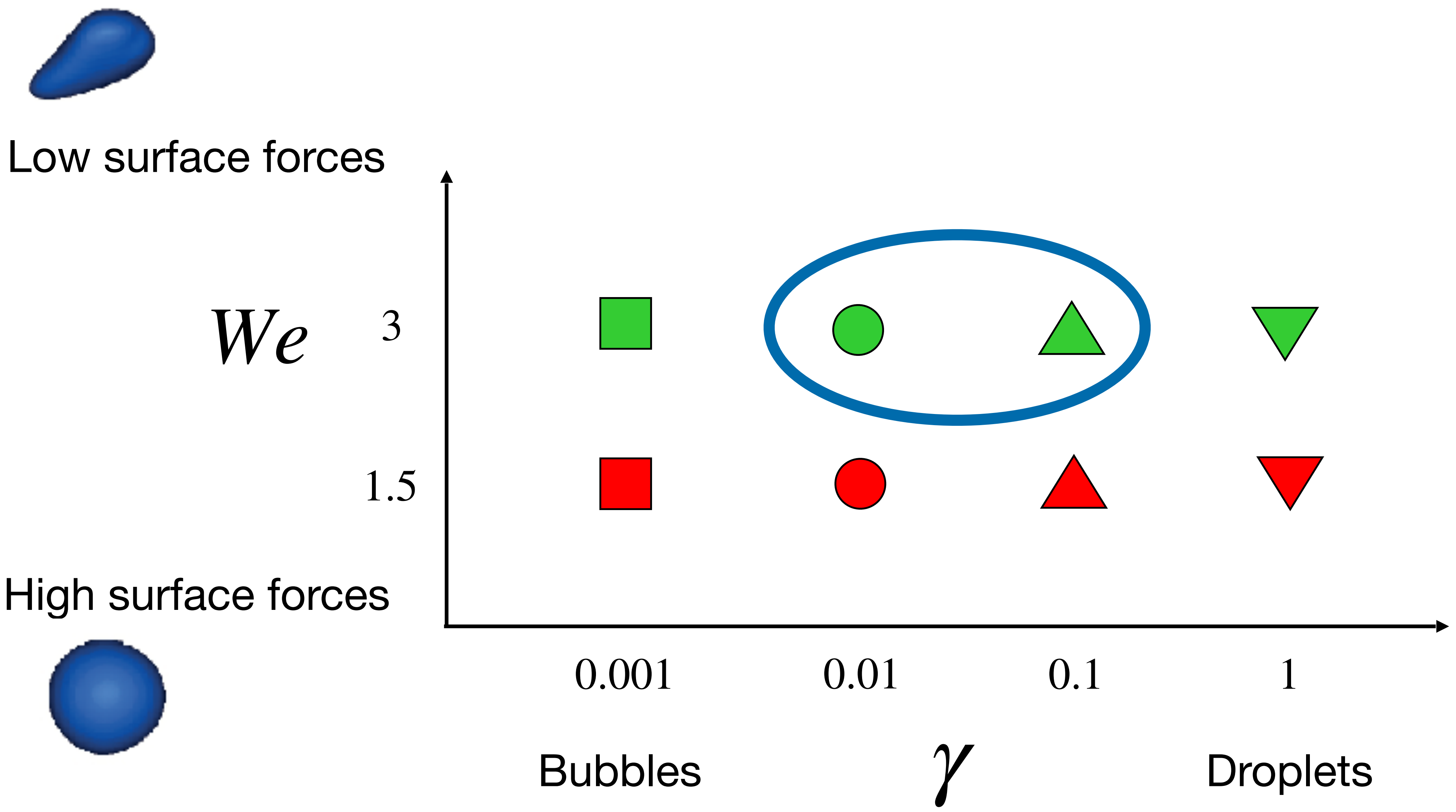
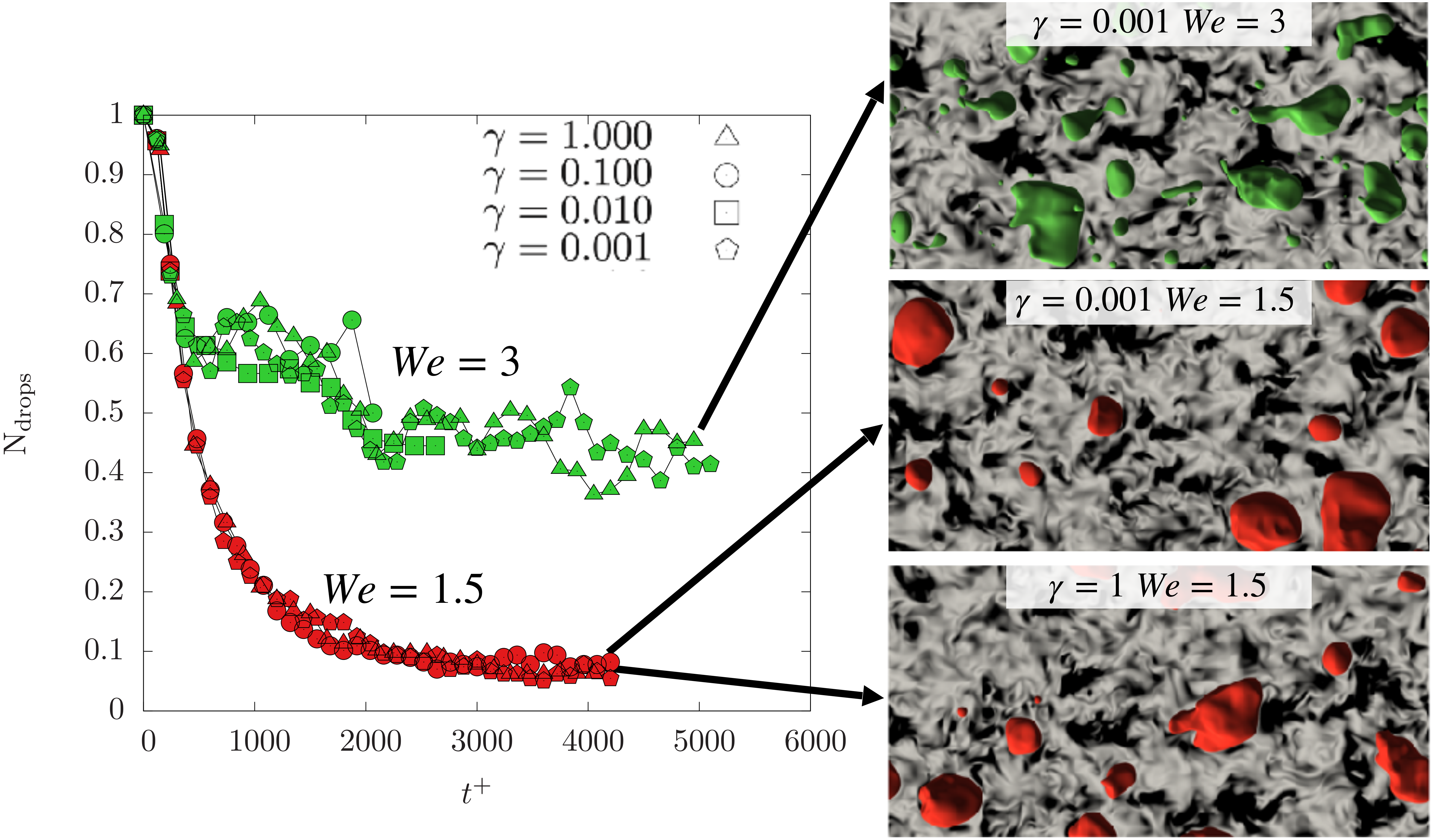
Effect of density ratio and Weber number



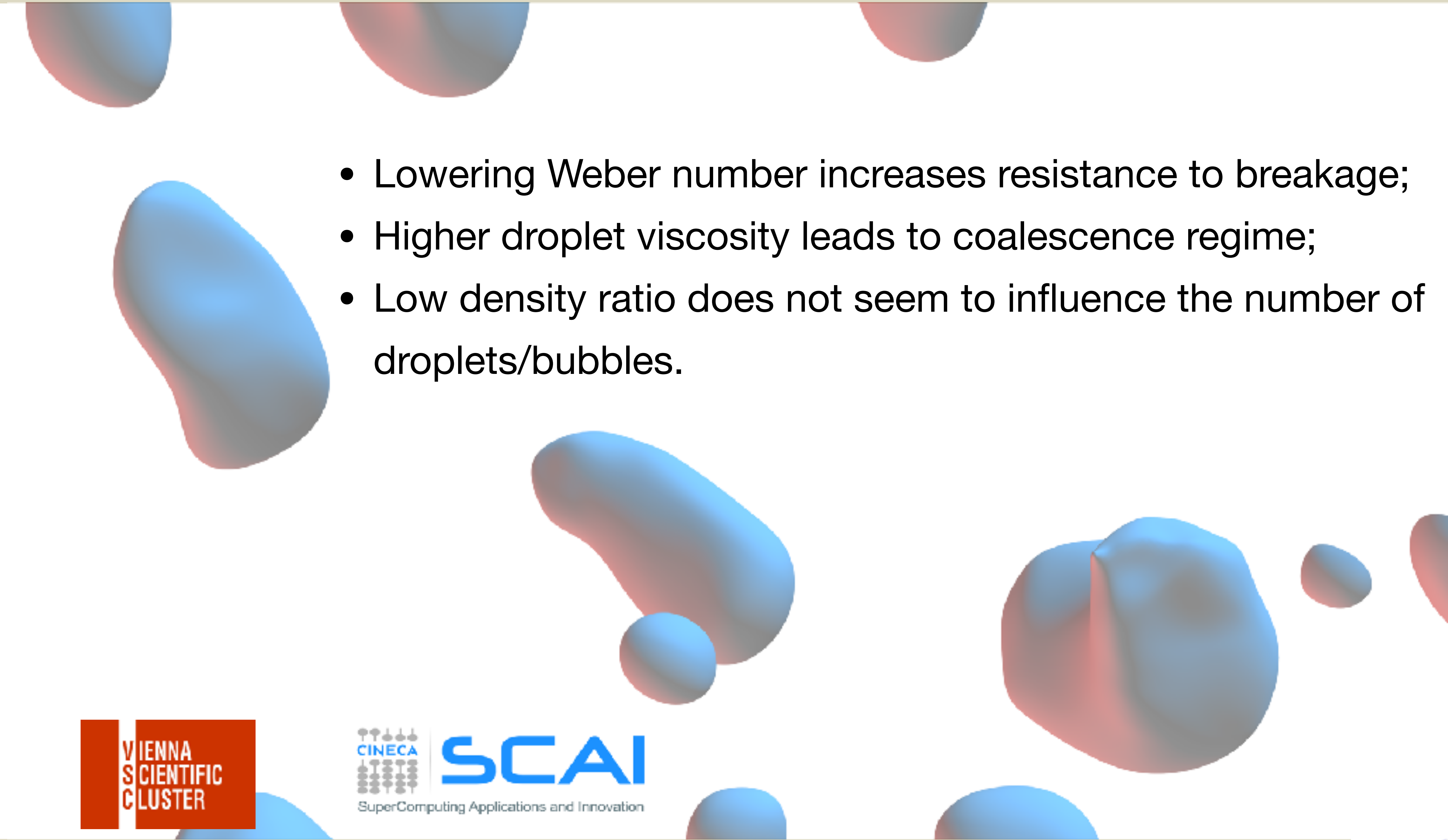
$$\gamma = \frac{\rho_d}{\rho_c}$$

Number of drops

Effect of density ratio and Weber number



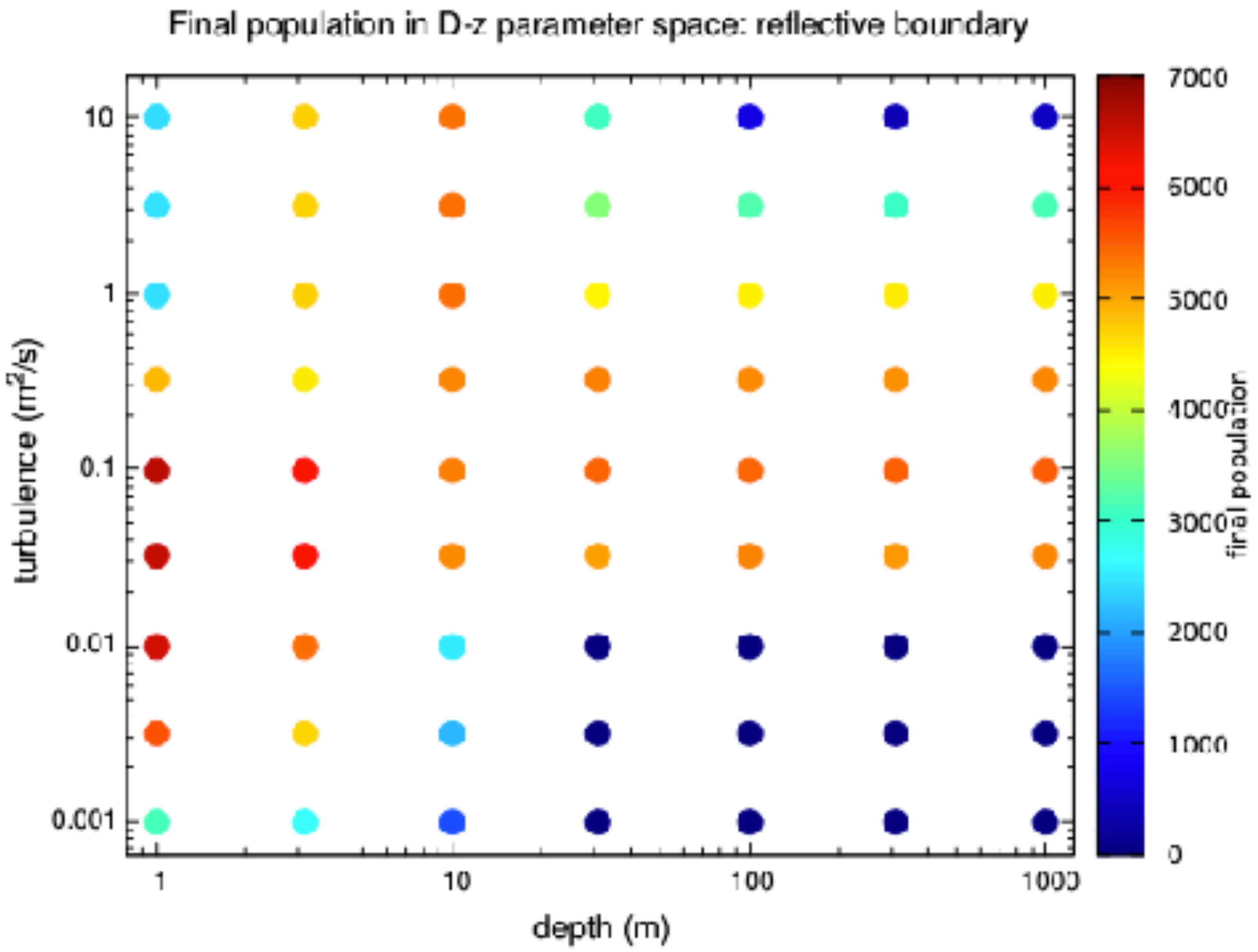
Conclusions

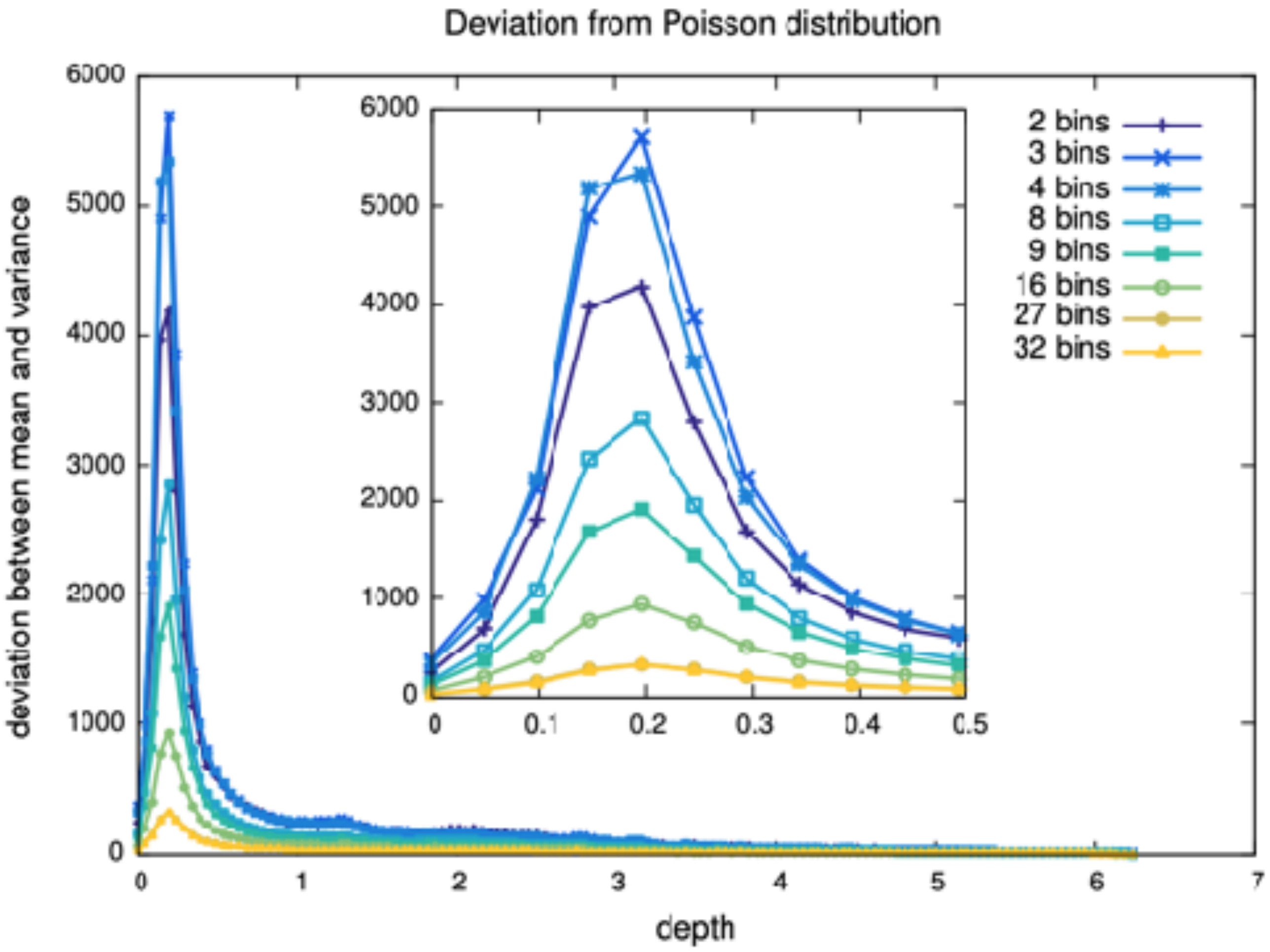


- Lowering Weber number increases resistance to breakage;
- Higher droplet viscosity leads to coalescence regime;
- Low density ratio does not seem to influence the number of droplets/bubbles.

Korteweg tensor:
Accounts for surface tension forces

$$\tau_c = \left| \nabla \phi \right|^2 \mathbf{I} - \nabla \phi \otimes \nabla \phi$$





Huisman, Arrayás, et al. (2002). “How Do Sinking Phytoplankton Species Manage to Persist?”, The American Naturalist

Shigesada and Okubo (1981). “Analysis of the self-shading effect on algal vertical distribution in natural waters”, Journal of Mathematical Biology