Some similarity problems involving bubbles and filaments

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W. Mostert, E. Turkoz, C-Y. Lai, A. Riviere, D. Ruth, D. Shaw, J. Wu.

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Two mini-stories involving similarity solutions

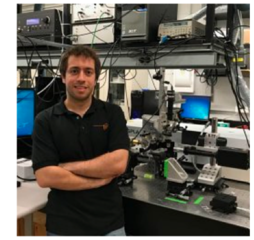
Visco-elastic filament thinning

E. Turkoz, J.M. Lopez-Herrera, J. Eggers, C.B. Arnold and L. Deike, Journal of Fluid Mechanics Rapids, 851, R2, 2018.

Inertio-capillary cavity collapse and jet ejection during bursting bubble

C-Y. Lai, J. Eggers and L. Deike , Physical Review Letters, 121, 2018.

Visco-elastic filament thinning

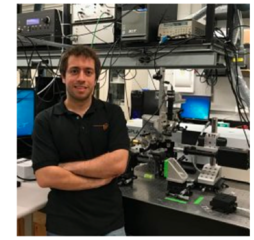


Exponential thinning of a viscoelastic filament (De = 60) in ambient air

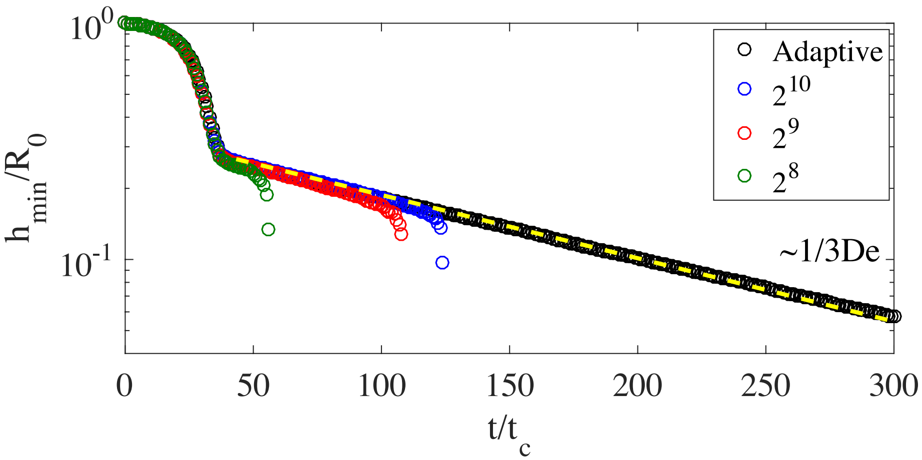
E. Turkoz, J. M. Lopez-Herrera, J. Eggers, C. B. Arnold and L. Deike, "*Axisymmetric simulation of viscoelastic filament thinning with the Oldroyd-B model*," **J. Fluid. Mech.**, 851, R2 (2018)

Uses the implementation from **López-Herrera, J.M.**, Popinet, S. and Castrejón-Pita, A.A., 2019. *An adaptive solver for viscoelastic incompressible two-phase problems applied to the study of the splashing of weakly viscoelastic droplets*. Journal of Non-Newtonian Fluid Mechanics, 264, pp.144-158.

Visco-elastic filament thinning: similarity solution

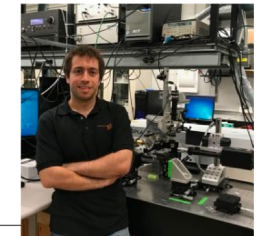


Filament thinning: $h_{min}(t) = h_0 \exp[-t/(3\lambda)],$



In the end of the simulation ($t/t_c = 300$): $h_{min}/R_0 \approx 0.06$, which corresponds to ~40 grid points in radial direction.

Visco-elastic filament thinning: similarity solution



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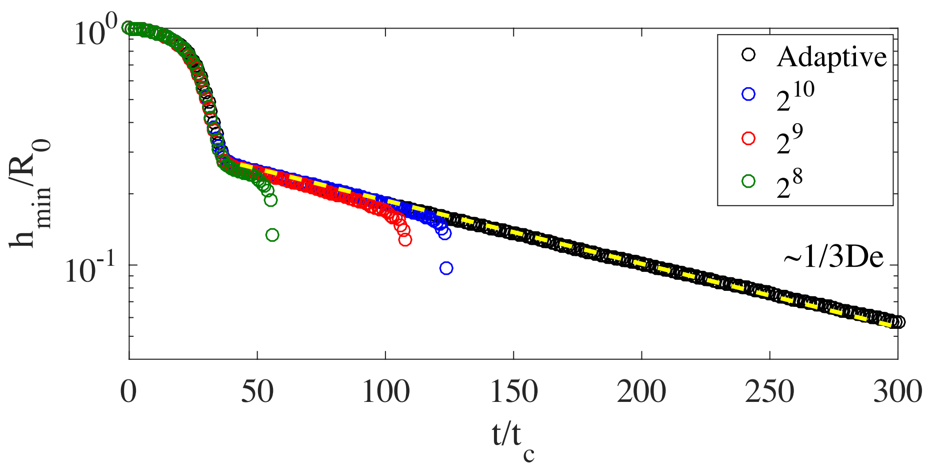

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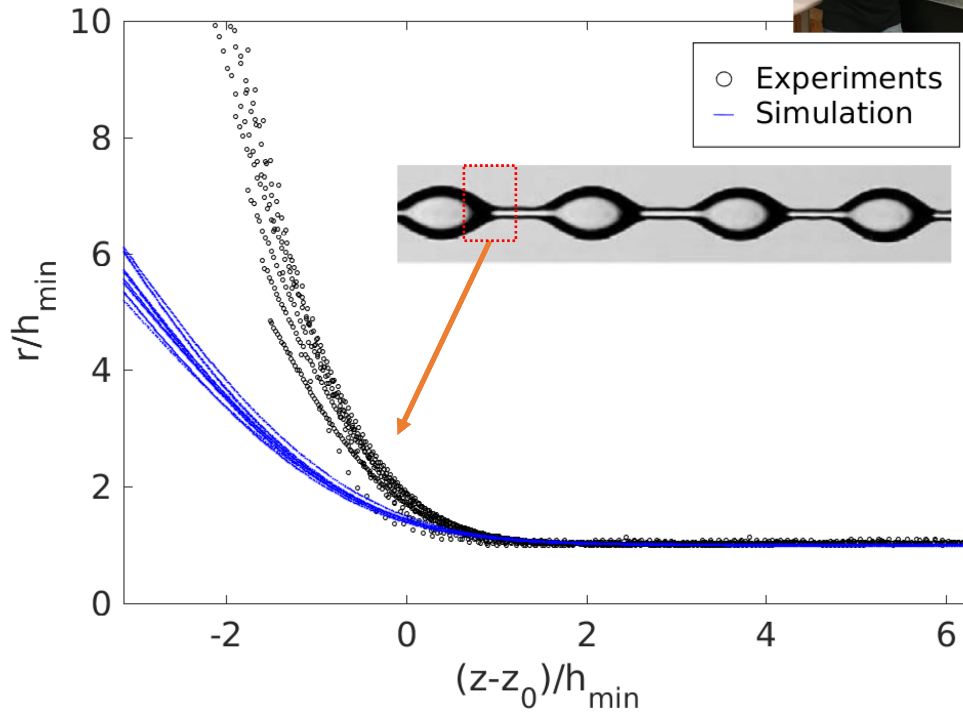
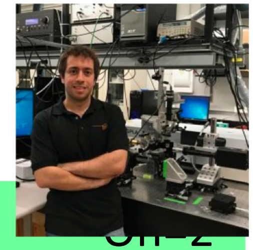


Both experimental and simulation profiles exhibit self-similarity. However, experimental profiles exhibit a larger curvature at the drop-thread connection

Moving forward: visco-elastic jetting



Two mini-stories involving similarity solutions

Visco-elastic filament thinning
E. Turkoz, J.M. Lopez-Herrera, J. Eggers, C.B. Arnold and L. Deike, Journal of Fluid Mechanics Rapids, 851, R2, 2018.

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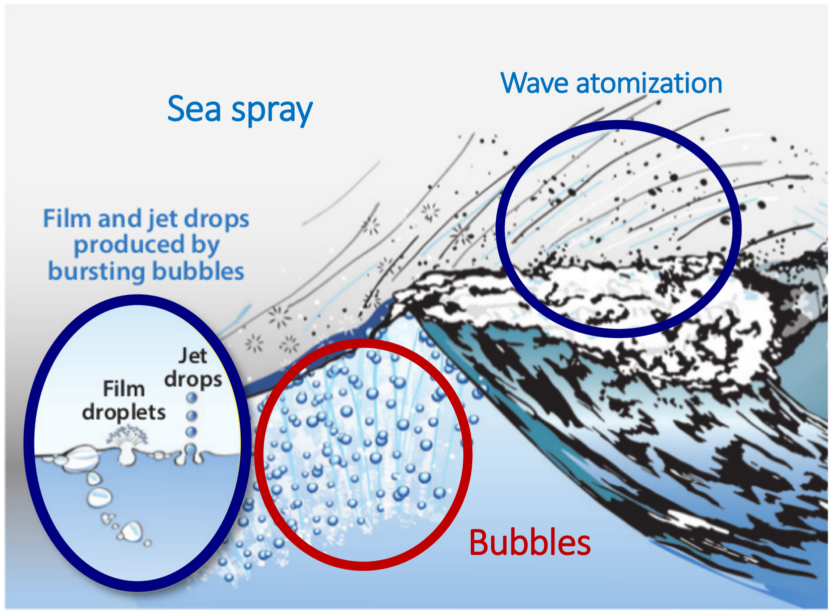
Context: Mass transfers at the ocean-atmosphere interface

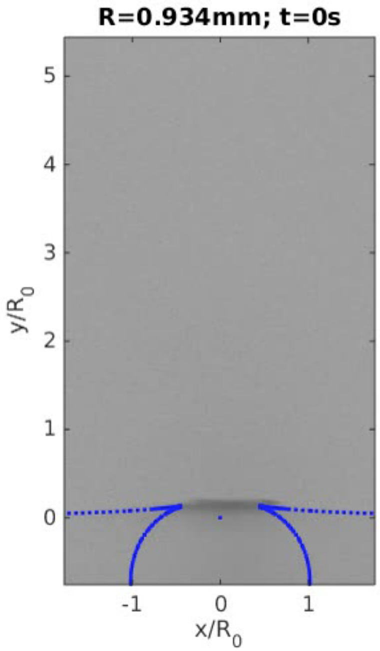


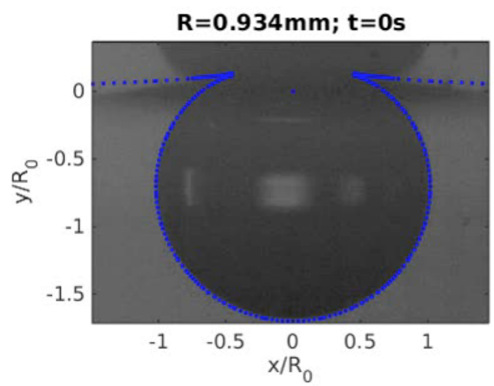
Adapted from Veron, 2015

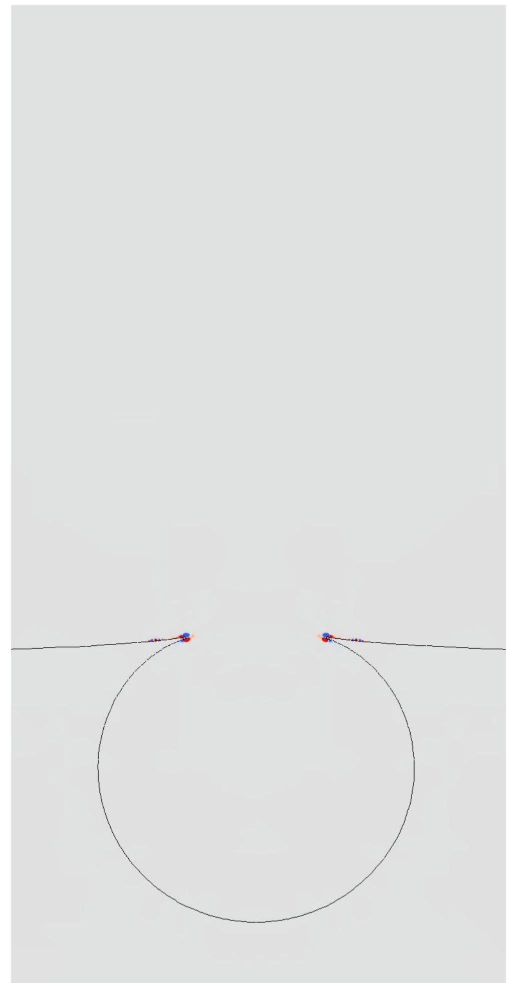
From water to air: Transfer of momentum, heat, moisture
Production of aerosols (sea salt, biological particles)
→climate impact (cloud nucleation & radiative balance)

From air to water: Air entrainment & gas transfer
→climate impact (carbon uptake)

Bubble bursting: jet dynamics and jet drops

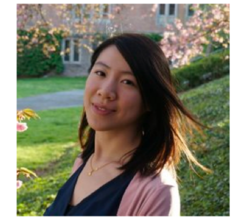






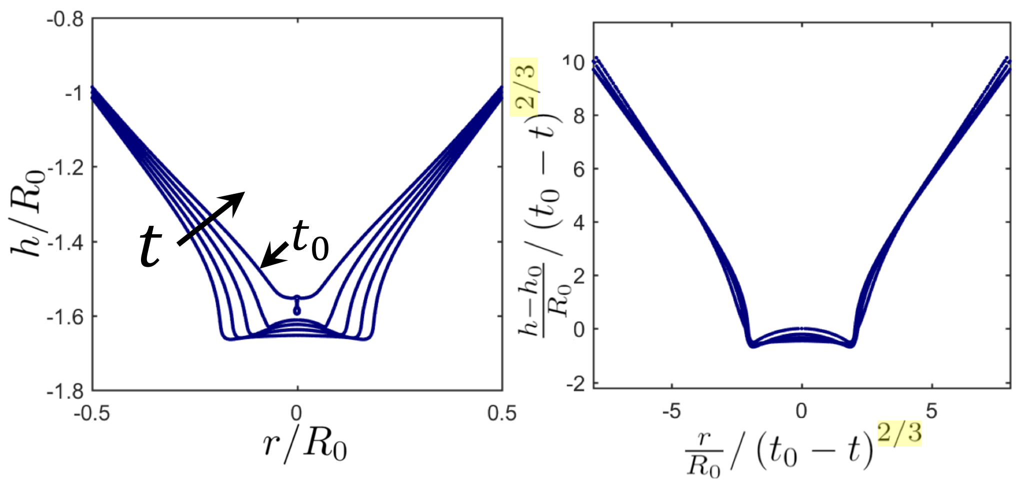
Deike et al 2018
Lai, Eggers and Deike, 2018

Bubble bursting: time evolution and similarity solutions



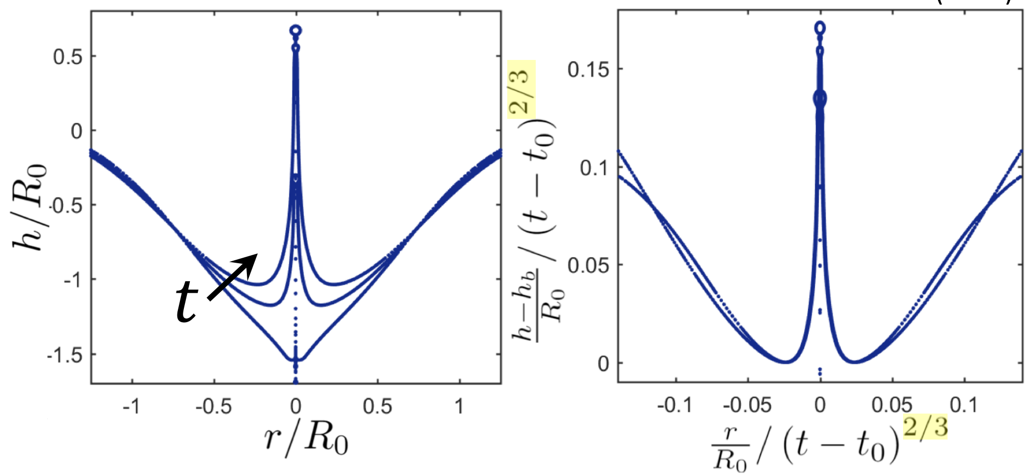
I. Cavity Collapse ($t < t_0$)

Duchemin (2002)
Ghabache et al. (2014)



II. Jet Ejection ($t > t_0$)

Brasz et al. (2018)



- Irrotational & Incompressible
- Inertia vs surface tension Zeff et. al. (2000)

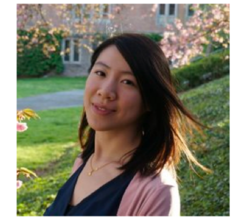
Universal profiles:

$$\frac{h(r,t)}{|t-t_0|^{2/3}} = f\left(\frac{r}{|t-t_0|^{2/3}}\right) \xrightarrow[r^*,h^*,t^*]{} \frac{h(r,t)/h^*}{|(t-t_0)/t^*|^{2/3}} = f\left(\frac{r/r^*}{|(t-t_0)/t^*|^{2/3}}\right)$$

Universal jet profiles

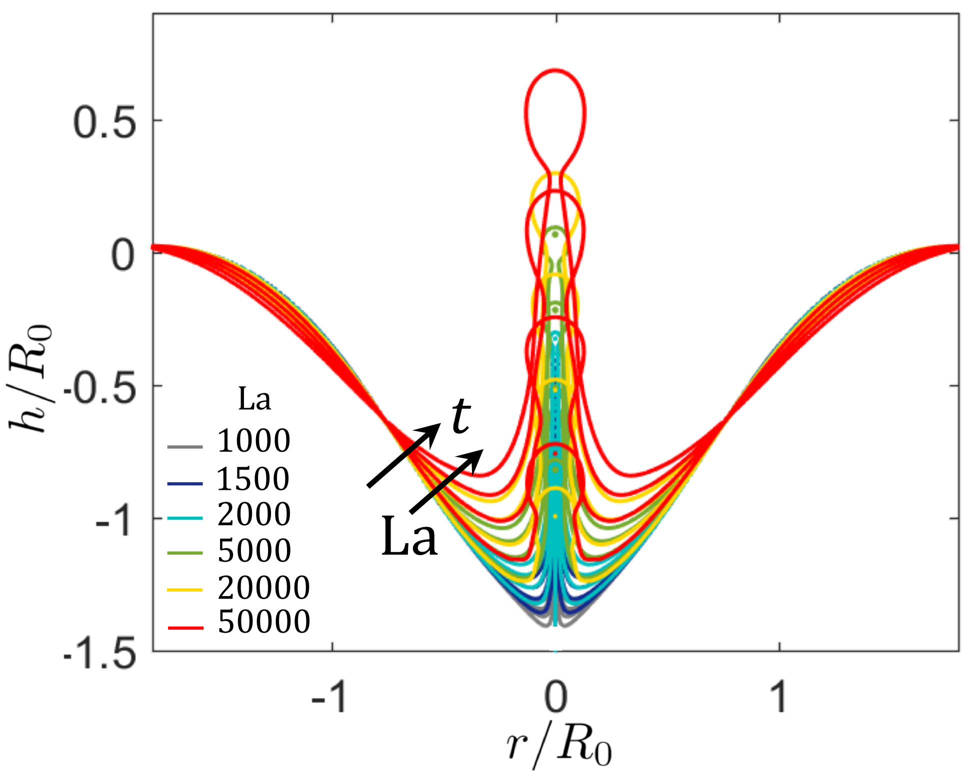
Lai, Eggers and Deike, PRL, 2018

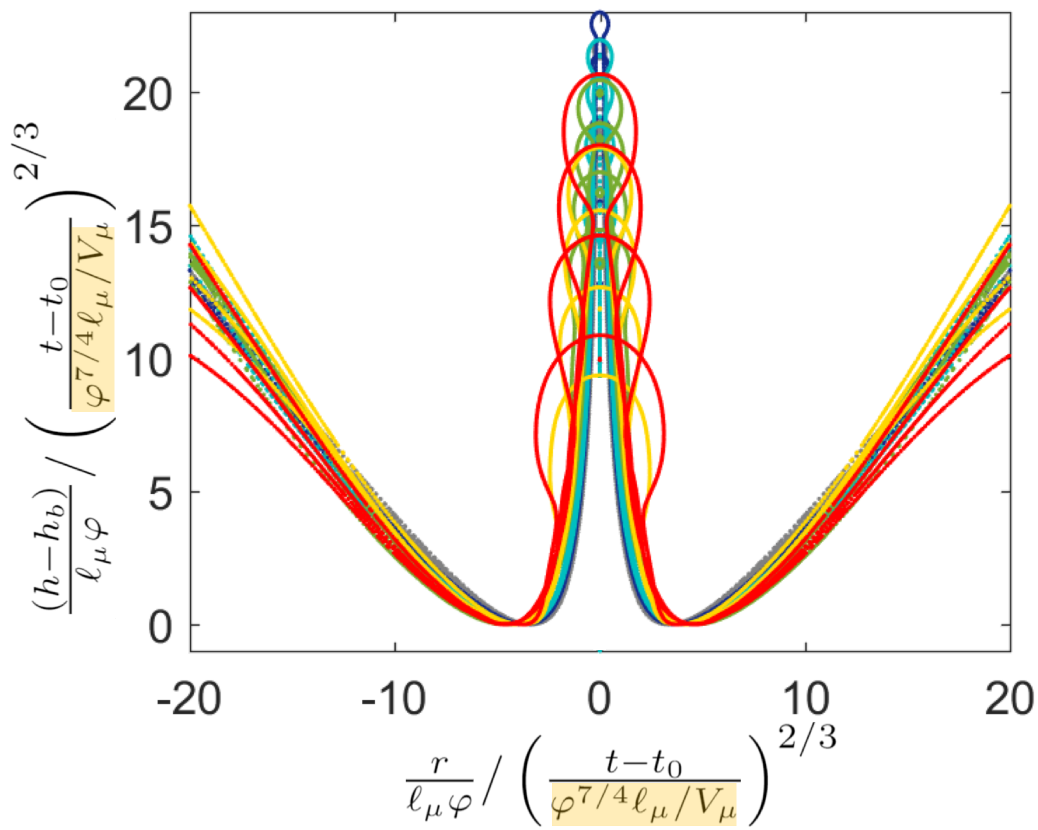
$$\frac{(h-h_b)/h^*}{|(t-t_0)/t^*|^{2/3}} = f\left(\frac{r/r^*}{|(t-t_0)/t^*|^{2/3}}\right)$$



$t^* = t_j \equiv \varphi^{7/4} l_\mu / V_\mu$ $\quad$ $h^* = r^* \equiv l_\mu \varphi$

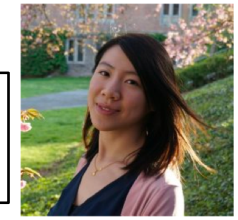
$\mathrm{La} = \rho\gamma R_0/\mu^2 \quad Oh = La^{-2}$





Universal cavity profiles

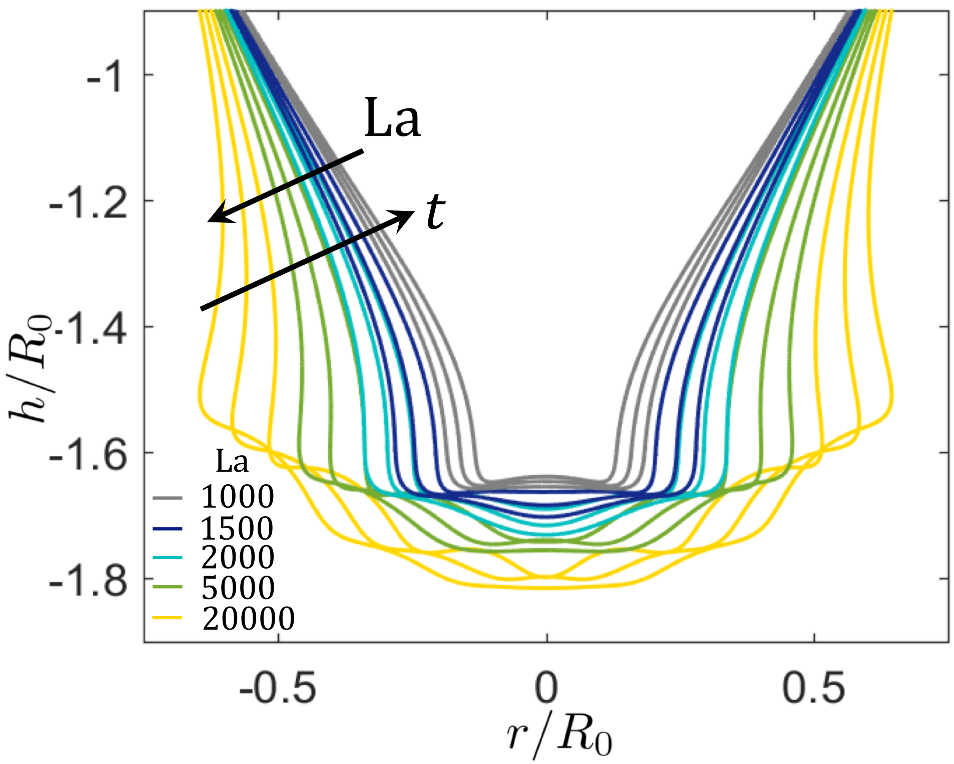
Lai, Eggers and Deike, PRL, 2018

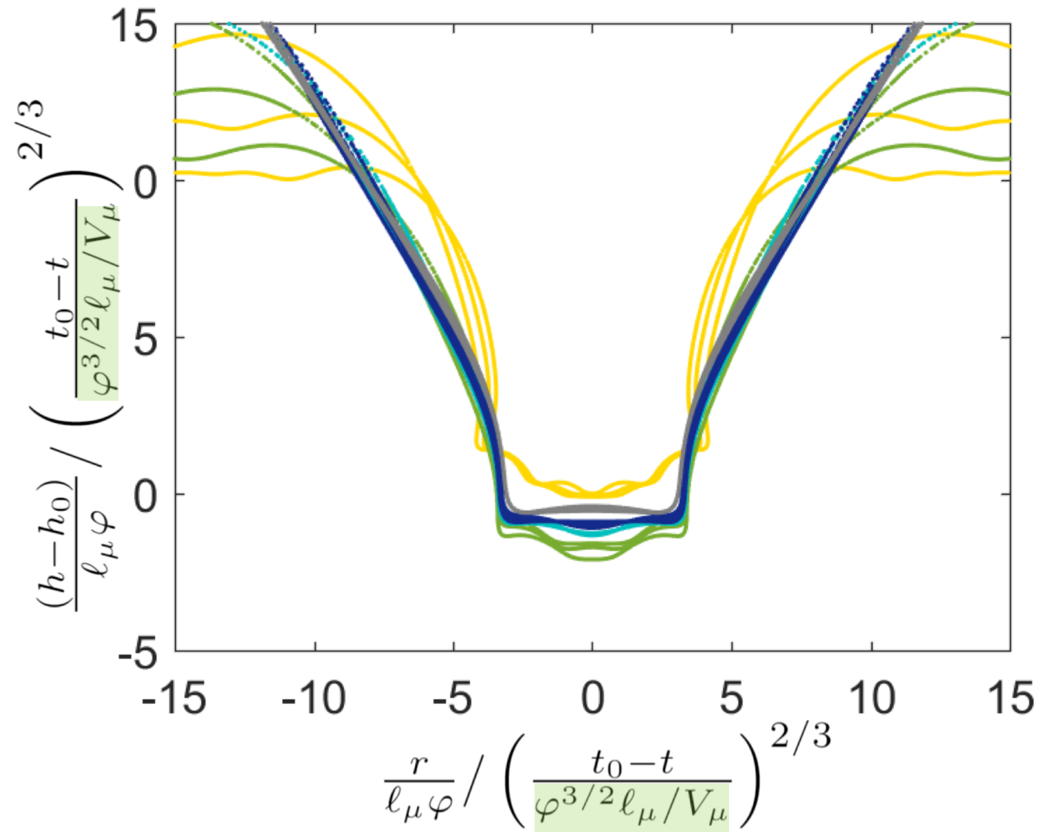


$$\frac{(h-h_0)/h^*}{|(t-t_0)/t^*|^{2/3}} = f\left(\frac{r/r^*}{|(t-t_0)/t^*|^{2/3}}\right)$$

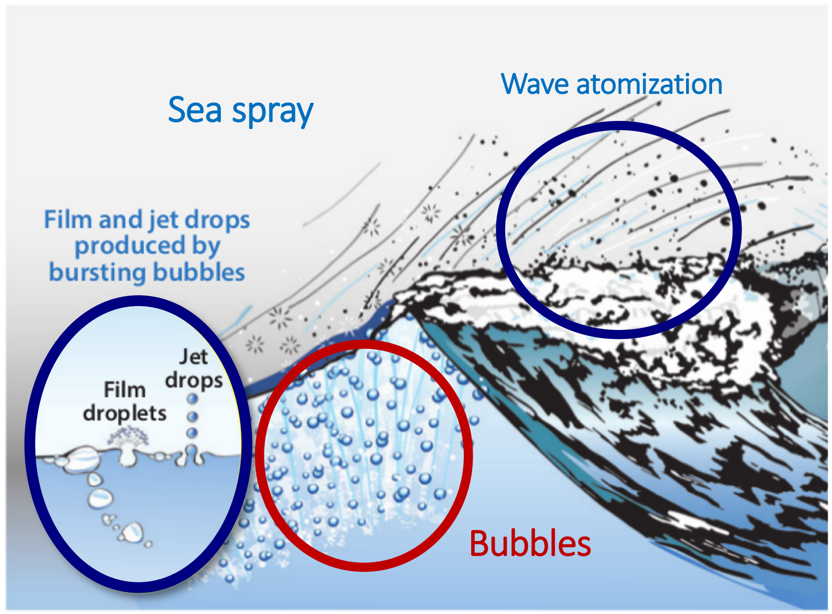
$\mathrm{La} = \rho\gamma R_0/\mu^2 \quad Oh = La^{-2}$

$t^* = t_c \equiv \varphi^{3/2} l_\mu / V_\mu \qquad h^* = r^* \equiv l_\mu \varphi$





And now bubble break-up in turbulence by Alienor Riviere



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