Taming singularities: yield-stress regularization in bubble-bursting

Capillary collapse of a bursting bubble is a canonical inertio-capillary singularity: the retracting rim launches a wave packet that focuses at the cavity base, driving a high-speed Worthington jet and, classically, droplets. Non-Newtonian physics rewrites this script. For example, yield stress and elasticity tame these waves and the jet and often suppress them [1]. Using high-fidelity simulations carried out with *MultiRheoFlow* (https://comphy-lab.org/MultiRheoFlow/) — a new open-source Basilisk C framework for interfacial flows with arbitrary rheology — we explore how viscoplasticity and its elastoviscoplastic extension regularizes the singular flow. Yield stress intercepts the collapsing wavepacket, arrests curvature blow-up, and suppresses Worthington jetting [2]. In contrast, elasticity relaxation can reopen a singular path, reinstating a solitary jet or droplet [3]. By tracking curvature histories, kinetic–plastic energy exchange, and stoppage times, we build a compact regime map that exposes the mechanical routes by which non-linear rheology regularizes free-surface singularities. The findings extend beyond bubbles, offering a template for predicting and controlling singular events in yield-stress and other complex fluids.

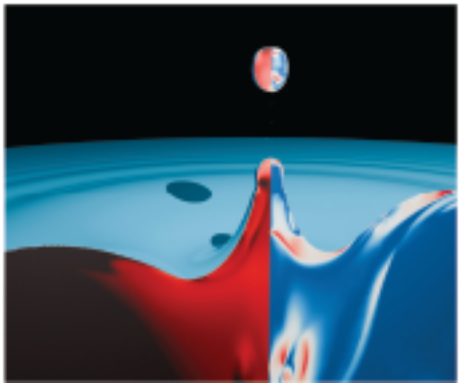

Fig. Worthington jet vs. elastoviscoplastic medium, adapted from [1]

[1] A. G. Balasubramanian, V. Sanjay, M. Jalaal, R. Vinuesa, and O. Tammisola, "Bursting bubble in an elasto-viscoplastic medium," *J. Fluid Mech.*, vol. 1001, p. A9, Dec. 2024, doi: 10.1017/jfm.2024.1073.

[2] V. Sanjay, D. Lohse, and M. Jalaal, "Bursting bubble in a viscoplastic medium," *J. Fluid Mech.*, vol. 922, p. A2, 2021.

[3] A. K. Dixit, A. Oratis, K. Zinelis, D. Lohse, and V. Sanjay, "Viscoelastic Worthington jets and droplets produced by bursting bubbles," *J. Fluid Mech.*, vol. 1010, p. A2, May 2025, doi: 10.1017/jfm.2025.237.