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Dependence of self-similar Rayleigh-Taylor growth on initial conditions

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In the self-similar regime, Rayleigh-Taylor bubbles are found to grow as $h_b \sim \alpha_b Agt^2 \sim \lambda_b / \beta_b$ where $h_b \equiv$ amplitude, $\lambda_b \equiv$ dominant wavelength, $A \equiv$ Atwood number, $g \equiv$ acceleration, and $t \equiv$ time. The self-similarity ratio is found to be $\beta_b \sim 1/4\text{-}1/2$ in experiments and numerical simulations. However, the acceleration constant varies from $\alpha_b \sim 0.04\text{-}0.08$ in experiments and $\alpha_b \sim 0.02\text{-}0.08$ in 3D simulations. This variability may be due to numerics or it may signal a dependence on additional attributes like the initial perturbations. This can occur because the self-similar growth can proceed in two limiting ways:

nonlinear coupling of saturated modes (merger)

amplification and saturation of ambient modes (competition)

The mode-coupling limit has been widely investigated with 3D simulations by imposing only short wavelength modes, such as by Youngs [1994] and the Alpha-Group [1]. Here, we investigate both processes by considering initial perturbations with (1) an annular spectrum and (2) a broadband spectrum $\propto \lambda^2$ as suggested by Inogamov [1978]. We develop a model [2] that combines the essential results of Birkhoff [1955] and Haan [1989] and compare the results with LEM experiments [2000] and high-resolution 3D simulations [3]. We find that, with the annular spectrum, α_b and β_b are insensitive to the initial amplitude whereas, with the broadband perturbations, α_b and β_b increase weakly with the initial rms amplitude/wavelength.

References

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