

# Multiscale Simulation of Thin Films in Multiphase Flow



Ananthan M

Multiphase Flow Simulations Lab, Dept. of Mechanical Engineering  
Indian Institute of Science, Bangalore

A common scenario in multi-phase flow simulation is the formation of thin fluid films in between colliding fluid masses or when a fluid drop interacts with a surface. These films can be very thin  $O(100\text{nm})$  and cannot be fully resolved in DNS of multiphase flows even with Adaptive Mesh Refinement. This means final stages of film drainage happens in a sub-grid scale and results in numerical coalescence which is nonphysical. Here we develop a Multiscale approach to compute the flow of the film by coupling a Thin Film model to our conventional N-S solver using which we can capture the evolution of thin film and finally rupture and dewetting.

Continuity Equation:  $\nabla \cdot \vec{V} = 0$

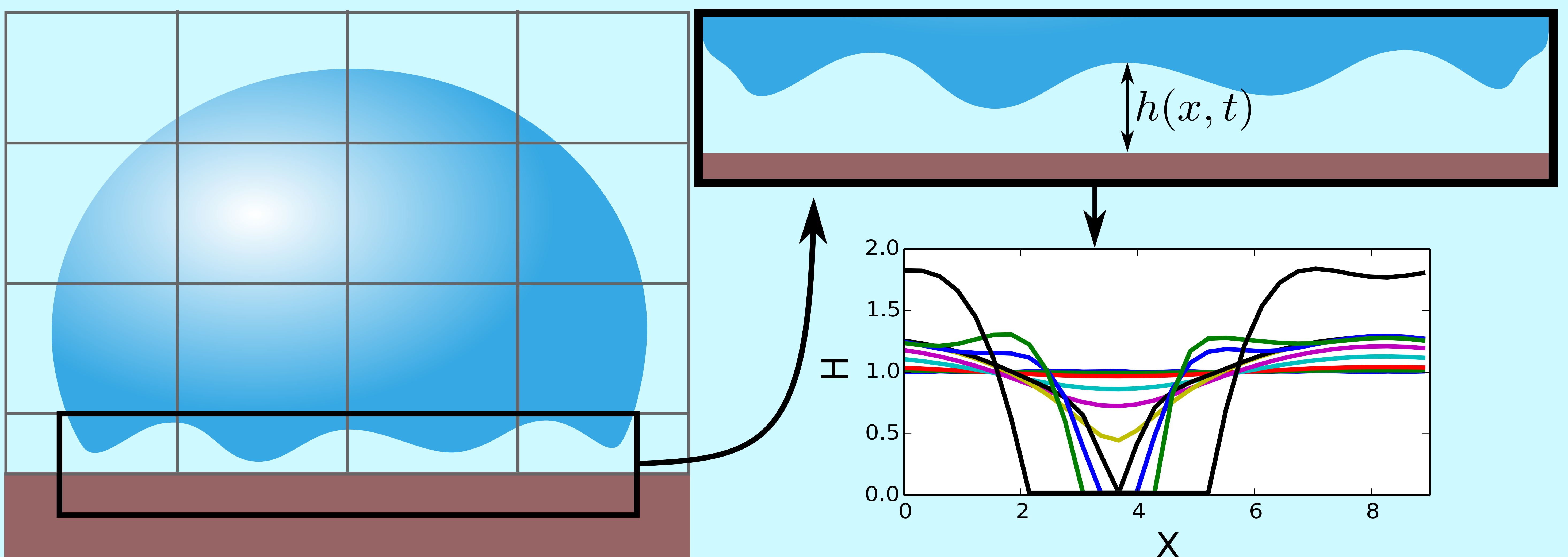
Navier-Stokes Equation with Surface Tension and van-der Waals forces

$$\rho \frac{D\vec{V}}{Dt} = \rho \left[ \frac{\partial \vec{V}}{\partial t} + (\vec{V} \cdot \nabla) \vec{V} \right] = -\nabla P + \nabla \Pi + \mu \nabla^2 \vec{V}$$

where  $\Pi = -\left(\frac{A}{6\pi h^3}\right) + \left(\frac{8B}{h^9}\right)$   $P = P_b - \sigma \frac{\partial^2 h}{\partial x^2}$

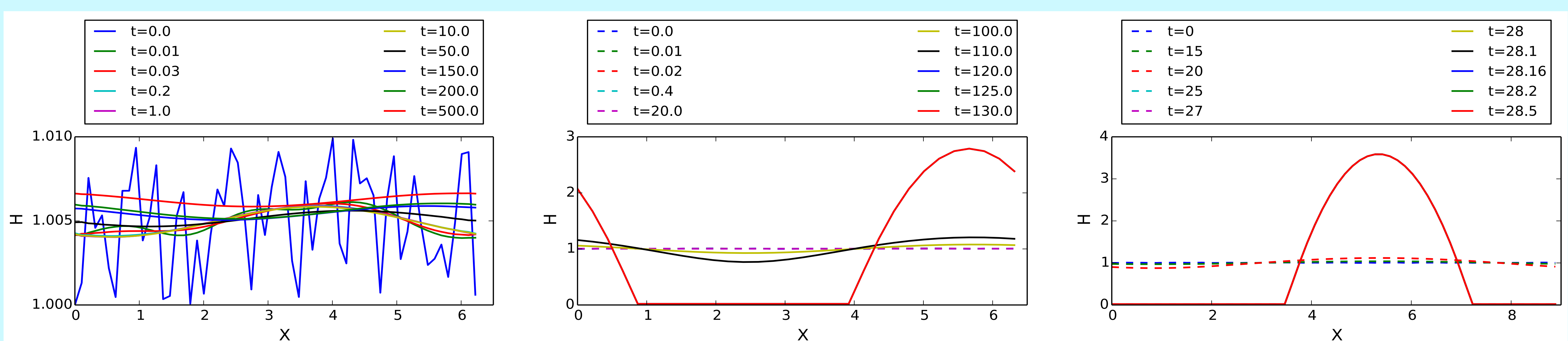
Thin Film Equation

$$\frac{\partial h}{\partial t} + \frac{1}{3\mu} \frac{\partial}{\partial x} \left[ \left( \sigma \frac{\partial^3 h}{\partial x^3} + \frac{\partial \Pi}{\partial h} \frac{\partial h}{\partial x} \right) h^3 \right] = 0$$



Wide range of length scales visible as the evolution of the thin film progresses culminating in the formation of a film in the sub-grid scale, where we couple the conventional N-S solver to our Thin Film model and evolution of the film, rupture and dewetting can be seen.

**Evolution of Thin Film Instability in Non-denationalized form of Thin Film equation with  $H = 1$  and a small amplitude perturbation of 0.01 in various domains**



Subcritical domain,  $L = 1.98\pi$ .  
A uniform stable film eventually forms.

Slightly supercritical domain,  $L = 2.01\pi$ . Eventually hole formation happens and rapidly it grows.

Fastest growing linear mode wavelength i.e.  $L = 2\sqrt{2}\pi$ . Rupture and hole formation is fastest in this length scale.