Analysis of thin films - rupture & dewetting

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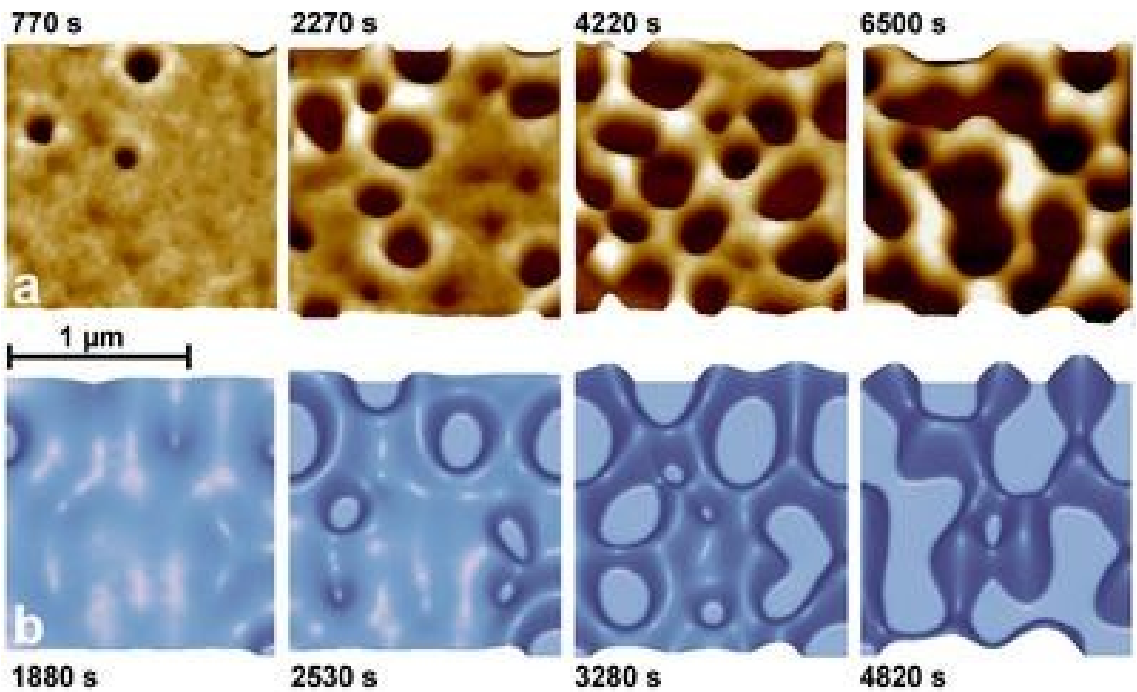
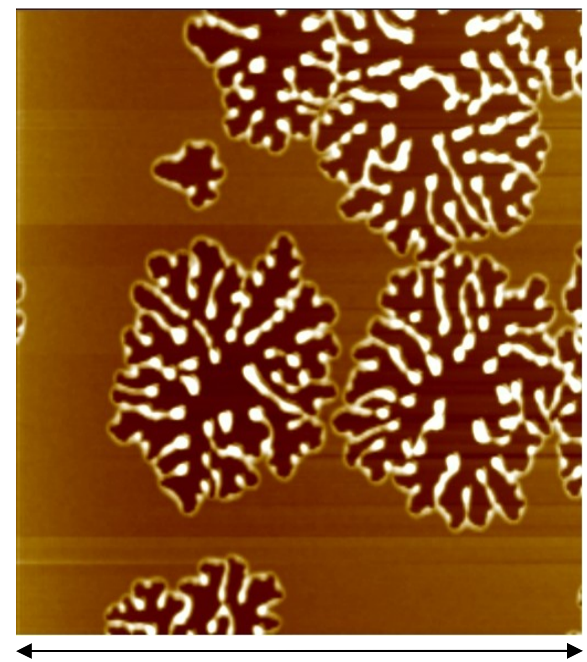
Motivation





20 μ with 5 nm thickness

Picture by J. Becker et al. (left) and Brockhouse Institute for Materials Research (right)

Applications: *adhesion, lubrication, painting, printing, coating*

Research goals

- Find a proper model approximation
- Effects of boundary conditions
- Understand rupture or dewetting pattern

Modelling

- Dissipation of momentum
- Incompressibility of the fluid
- Boundary condition

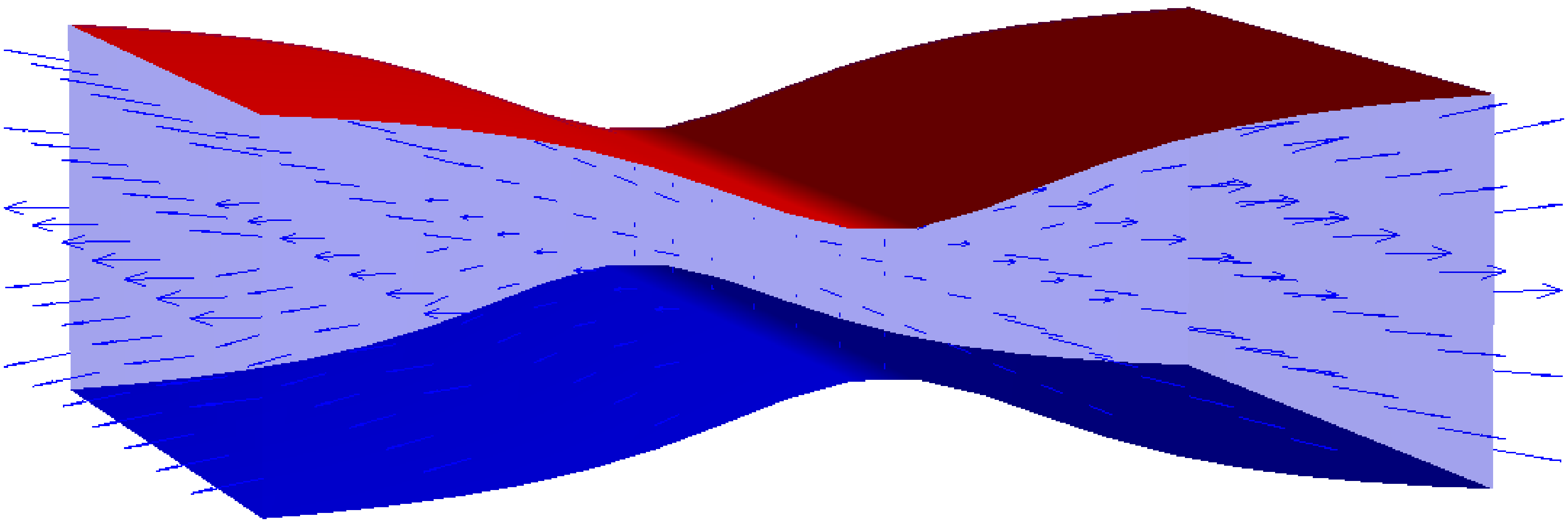
Driving forces

- Intermolecular forces
- Surface tension

Model approaches

- Lattice Boltzmann
- Molecular dynamics
- Continuum mechanics (Navier-Stokes)
- Lubrication models

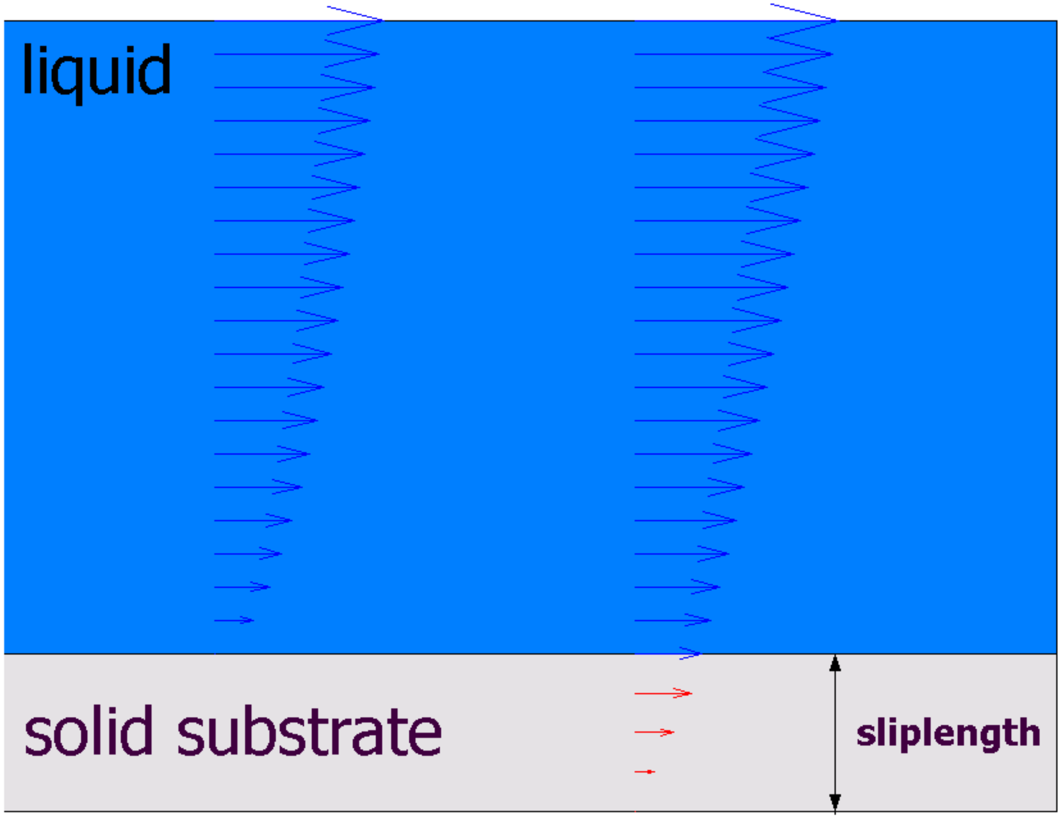
Geometry of a rupture



velocity u(x,t) and shape h(x,t)

... qualitative

Boundary conditions



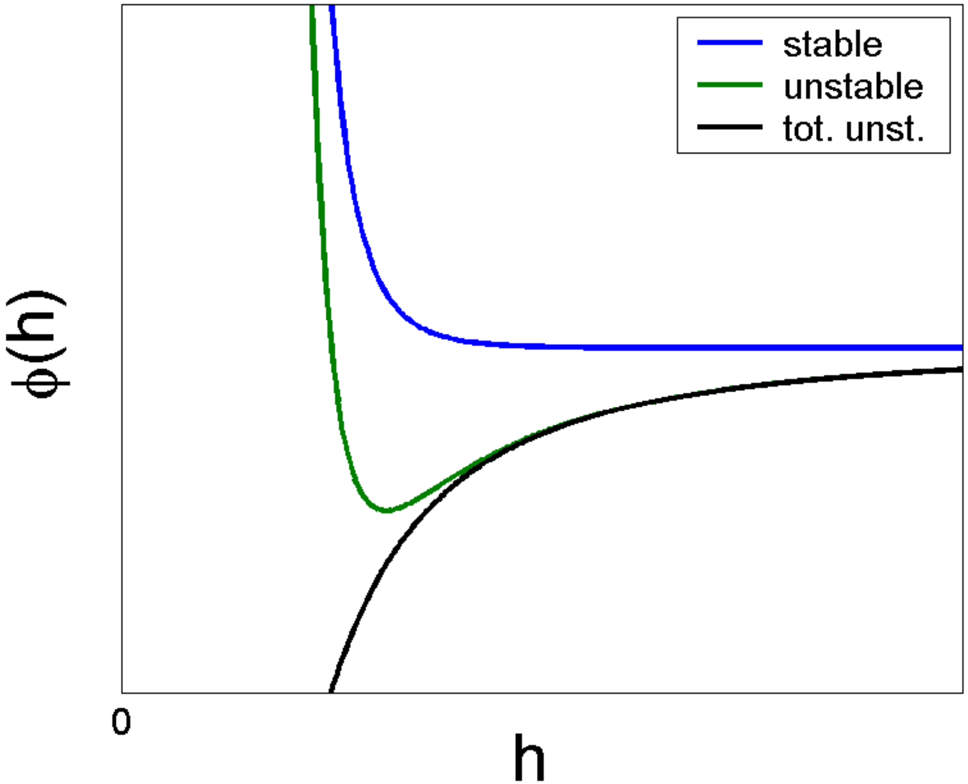
Basic assumptions

- Small scales (height, vertical component of velocity)
- Surface tension and intermolecular forces (van-der-Waals forces)
- Symmetry boundary conditions for rupture of a thin liquid sheet or
- Slip boundary conditions for dewetting of the thin film on a substrate

Model equations

$$u_t + u\,u_x = 3\mathrm{S}h_{xxx} + \tfrac{4}{h}(hu_x)_x - \phi(h)_x$$

$$h_t + (hu)_x = 0$$



Mathematical techniques

- Stability analysis predicts the occurance of a rupture/ instability for some wavelength
- Rupture profile shows self-similar behavior
- Supported by non-linear (numerical) investigation

Stability

$$h(x,t)=\frac{1}{2}+\delta h \exp(ikx+\lambda t)$$

↓

$$u_t+u\,u_x=3\mathrm{S}h_{xxx}+\frac{4}{h}(hu_x)_x-2\mathrm{A}\left(h^{-3}\right)_x$$

$$h_t+(hu)_x=0$$

↑

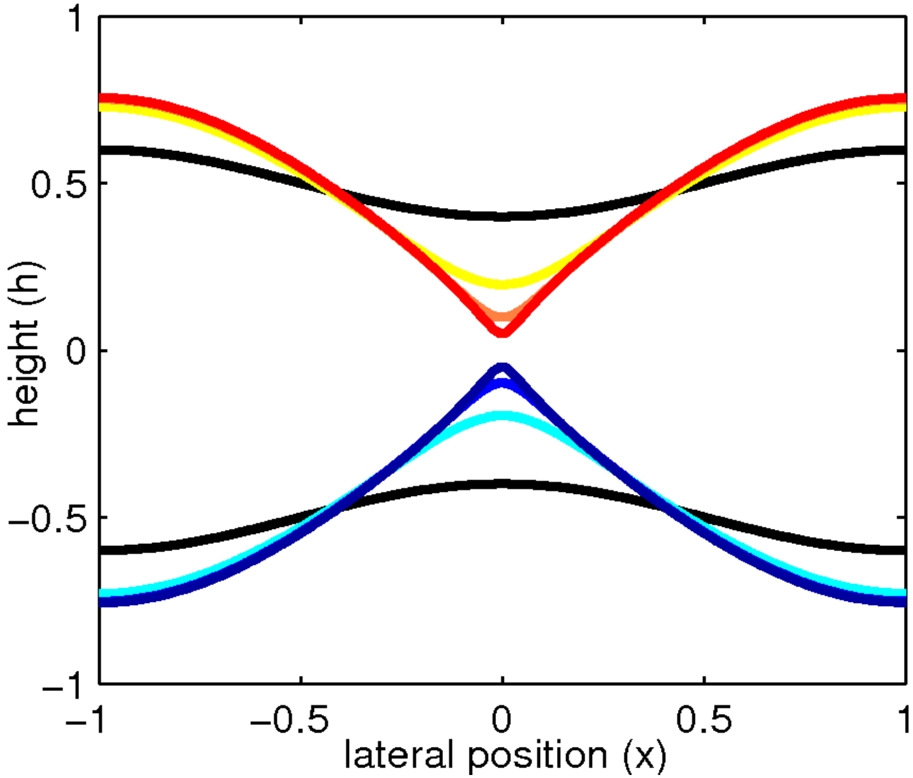
$$u(x,t)=0+\delta u \exp(ikx+\lambda t)$$

→

$$k_{cr}<\left(\frac{2\mathrm{A}}{S}\right)^{1/2}$$

admits positive λ

Results on rupture profile



... quantitative result from numerical computation

... suggests self-similarity

$$h(x,t)=\tau^{\alpha} H(\eta)$$

$$u(x,t)=\tau^{\gamma} U(\eta)$$

$$\eta = x\,\tau^{\beta}$$

$$\tau = (\hat{t}-t)$$

End

Thank you for your attention!