

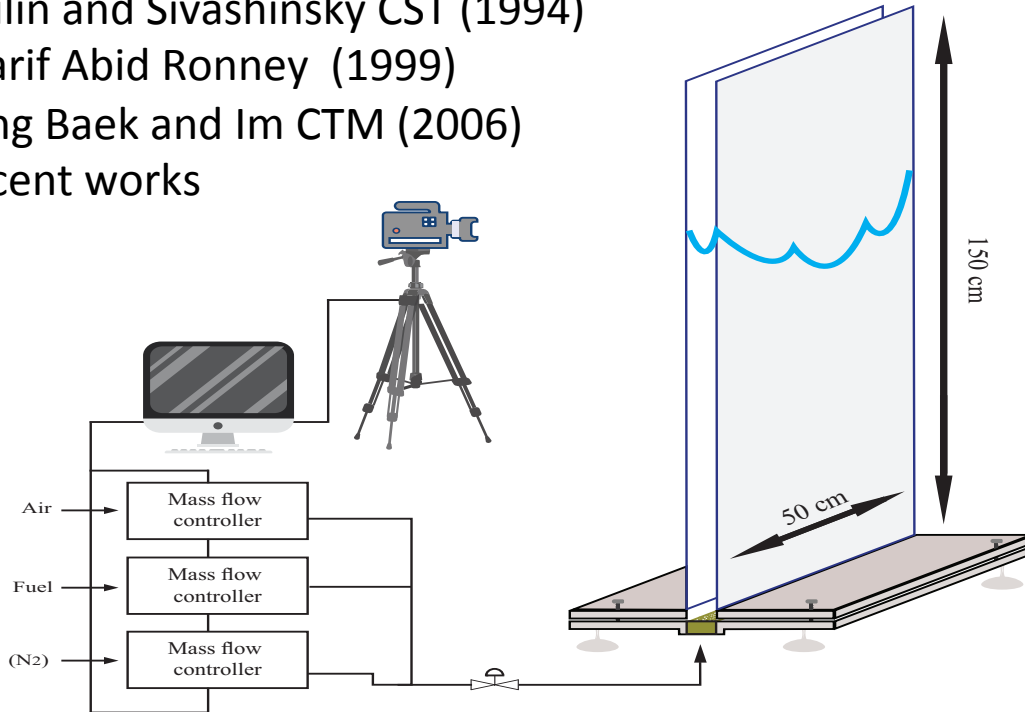
Non linear dynamics of premixed flames in a Hele-Shaw burner

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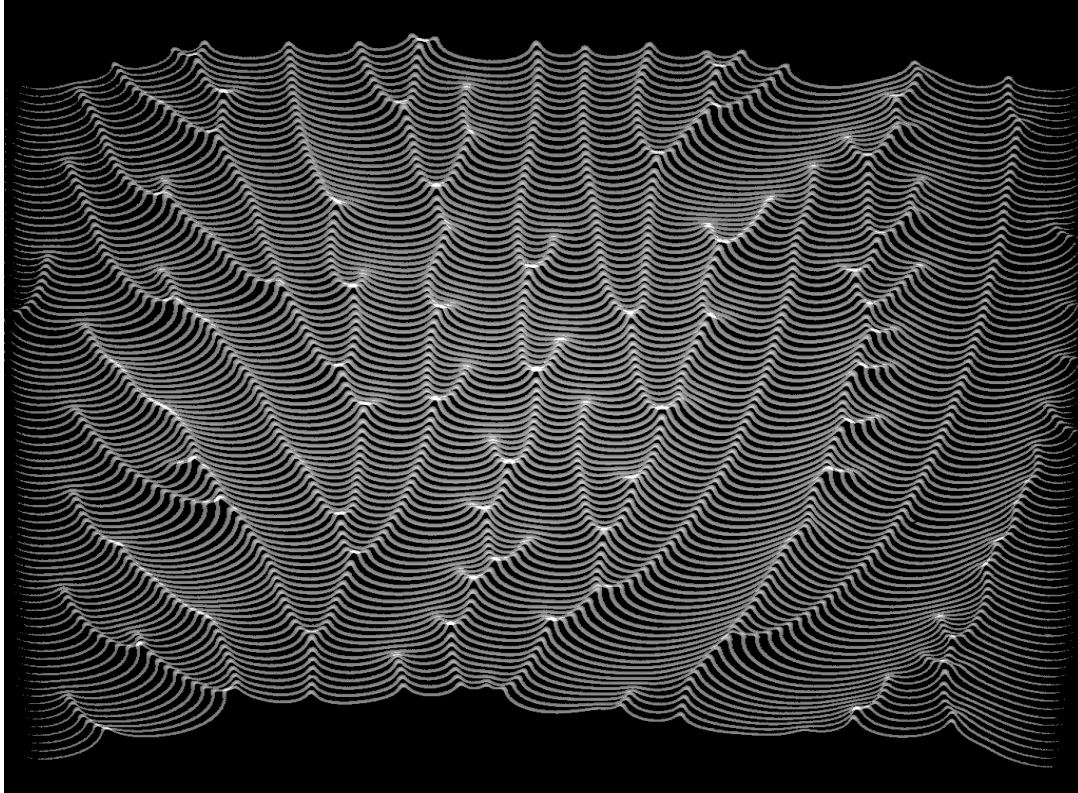
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Premixed flame instabilities in a Hele-Shaw burner (thickness 4.7 mm)

- Joulin and Sivashinsky CST (1994)
- Sharif Abid Ronney (1999)
- Kang Baek and Im CTM (2006)
- Recent works



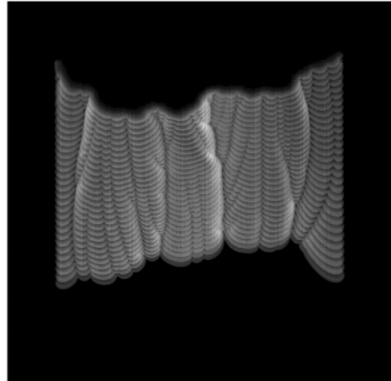
Flame propagation in a Hele-Shaw cell



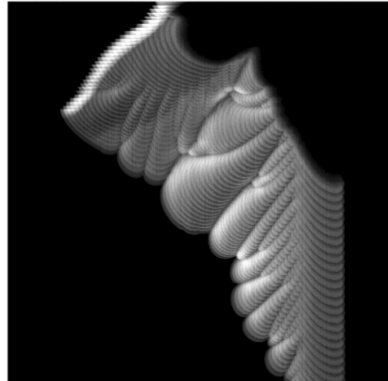
Flame propagation (methane $\phi=0.88$)

- Central ignition: small slopes
- Lateral ignition: large slopes
- Same properties in 3D: Almarcha Denet Quinard

a)



b)



Sivashinsky equation

- Small expansion development, several orders
- Sivashinsky 77, Sivashinsky Clavin 87, Kazakov 2005
Joulin Cambray 92
- Small slopes
- Non dimensional form: one parameter, inverse of the number of unstable modes

$$\sigma = 4 \frac{\sigma_M}{k_c} \left(|k| - \frac{k^2}{k_c} \right)$$

$$\phi_t + \frac{u_A}{2} \phi_x^2 = \frac{4\sigma_M}{k_c} \left(\frac{\phi_{xx}}{k_c} + I(\phi, x) \right)$$

$$\Phi_\tau + \frac{1}{2} \Phi_X^2 = \nu \Phi_{XX} + I(\Phi, X)$$

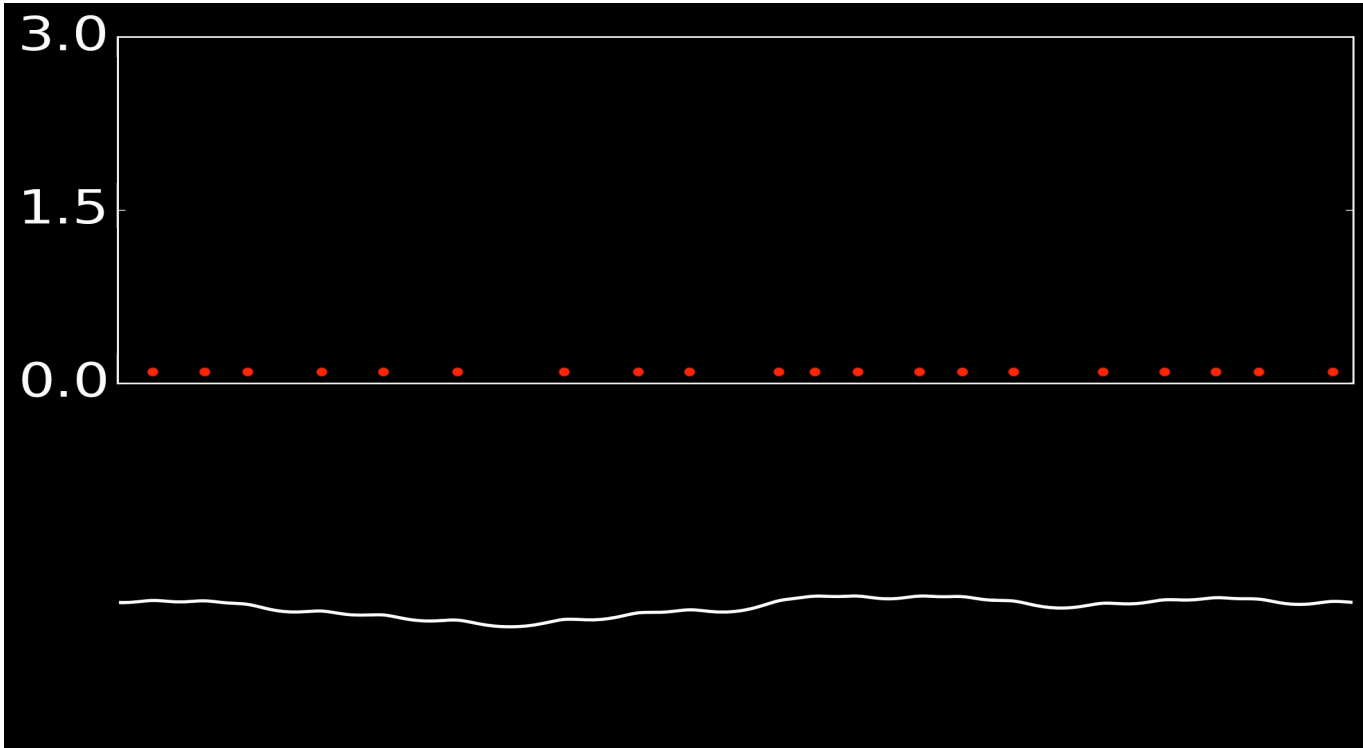
Sivashinsky equation : pole solutions

- Poles in complex conjugate pairs
- Differential equations for the position of poles in the complex plane

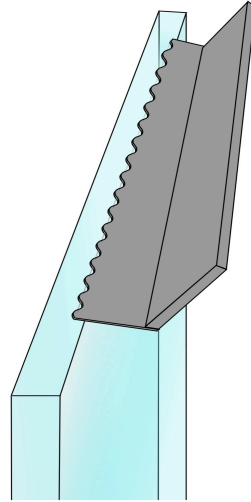
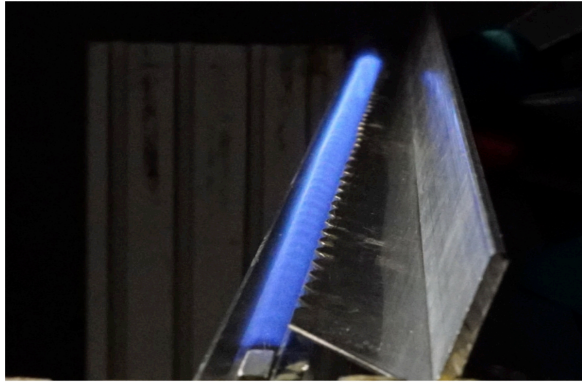
$$\phi(x, t) = -\frac{8\sigma_M}{u_A k_c^2} \sum_{n=1}^{2N} \ln \left(\sin \left(\frac{\pi (x - z_n(t))}{\Lambda} \right) \right)$$

$$\dot{z}_n = \frac{4\sigma_M}{k_c} \left[\frac{2\pi}{\Lambda k_c} \sum_{p \neq n} \cot \left(\frac{\pi}{\Lambda} (z_p - z_n) \right) - i \operatorname{sign}(\operatorname{Im}(z_n)) \right]$$

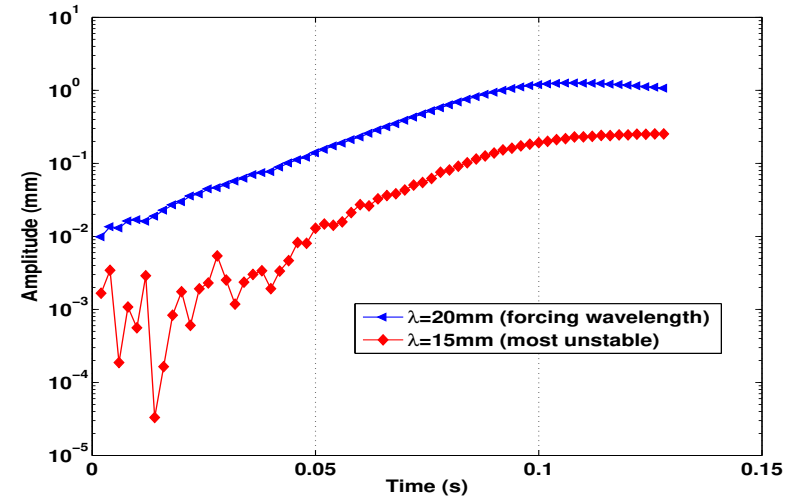
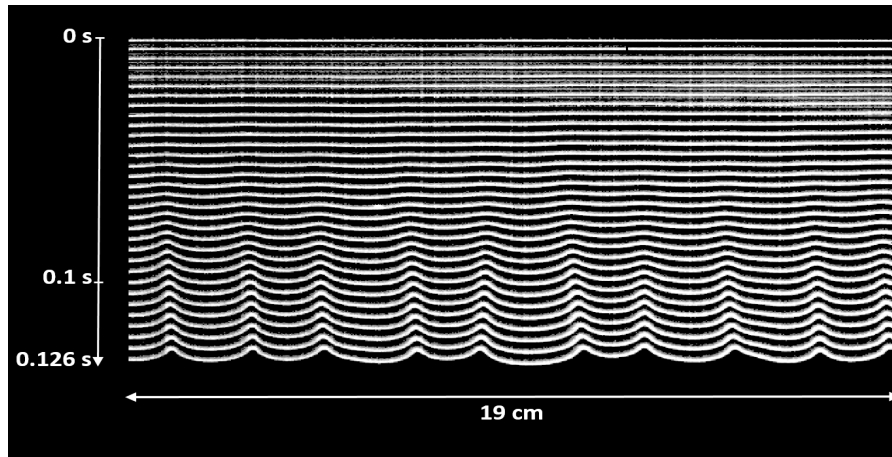
Pole dynamics



2D Bunsen flame at the top of the cell + forcing plate

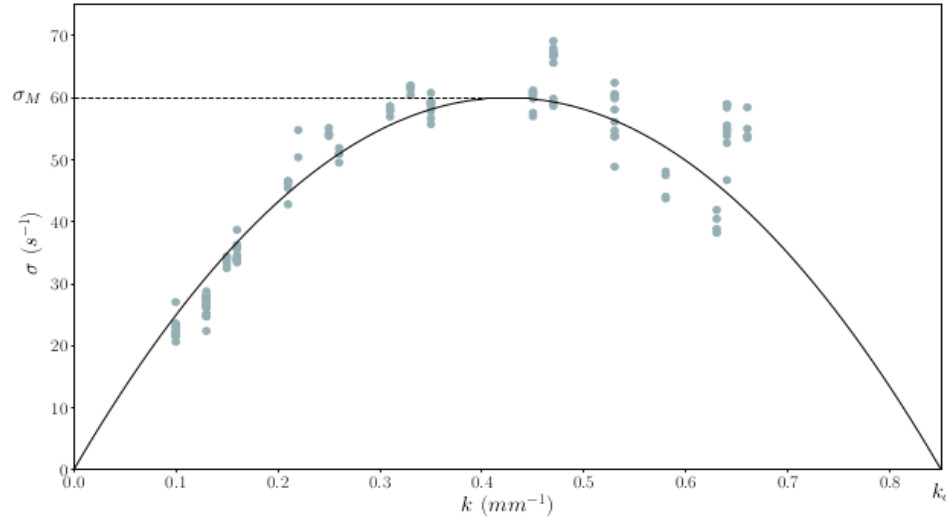


Amplitude vs time: growth rate measurement



Dispersion relation: propane $\phi=0.8$

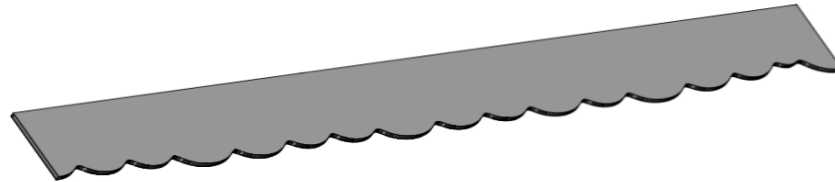
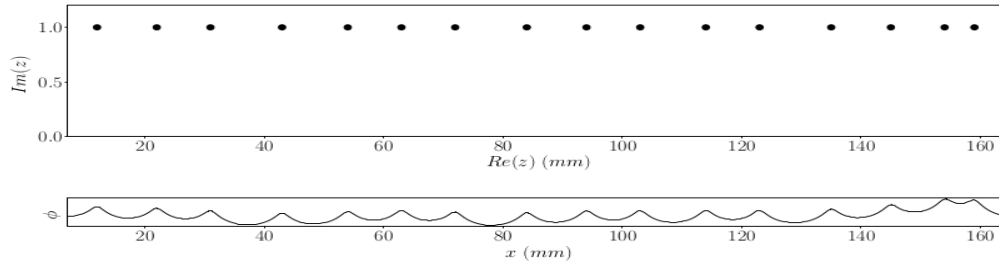
parameters σ_M k_c



$$\sigma = 4 \frac{\sigma_M}{k_c} \left(|k| - \frac{k^2}{k_c} \right)$$

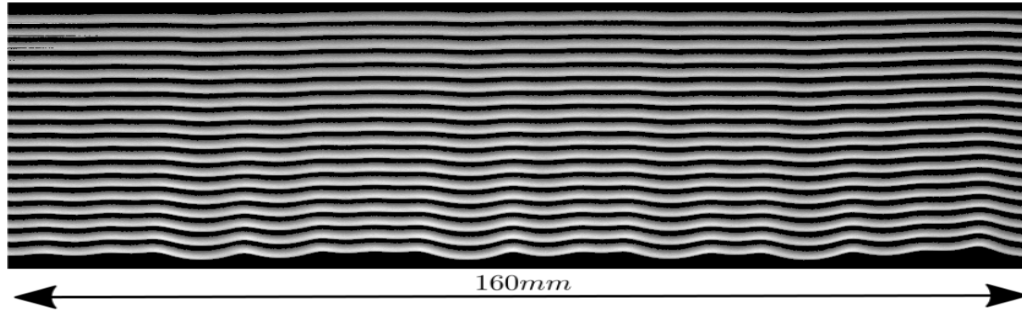
Printing of perturbations on the flame

- Laser cutting : pole solution for the shape of the forcing plate

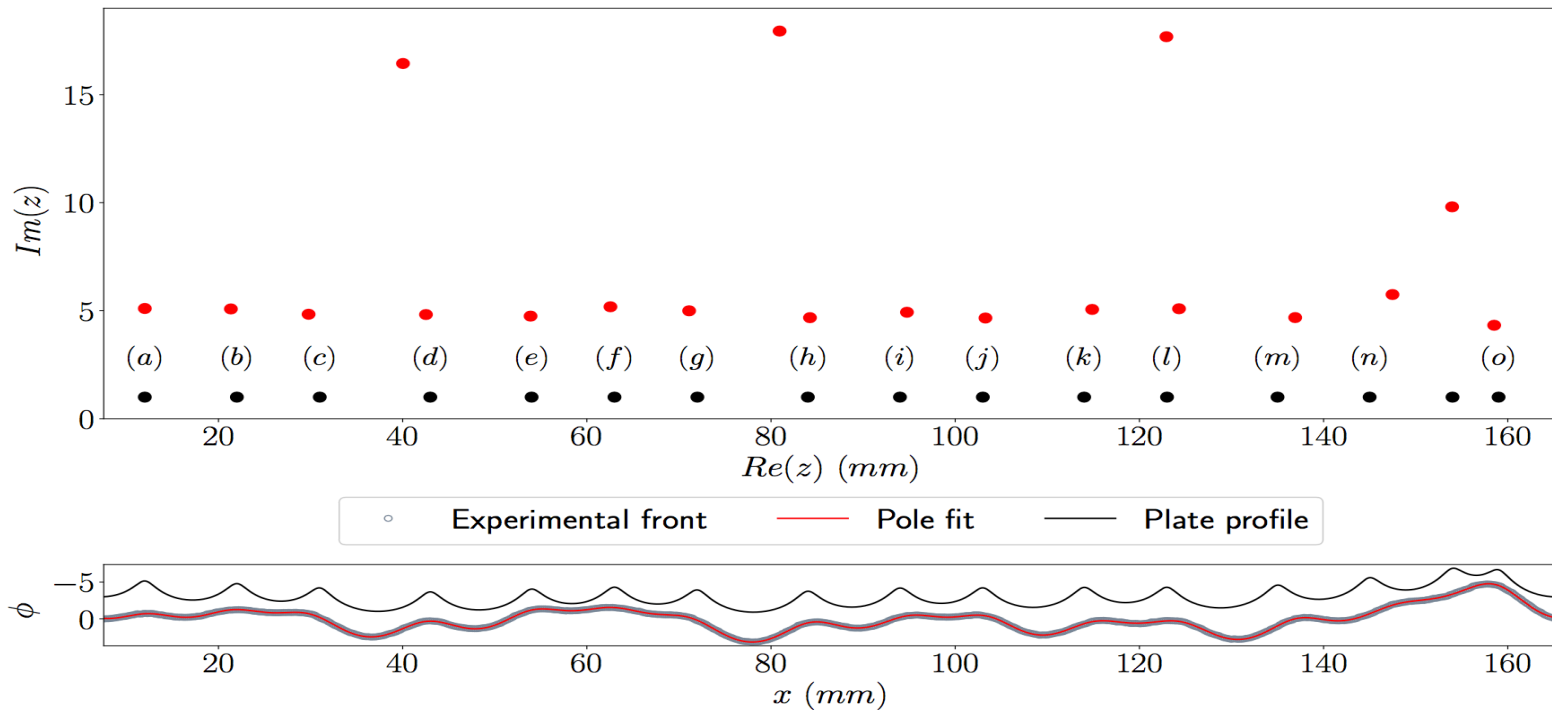


Forcing an initial condition

- Crests correspond to the forcing plate



Forcing an initial condition

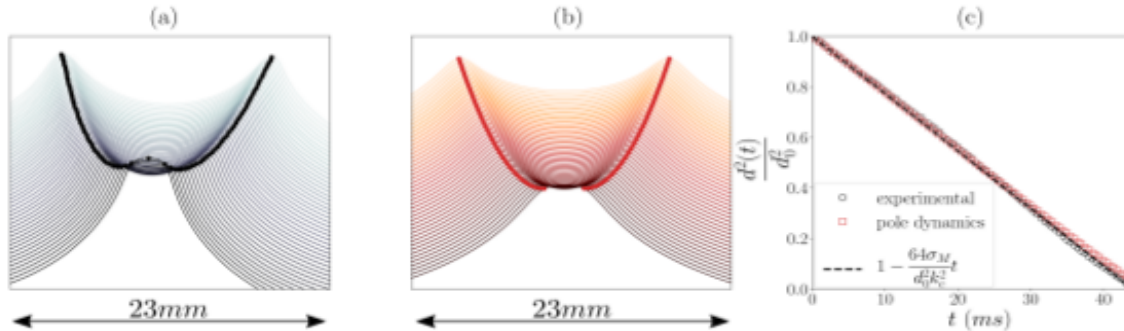


d2 law

- d distance between close cusps

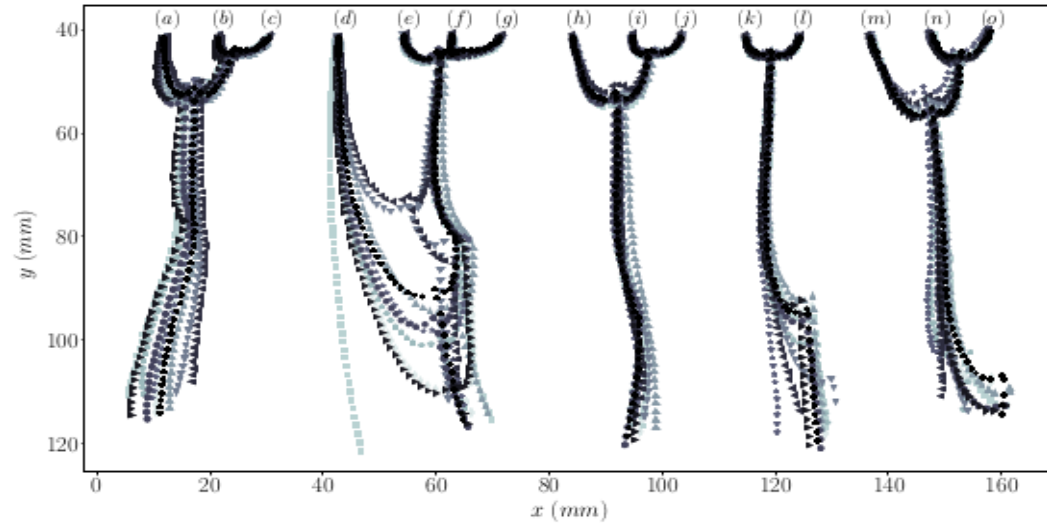
$$d^2(t) = d_0^2 - \frac{64\sigma_M}{k_c^2}t$$

Propane-air flame $\phi=0.8$ Pole dynamics



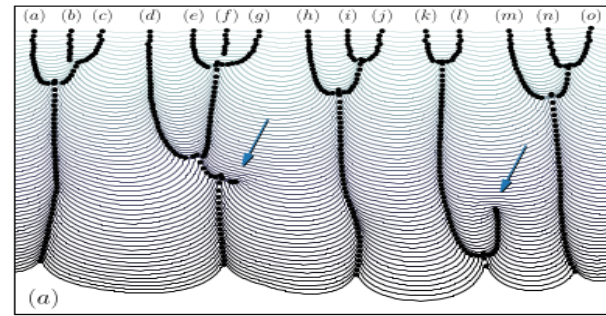
Repeatability

- Crests evolution, several experiments

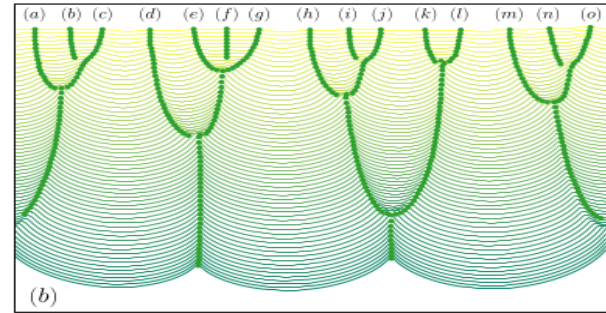


Comparison with the Sivashinsky equation

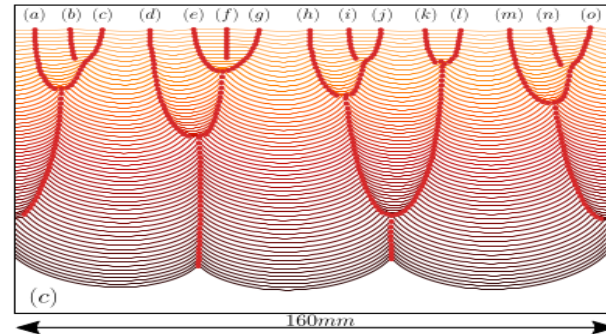
Propane-air flame $\phi=0.8$



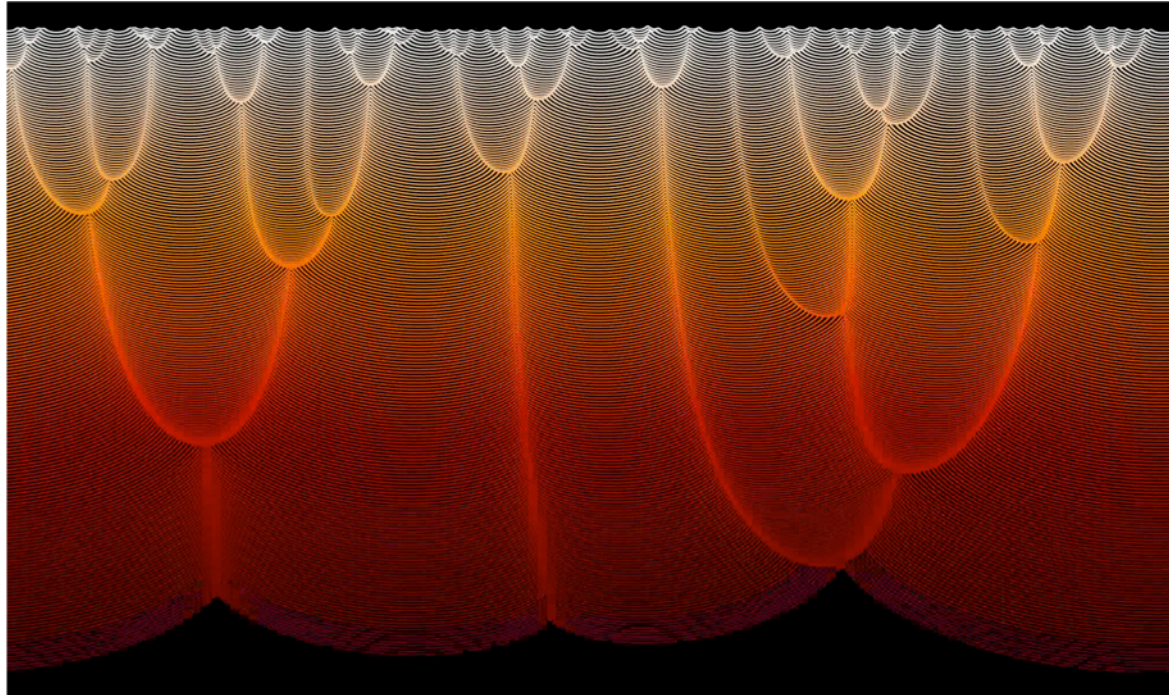
Sivashinsky equation



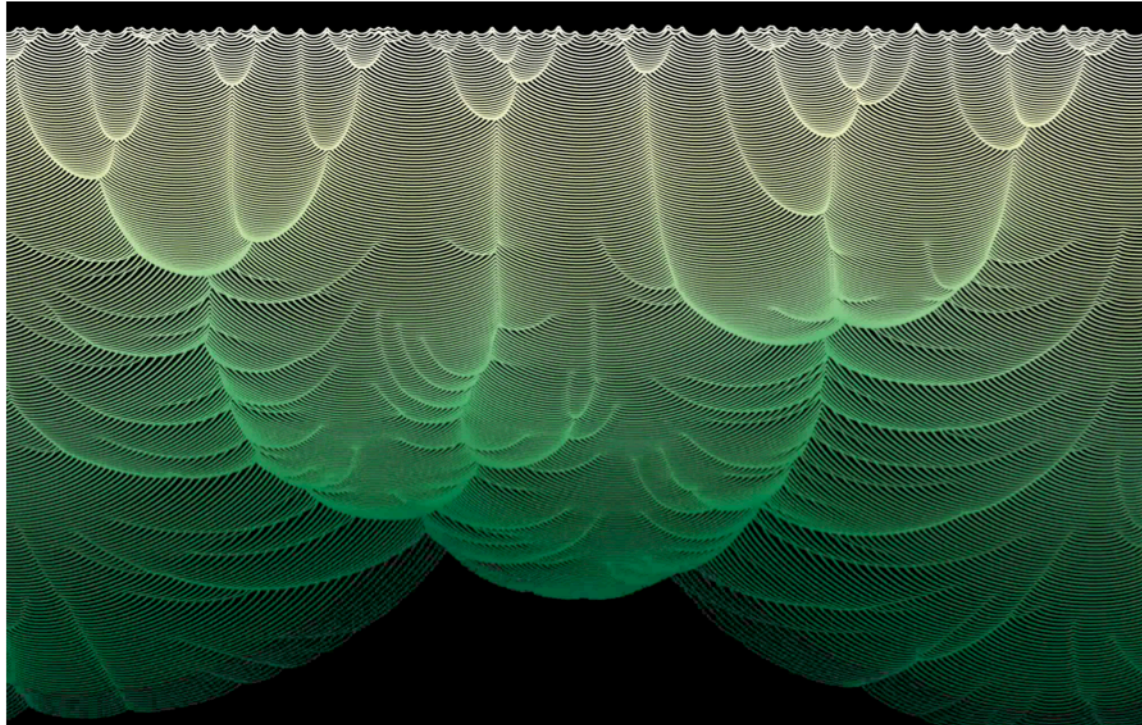
Pole dynamics



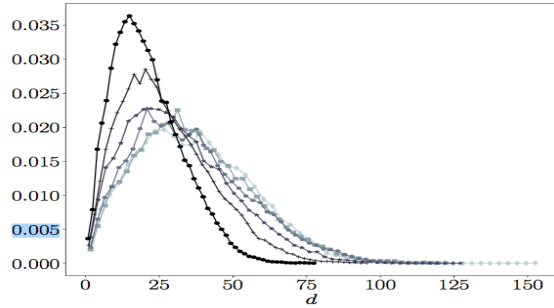
Pole dynamics: purely aggregative dynamics



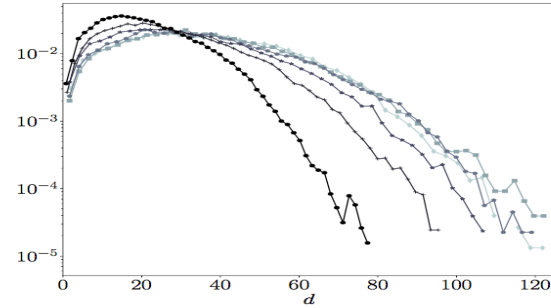
PDE + noise: permanent addition of
new crests



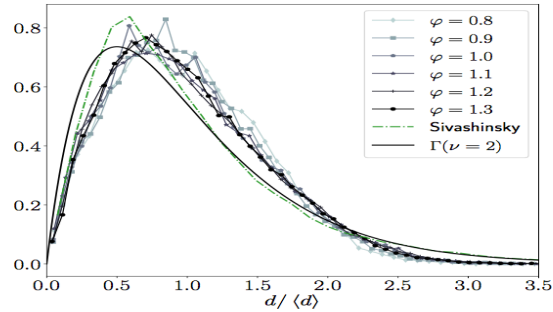
Experimental cell size distribution (downward propagating propane flames)



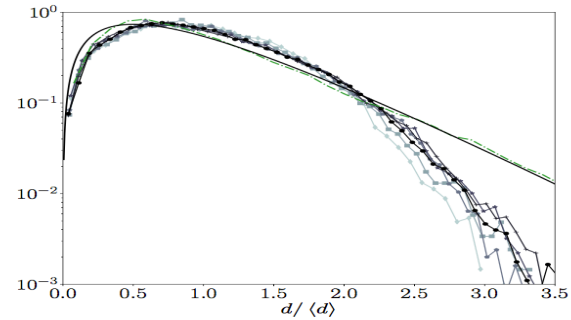
(a)



(b)



(d)



(e)

Conclusion

- Flame instability in a Hele-Shaw burner: forcing an initial condition
- Sivashinsky equation works reasonably for short times/ small slopes
- Deterministic evolution of crests trajectories for short times (pole dynamics)
- Cells creation : some role of noise and gravity