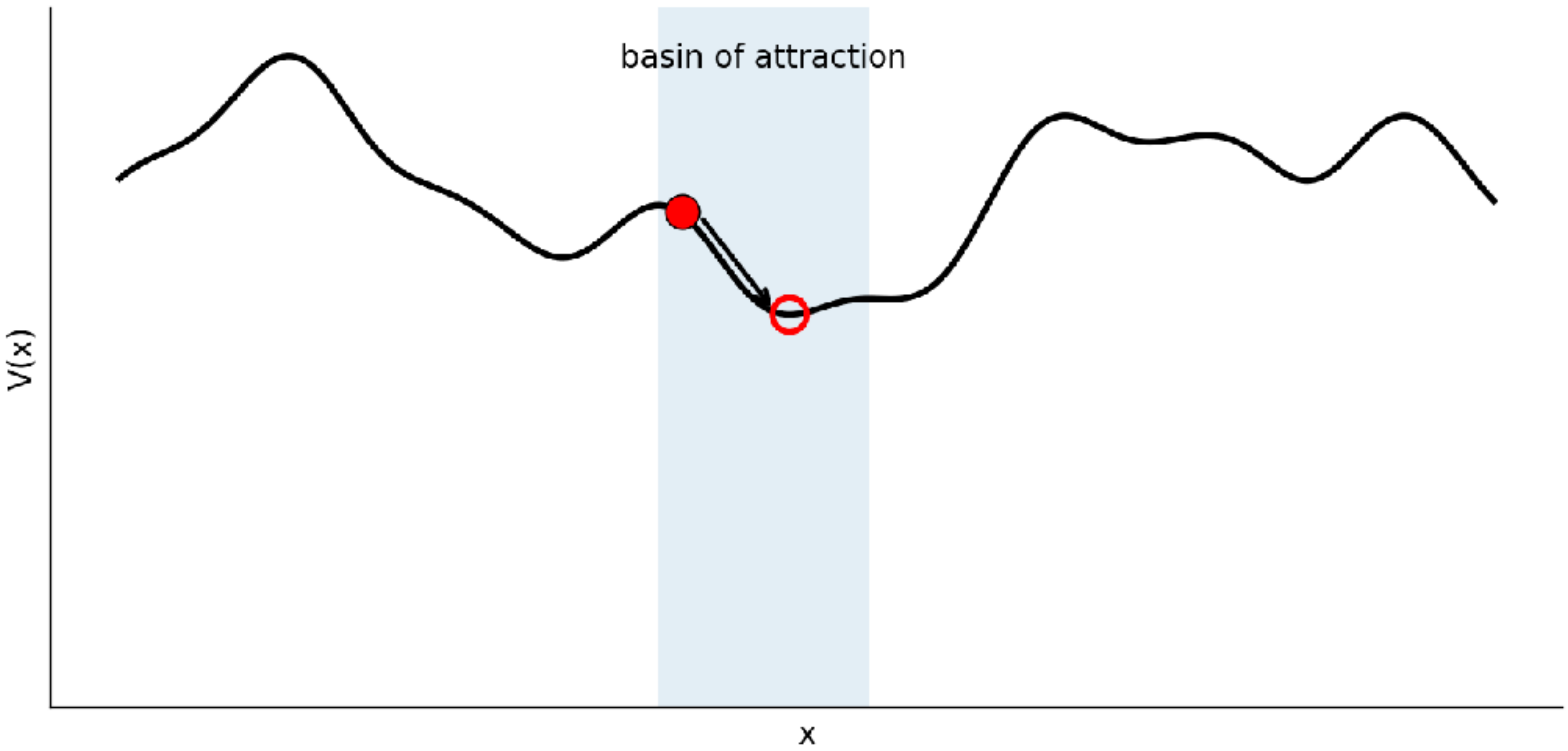
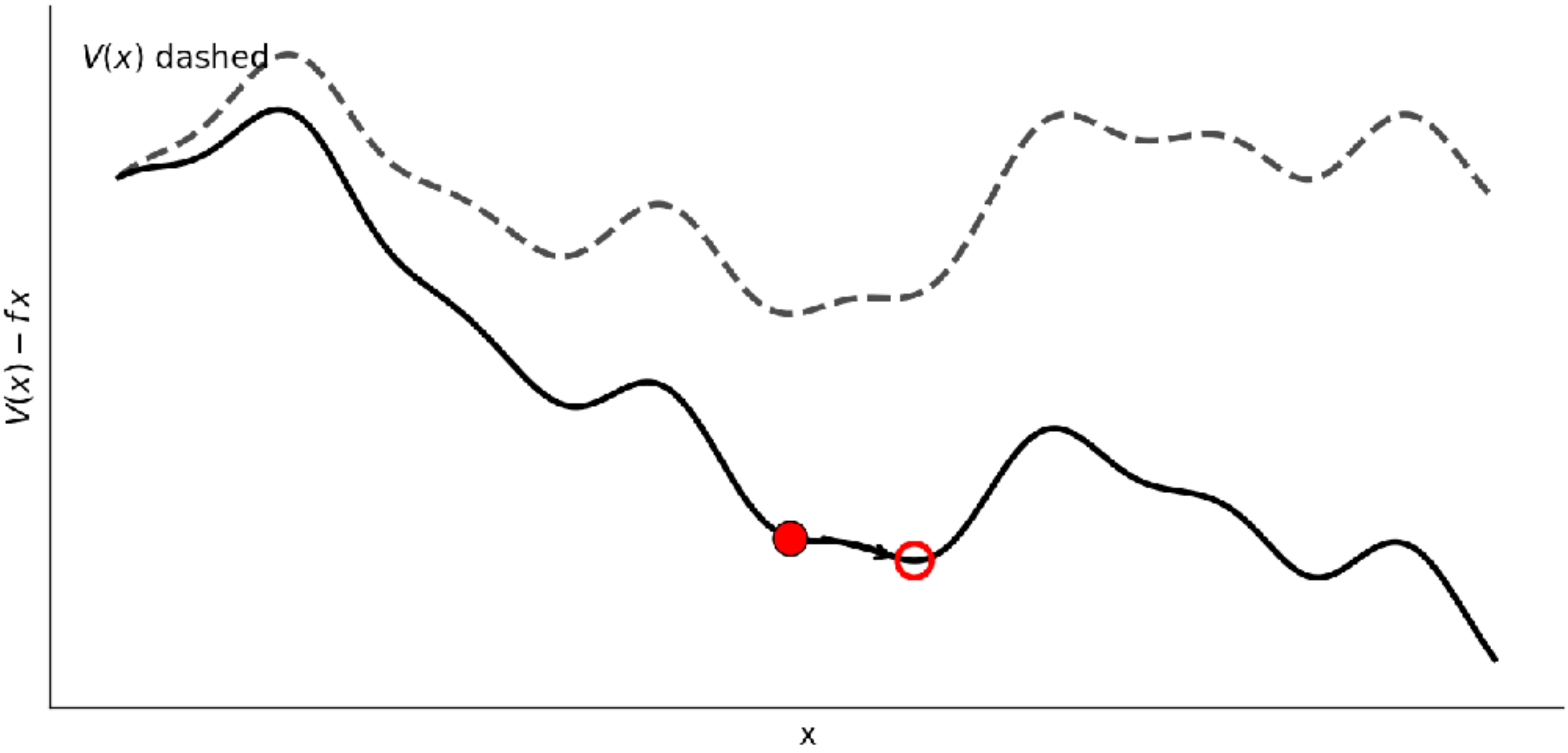
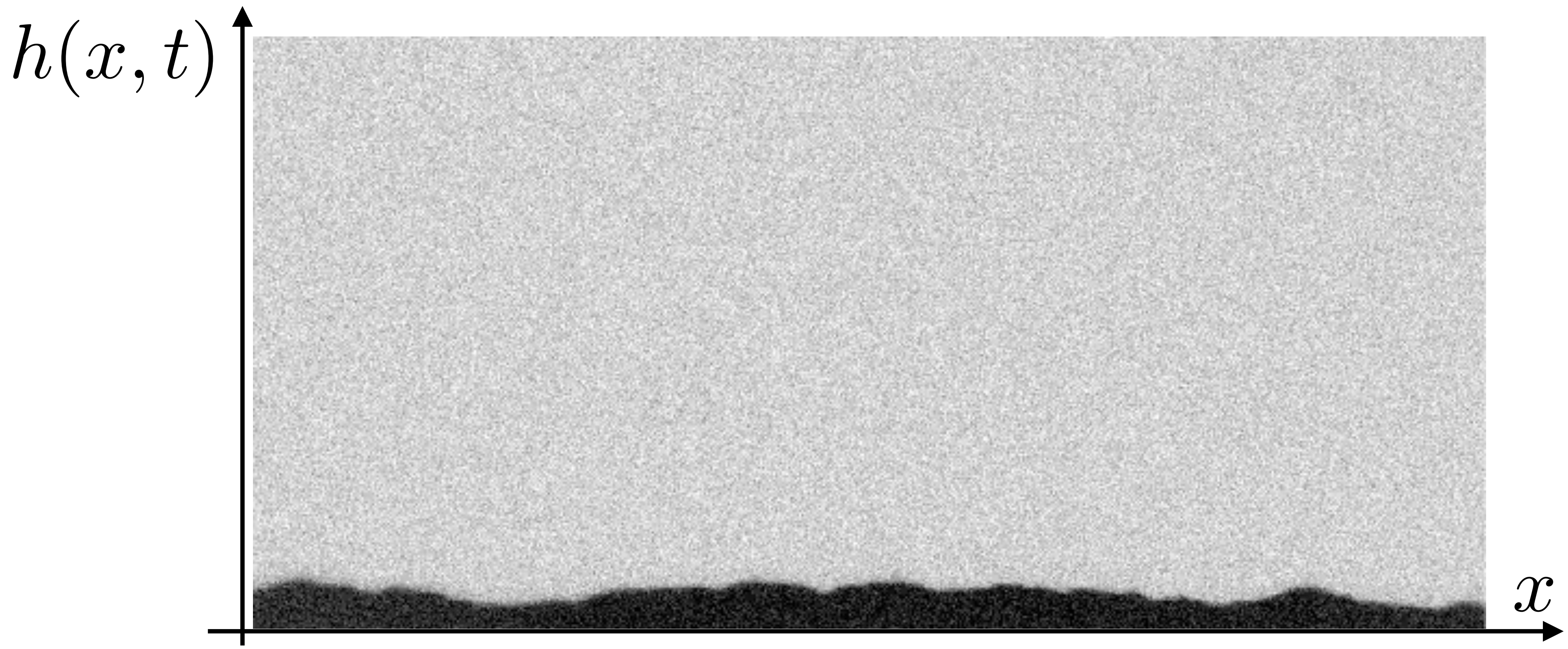
Driven Disordered Materials



Driven Disordered Materials



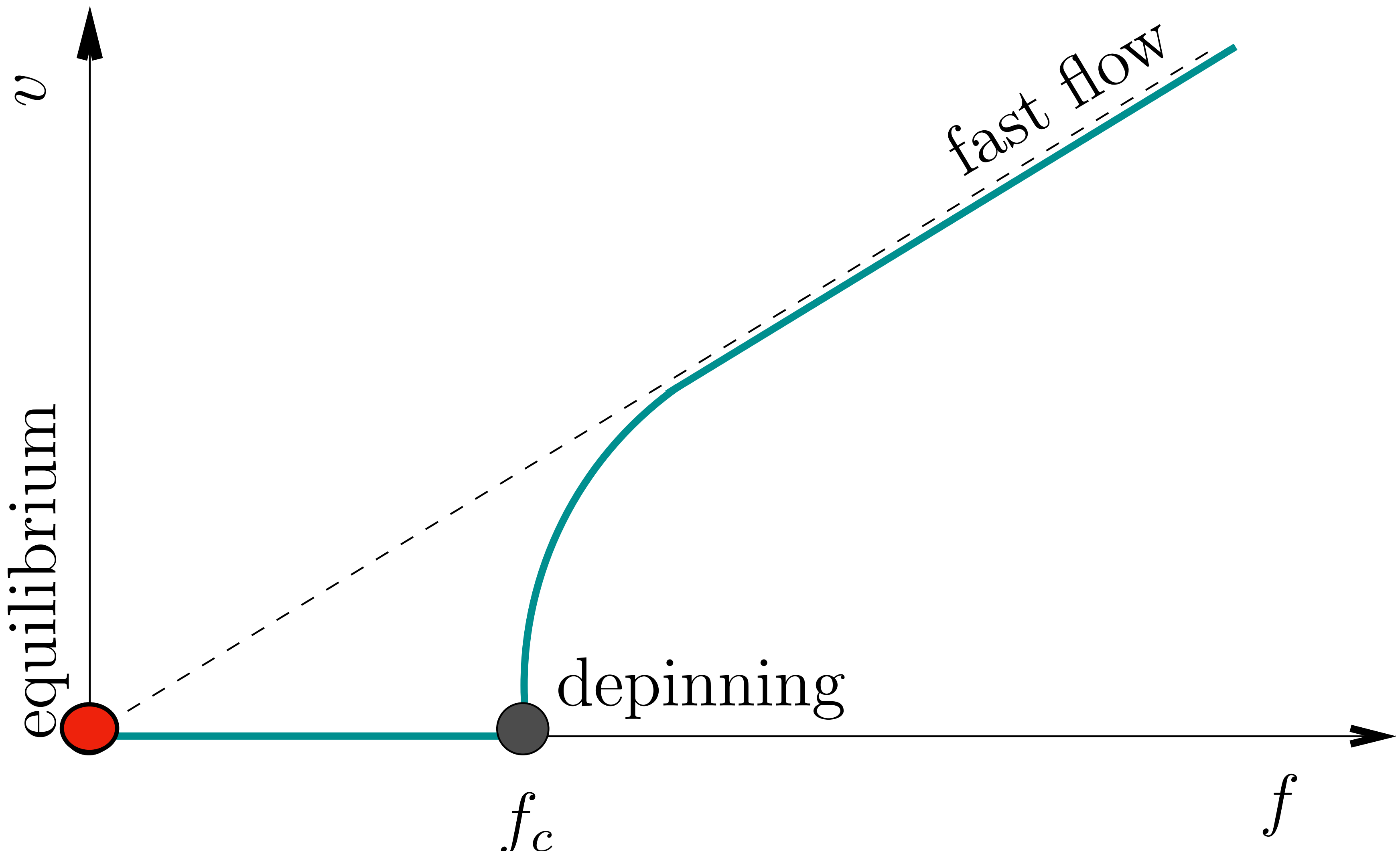
Interface Driven Dynamics: Disorder and Elasticity



$$\partial_t h(x,t) = \partial_x^2 h(x,t) + f + F\left(x, h(x,t)\right)$$

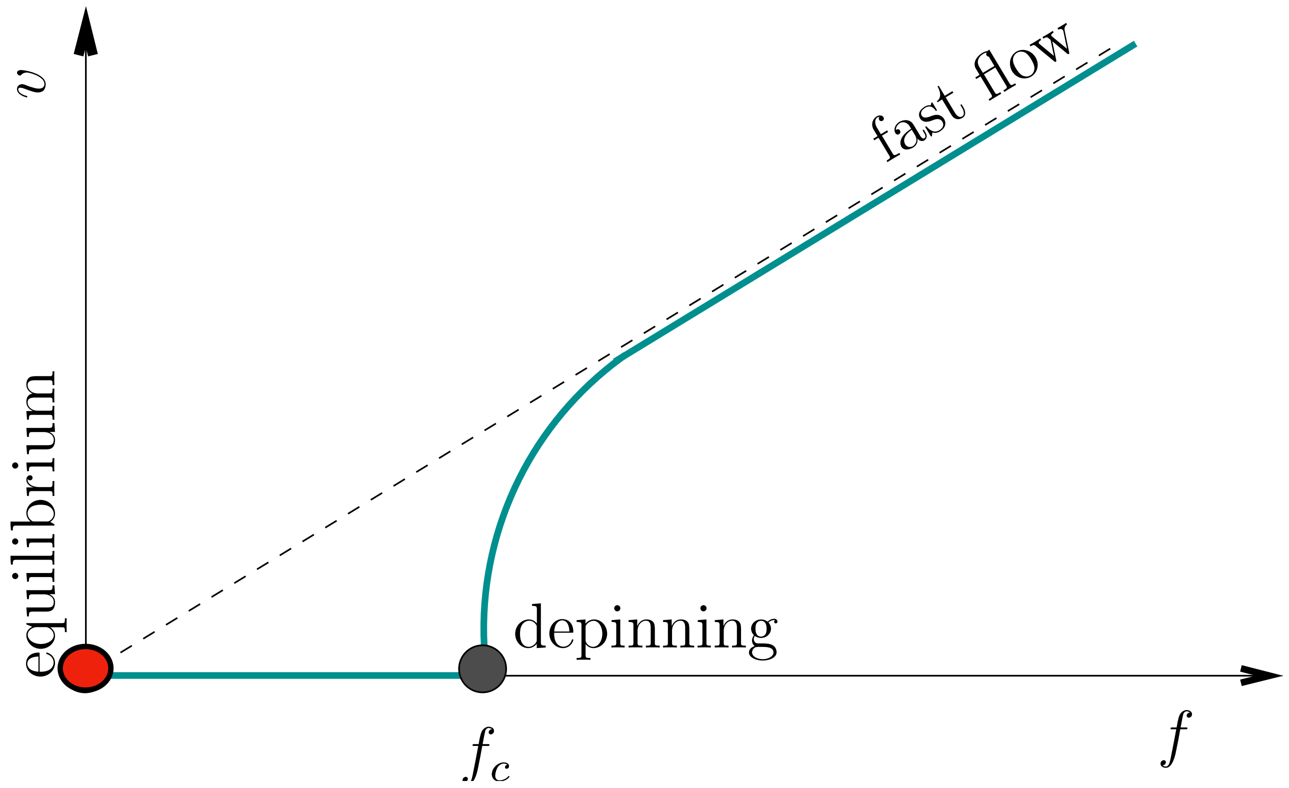
magnetic domain wall dynamics
by V. Jeudy & A. Mougin (Paris-Saclay)

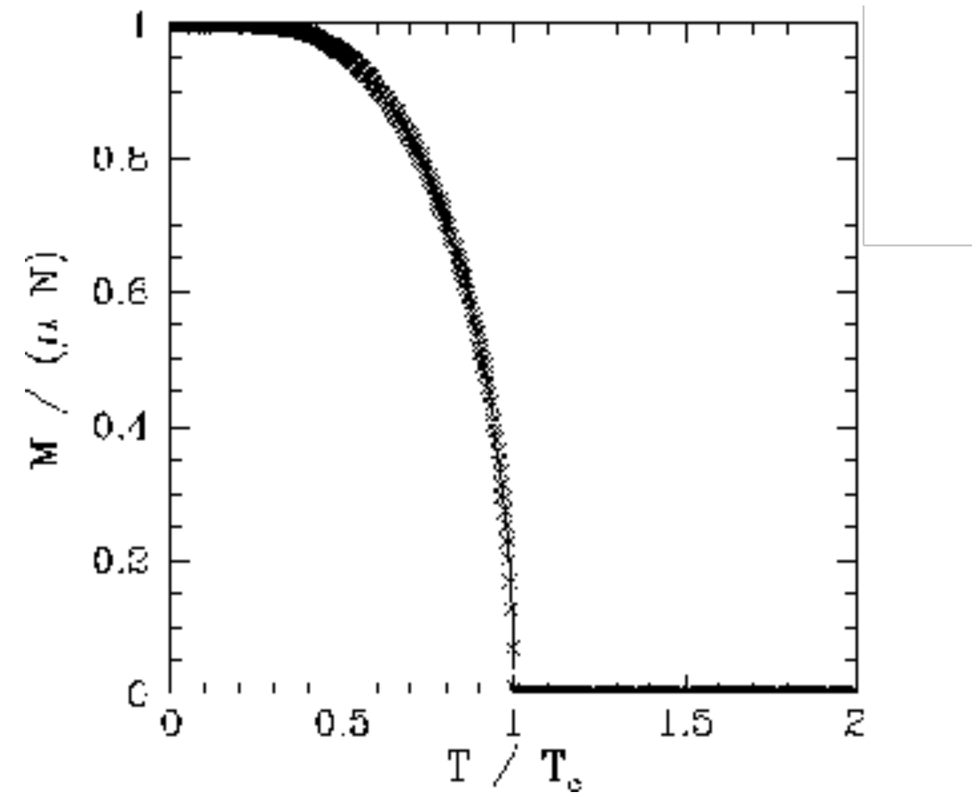
Pinning - Depinning

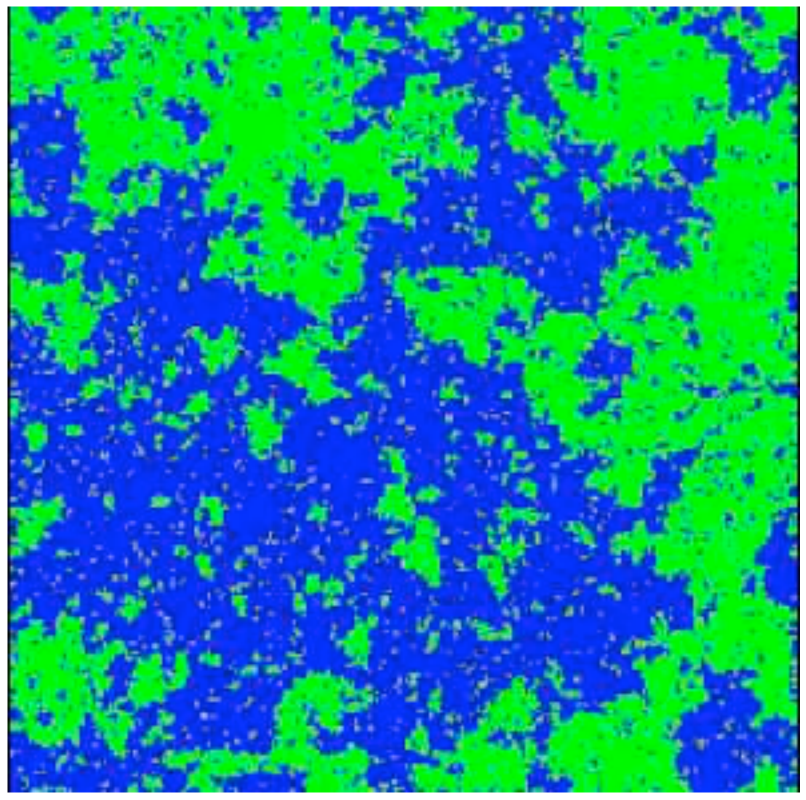


- no passing rule: for $f > f_c$ no metastability
- f_c is self-averaging when $L \to \infty$

Depinning as dynamical phase transition

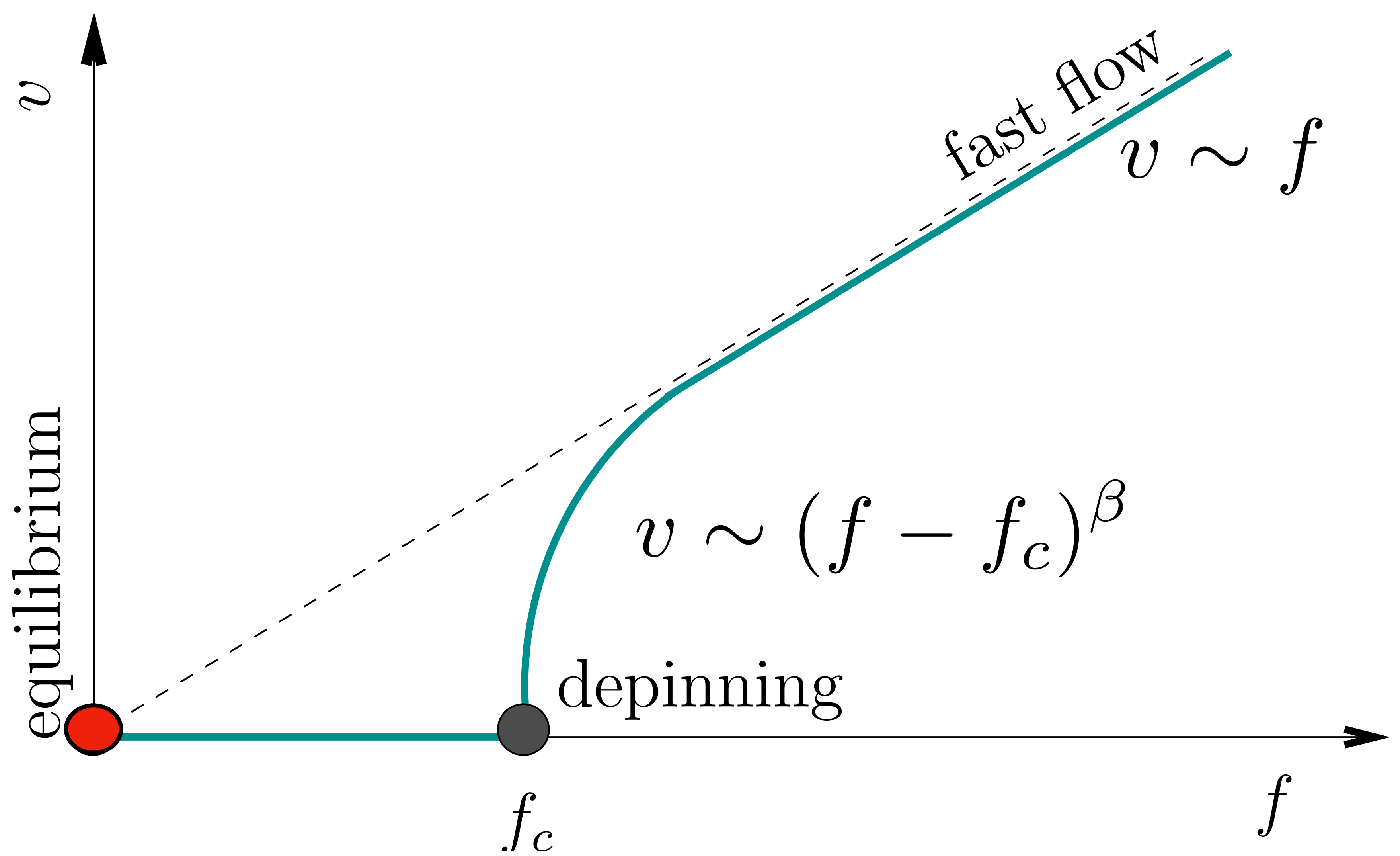




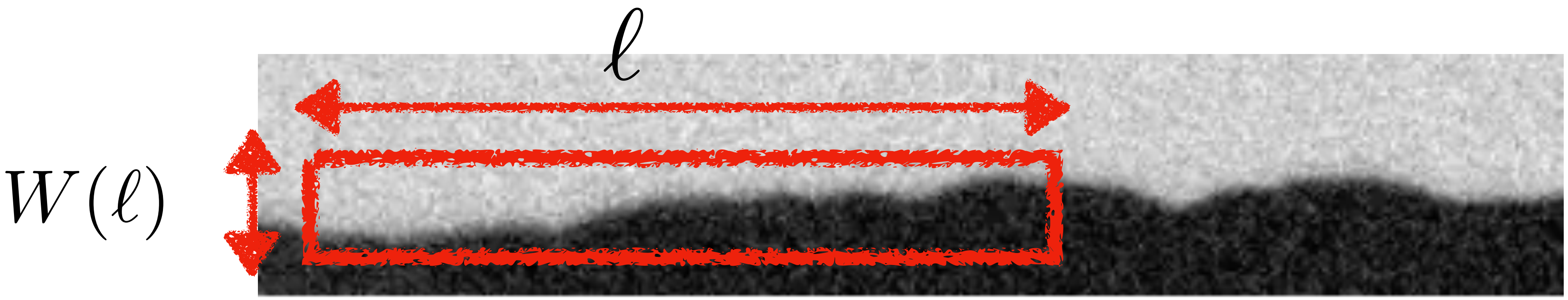


- At f_c : scaling invariance / self-similarity
- Off f_c : finite correlation length

Critical exponents (Universal)



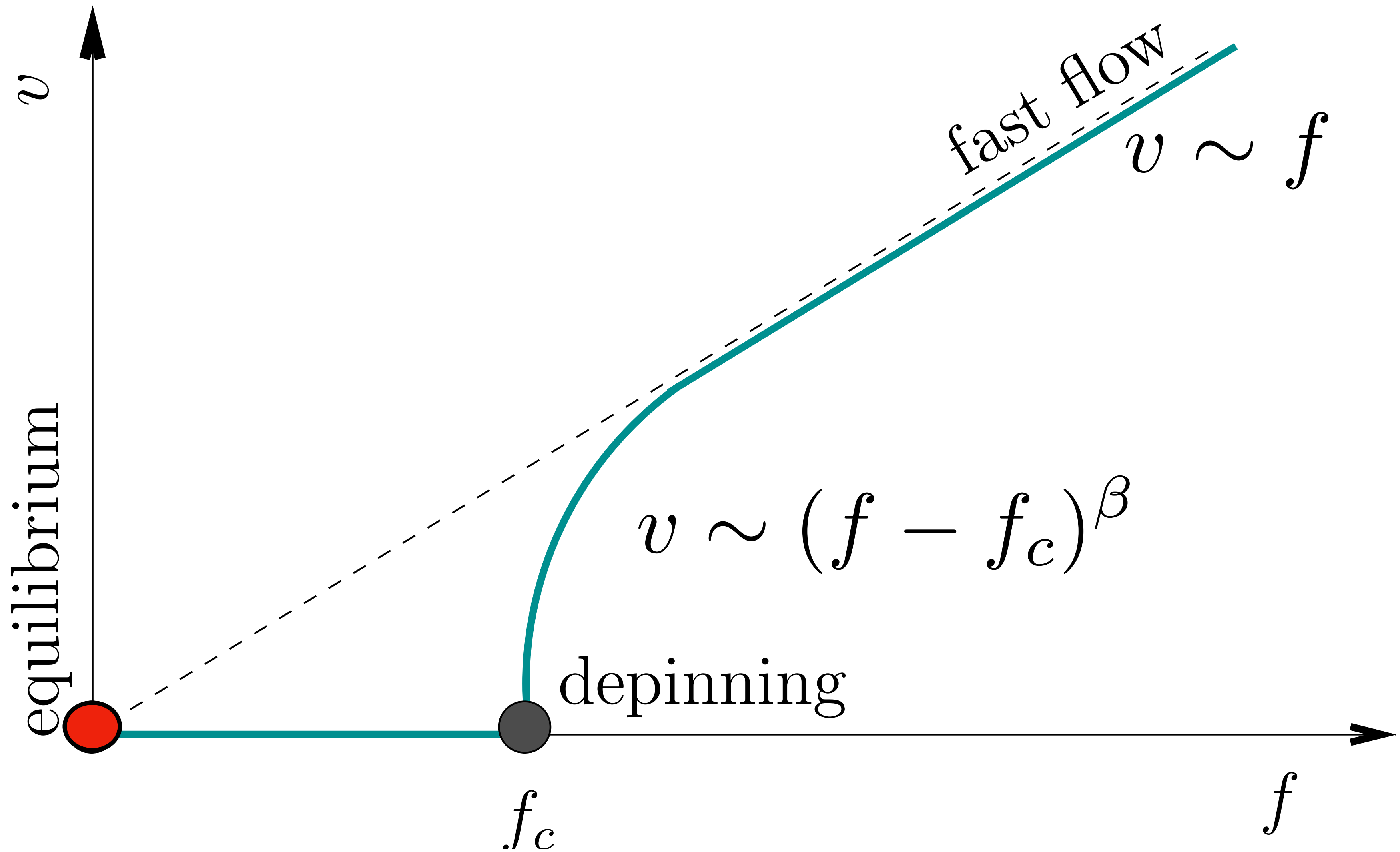
Shape of Driven Interfaces



$W(\ell) \sim \ell^{\zeta}$ $\qquad$ ζ Roughness exponent

- self similar interfaces (random fractal)
- Family-Vicsek scaling $W(\ell, t) \sim \ell^{\zeta} f\left(\frac{t}{L^z}\right)$

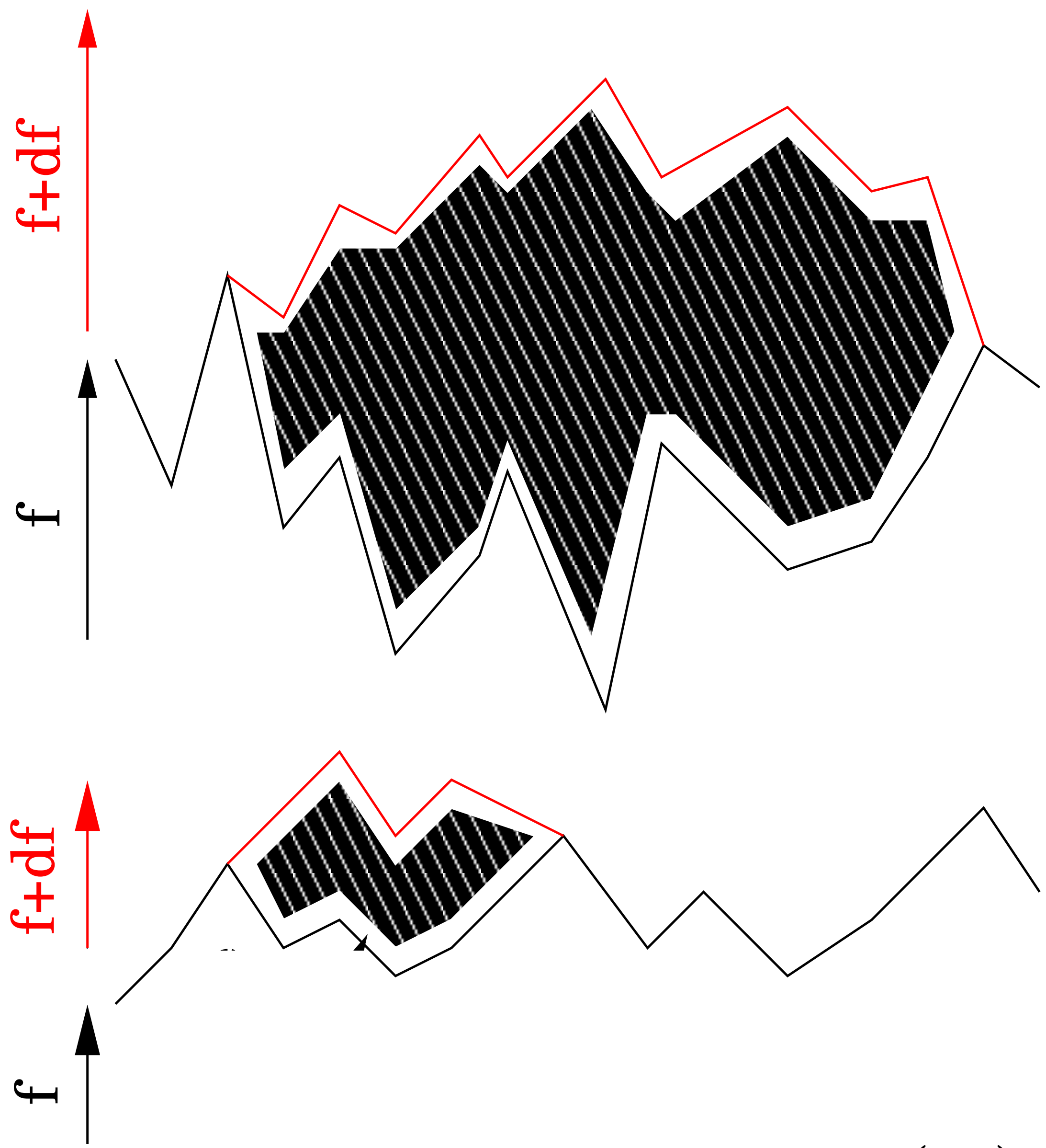
Shape of Driven Interfaces

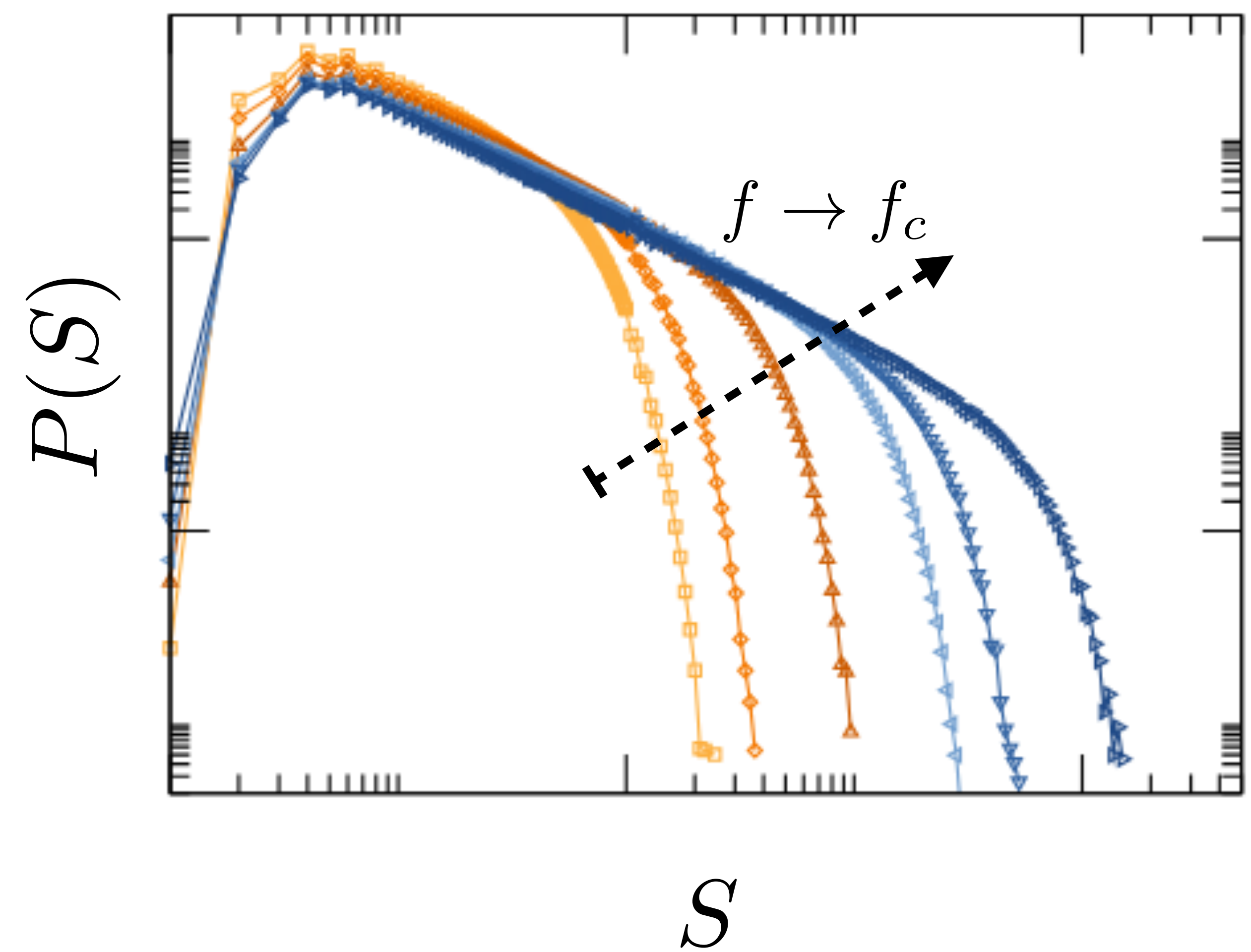


Three roughness exponents:

- Equilibrium $\zeta_{eq} = 2/3$
- Depinning $\zeta_{dep}^{(1)} = 1.25$ or $\zeta_{dep}^{(2)} = 0.63$
- Fast Flow $\zeta_{FF} = 0.5$

Scale invariance: avalanches below threshold

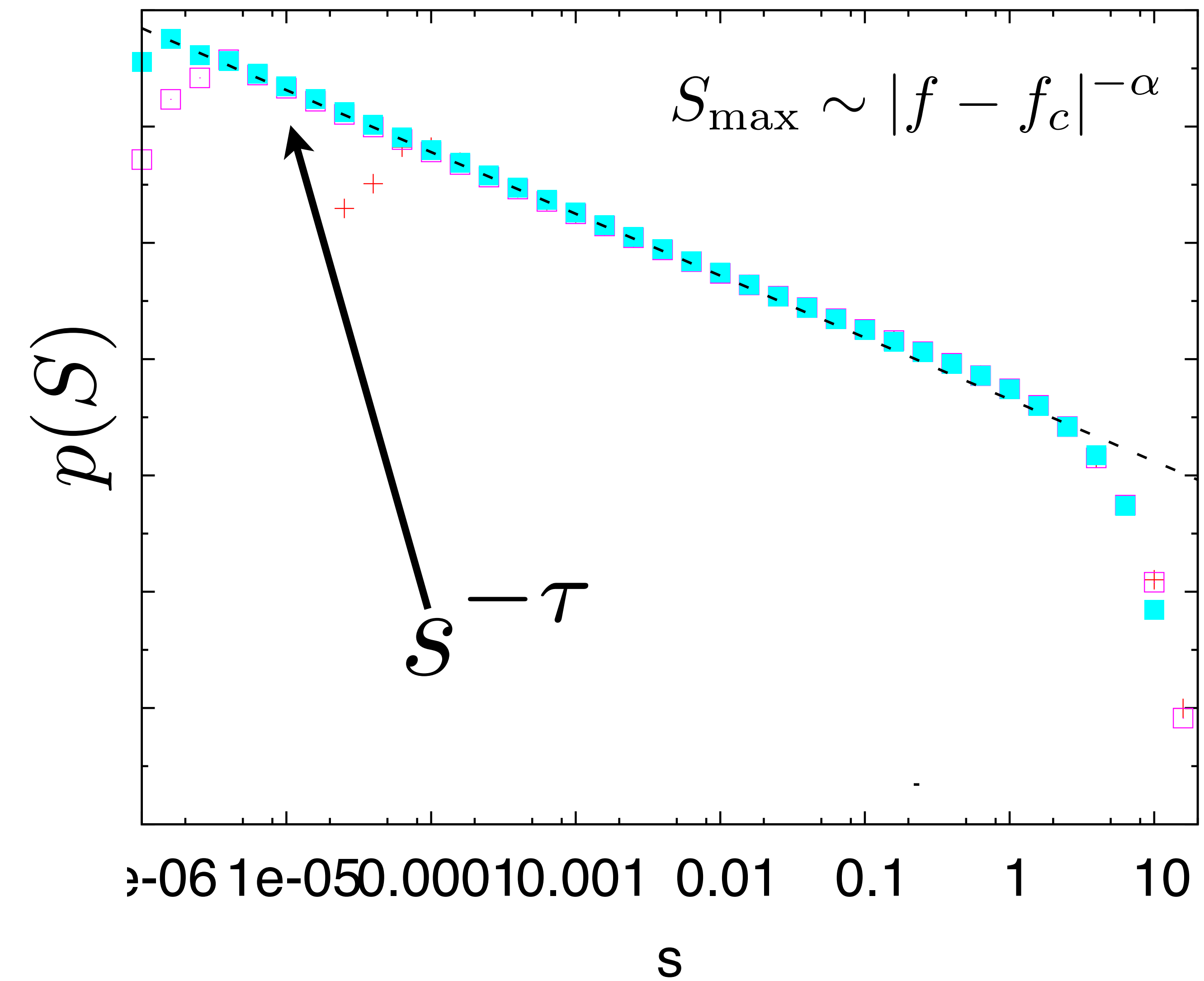




$$P(S) \sim S^{-\tau} F\left(\frac{S}{S_{\max}}\right)$$

$$S_{\max} \sim |f - f_c|^{-\alpha}$$

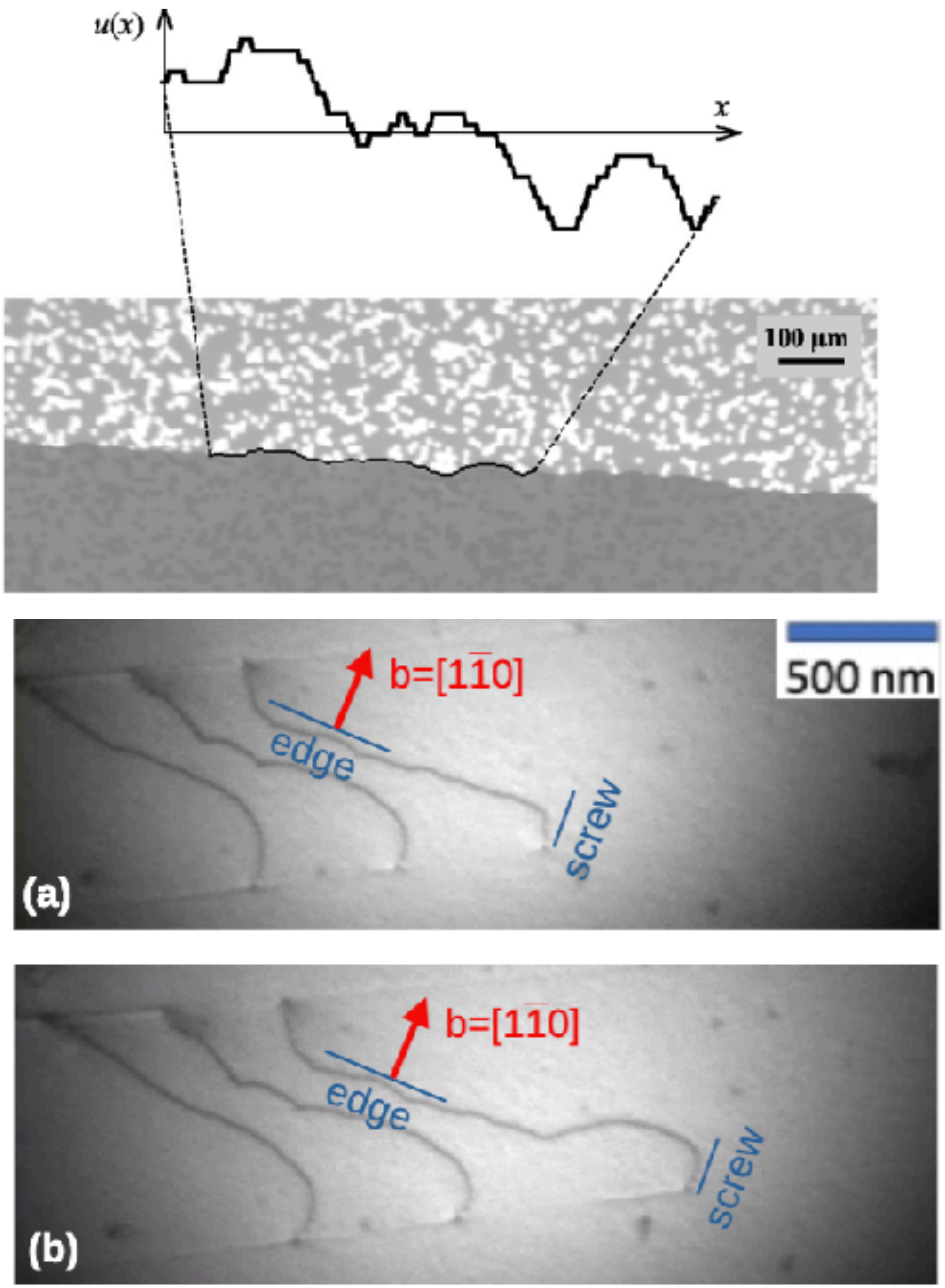
Avalanche Dynamics



α and τ are universal (*critical exponents*)

by Alejandro Kolton (Bariloche)

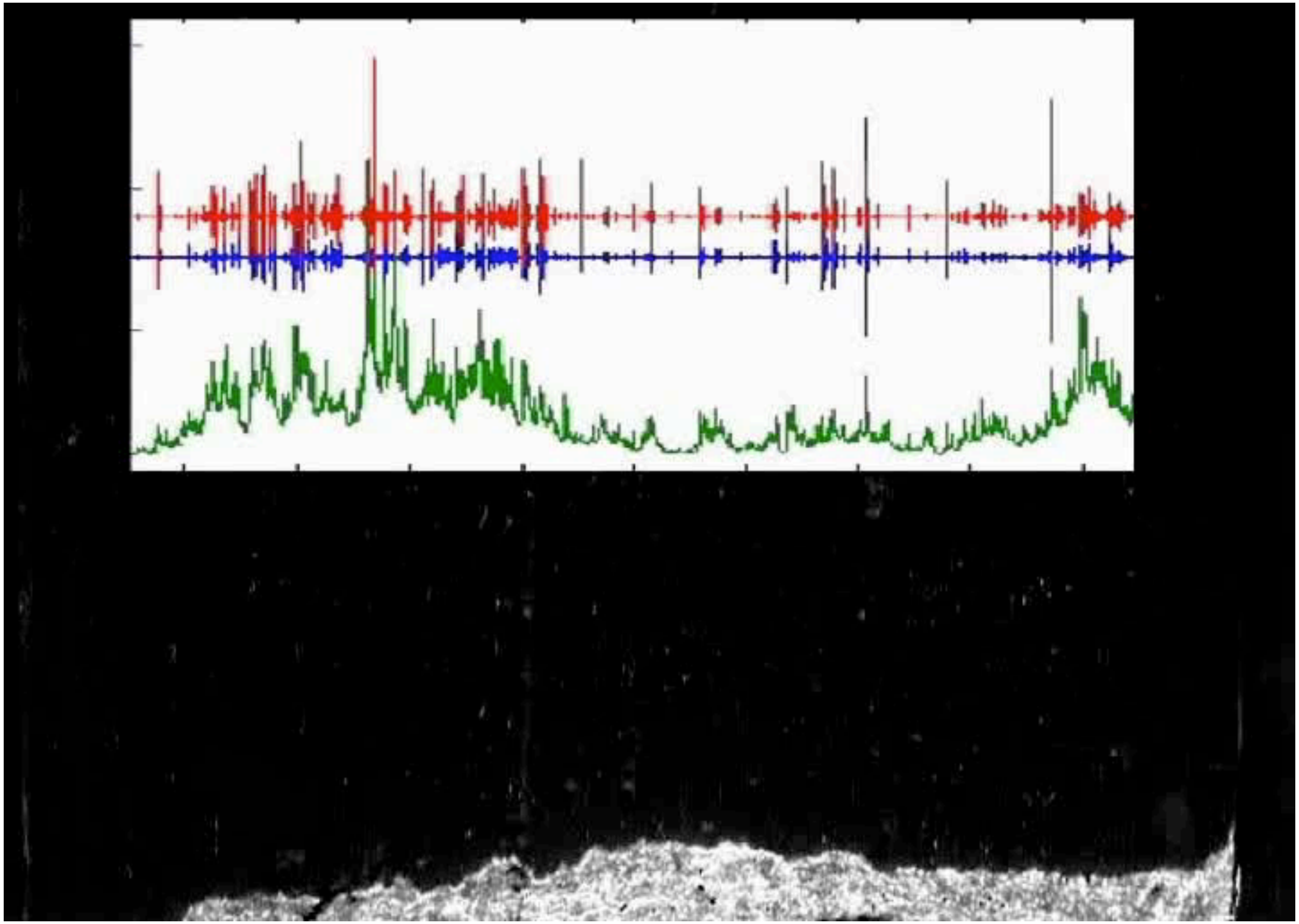
Depinning in other systems



Liquid contact lines

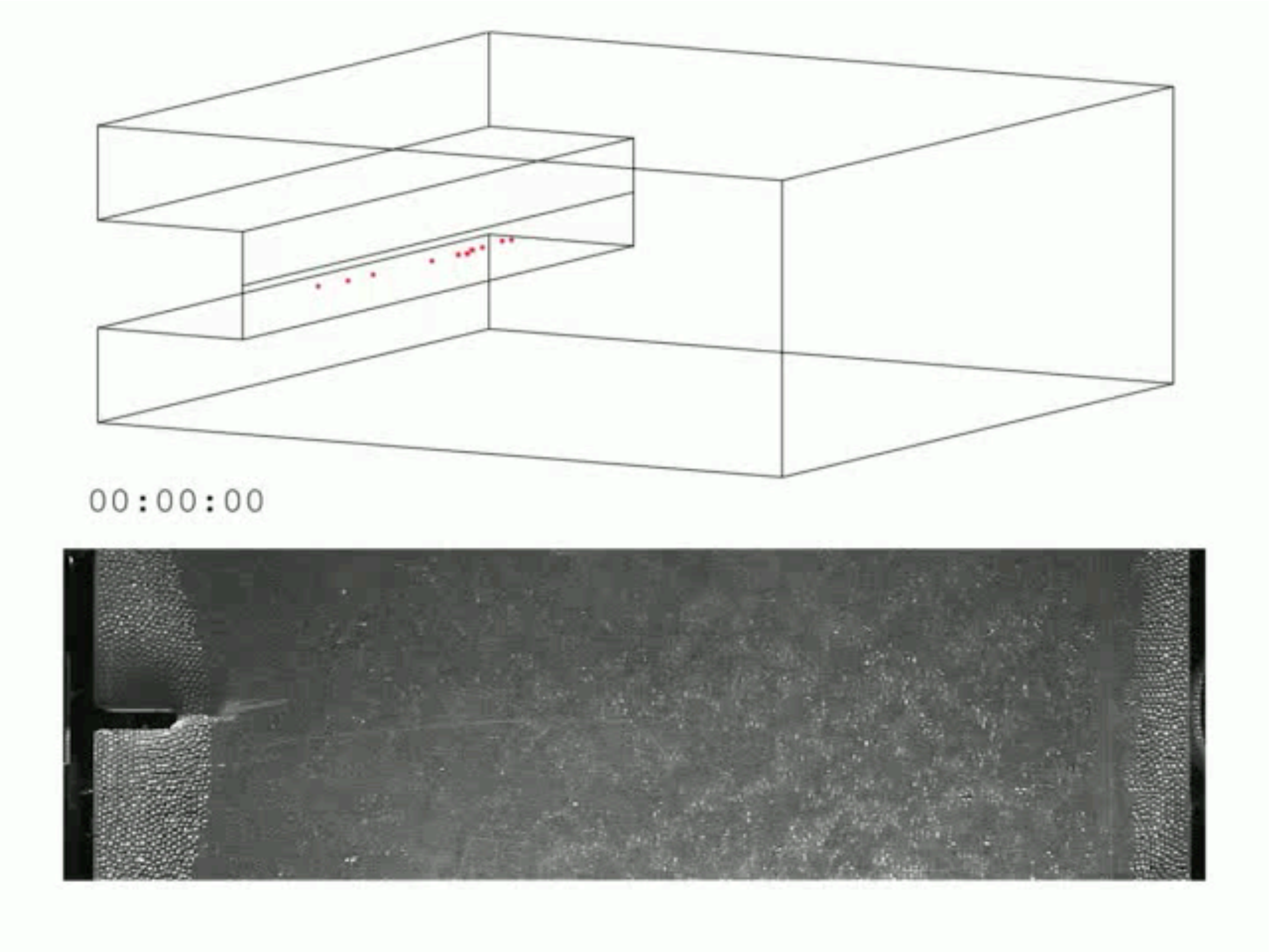
Dislocations in metals

Fracture front and avalanches



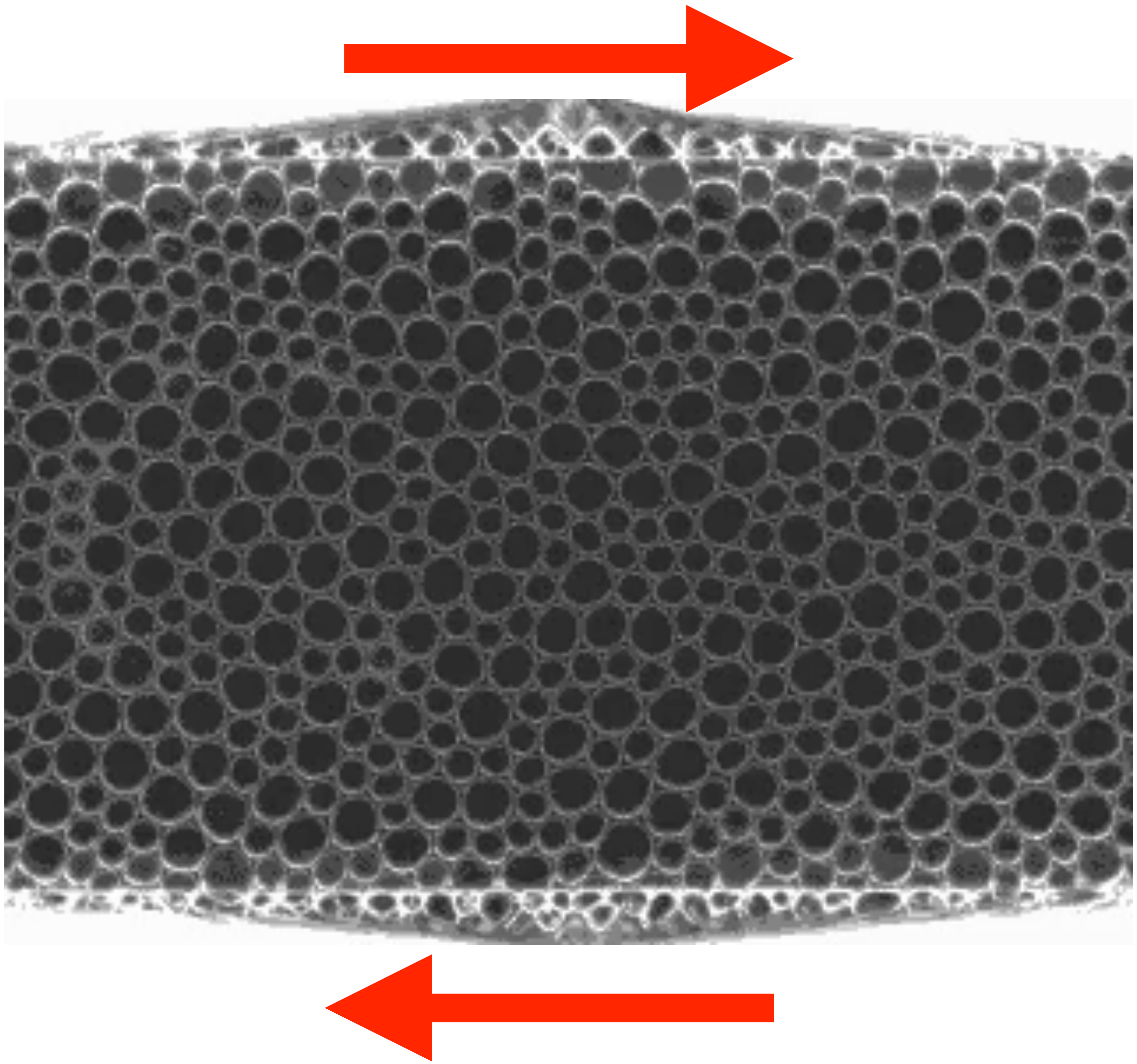
propagation of crack fronts in PMMA,
by S. Santucci in ENS- Lyon

Avalanches & intermittency



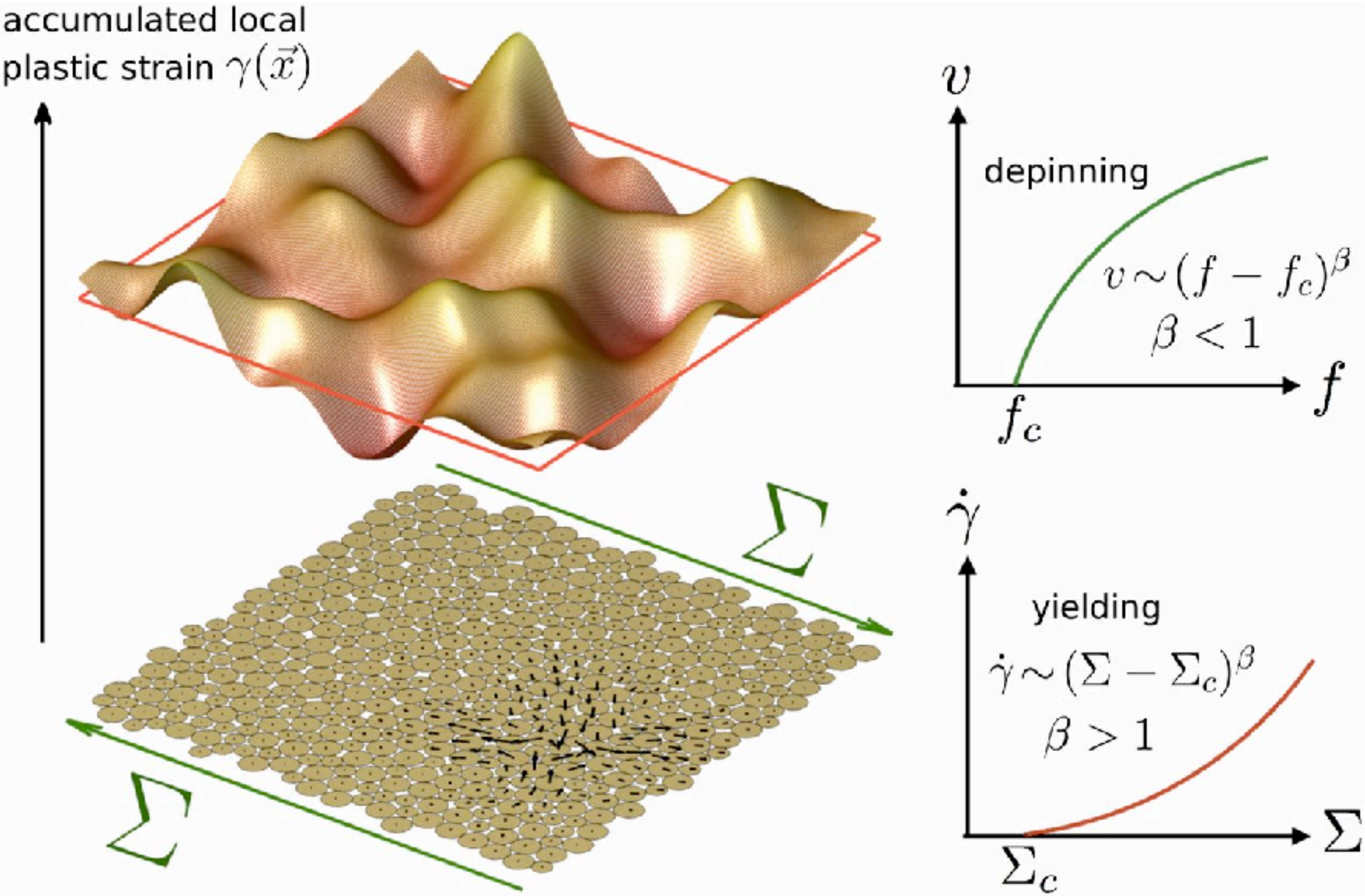
propagation of crack fronts in PMMA,
by J. Bares & D. Bonamy in Paris-Saclay

Beyond interface depinning: yielding of soft glasses

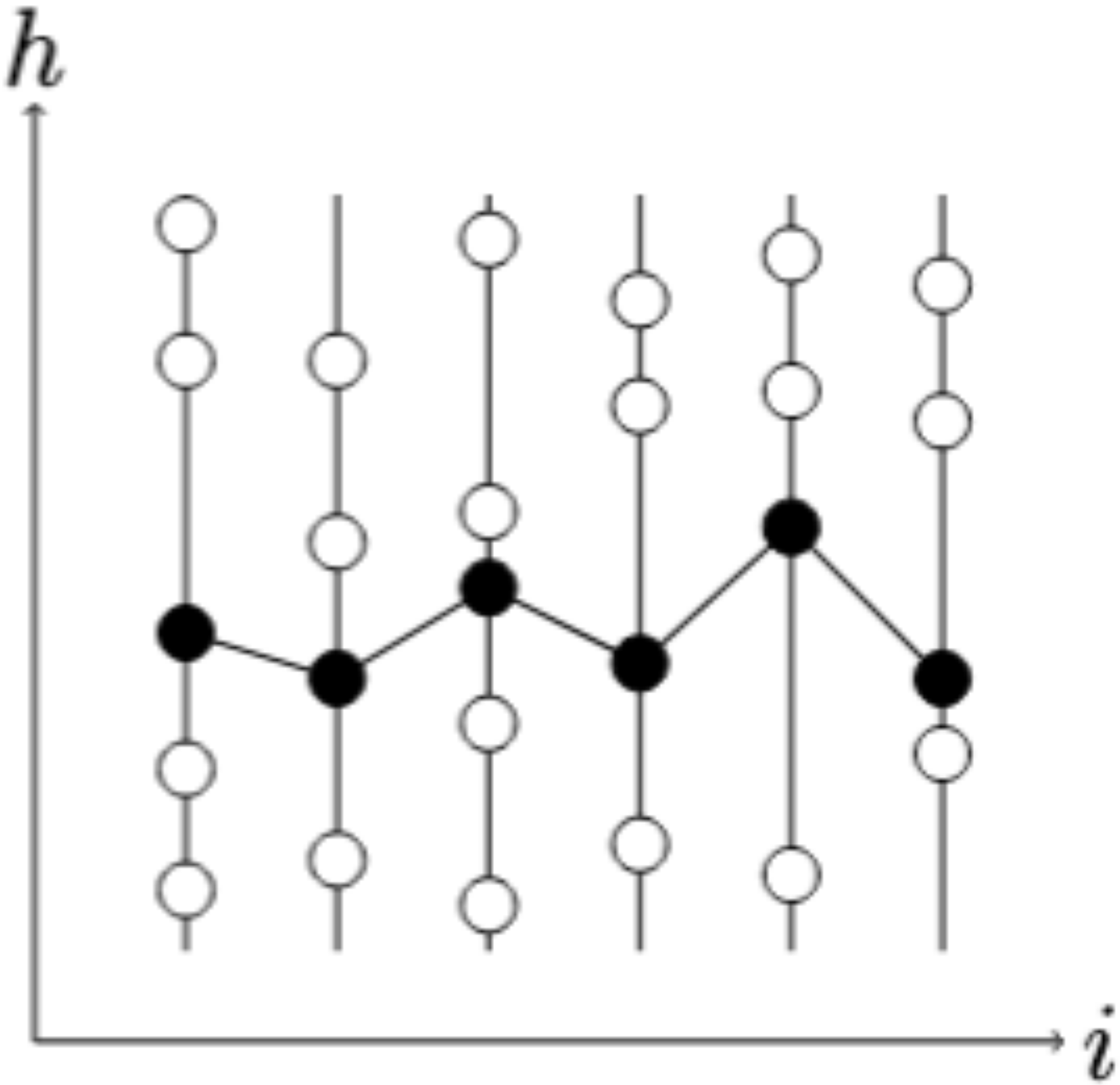


Shear transformation (Alan S. Argon 1979)

Yielding transition



Cellular Automata



Discrete random traps:

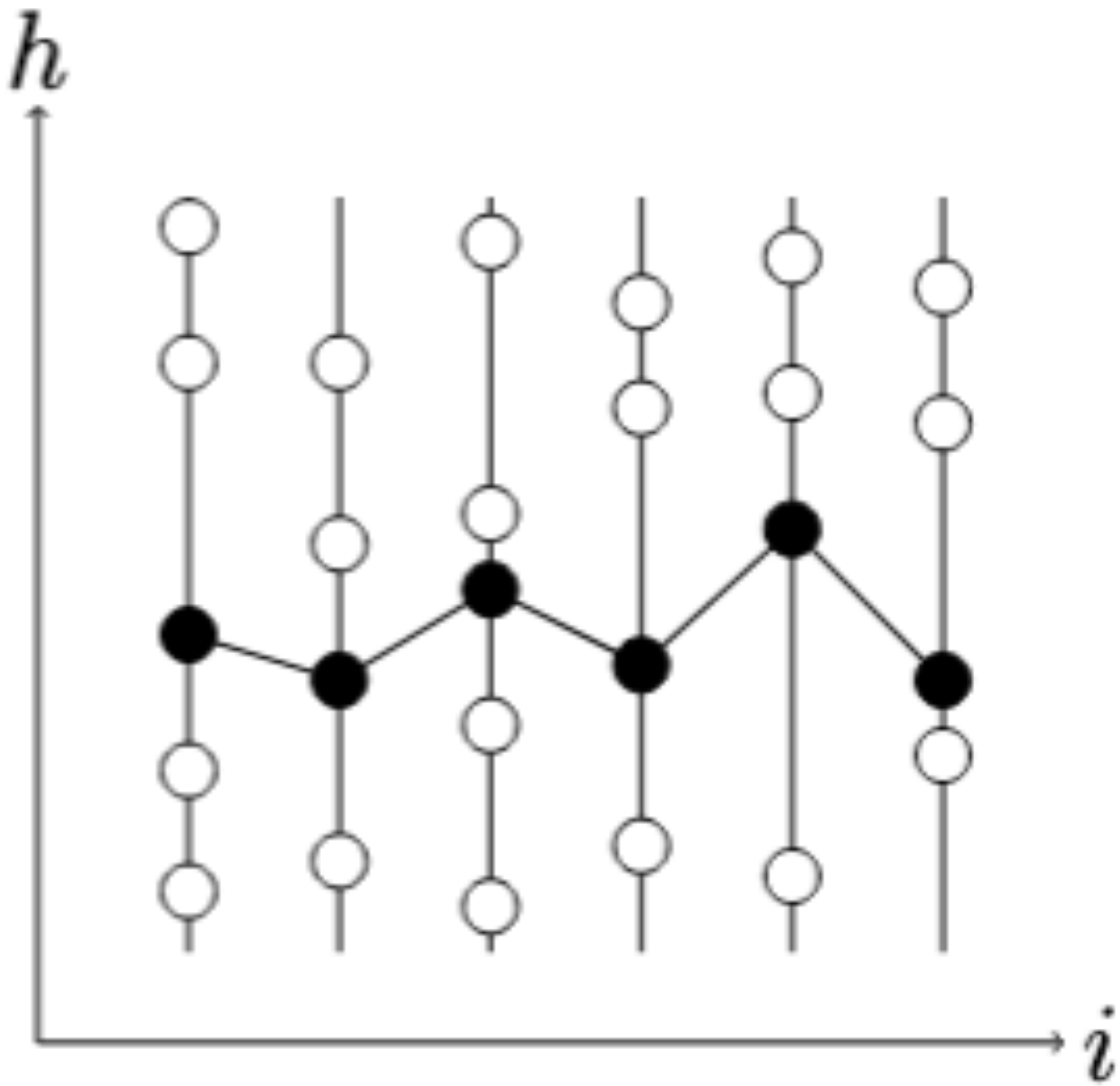
- Yield threshold fixed

$$f_Y = 1$$

- Consecutive distance random

$$\Delta \sim g(\Delta)$$

Cellular Automata



Distance to instability:

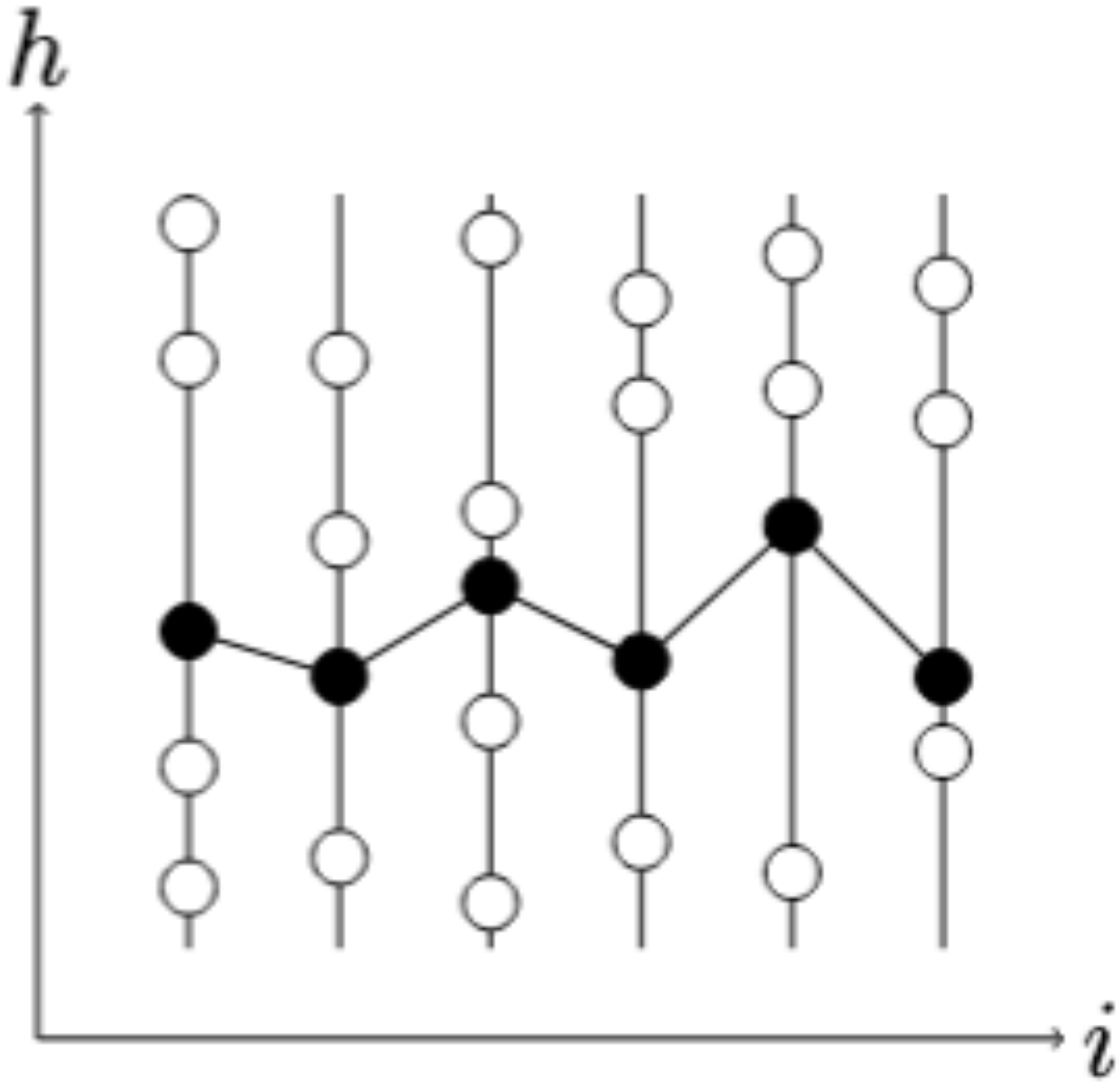
$$x_i = f_Y - F_i^{\text{elast.}} - f$$

- $x_i > 0$: Stable Block
- $x_i < 0$: Unstable Block
  $h_i \to h_i + \Delta$

Cellular Automata

$$F_i^{\text{elast.}} = \frac{1}{2}\left(h_{i+1} + h_{i-1} - 2h_i\right)$$

$$x_i = f_Y - F_i^{\text{elast.}} - f$$



Update rules

$$h_i \to h_i + \Delta$$

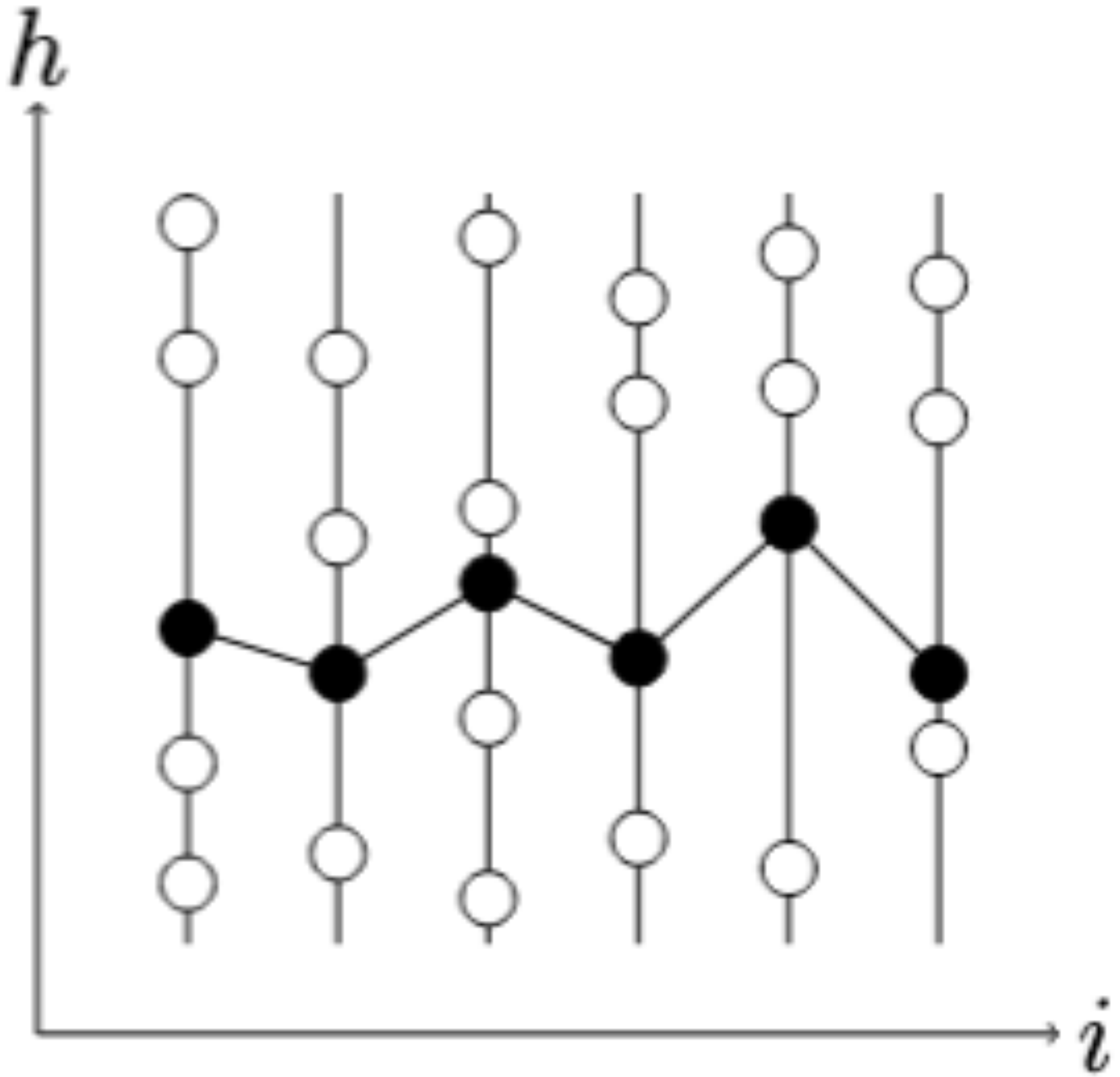
$$x_i \to$$

$$x_{i\pm1} \to$$

Cellular Automata

$$F_i^{\text{elast.}} = \frac{1}{2}\left(h_{i+1} + h_{i-1} - 2h_i\right)$$

$$x_i = f_Y - F_i^{\text{elast.}} - f$$



Update rules

$$h_i \rightarrow h_i + \Delta$$

$$x_i \rightarrow x_i + \Delta$$

$$x_{i\pm1} \rightarrow x_{i\pm1} - \frac{\Delta}{2}$$

Mean Field Cellular Automata

$$F_i^{\text{elast.}} = \frac{1}{N}\sum_{j=1}^{N}(h_j - h_i) = h_{CM} - h_i; \qquad h_{CM} = \frac{1}{N}\sum_j h_j$$

$$x_i = f_Y - F_i^{\text{elast.}} - f$$

Update rules

$$h_i \to h_i + \Delta$$

Mean Field Cellular Automata

$$F_i^{\text{elast.}} = \frac{1}{N}\sum_{j=1}^{N}(h_j - h_i) = h_{CM} - h_i; \qquad h_{CM} = \frac{1}{N}\sum_j h_j$$

$$x_i = f_Y - F_i^{\text{elast.}} - f$$

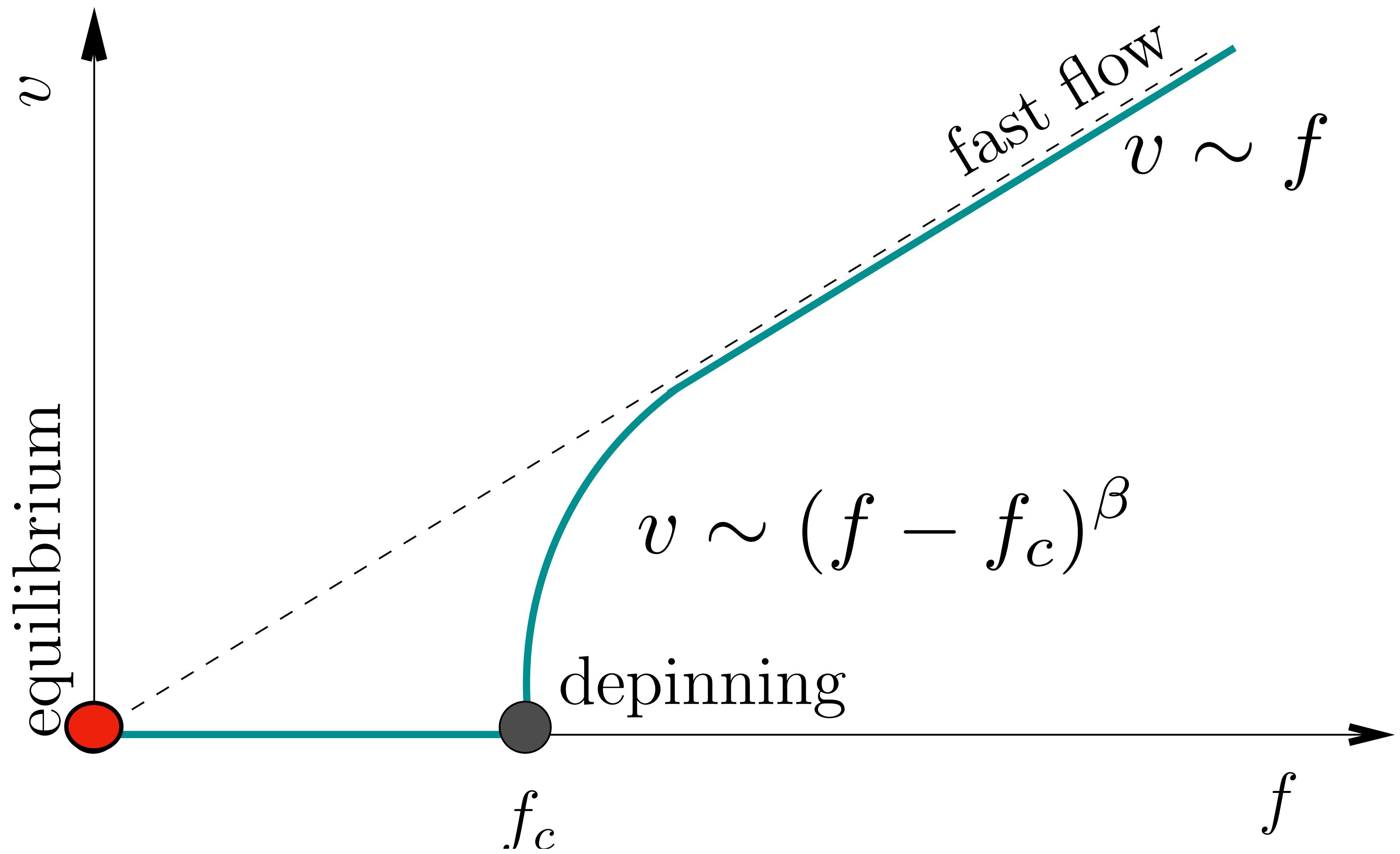
Update rules

$$h_i \to h_i + \Delta$$

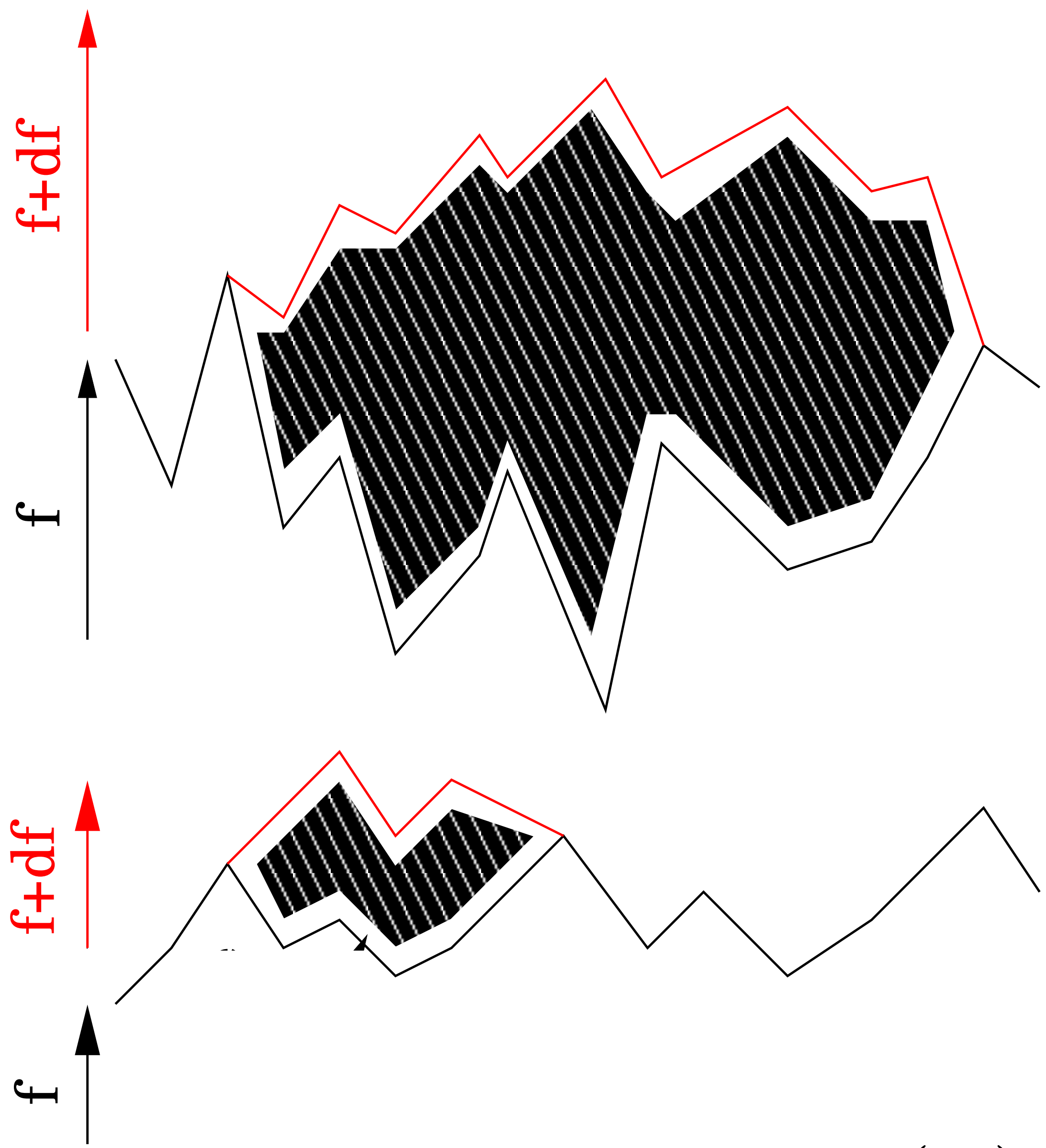
$$x_i \to x_i + \Delta(1 - \frac{1}{N})$$

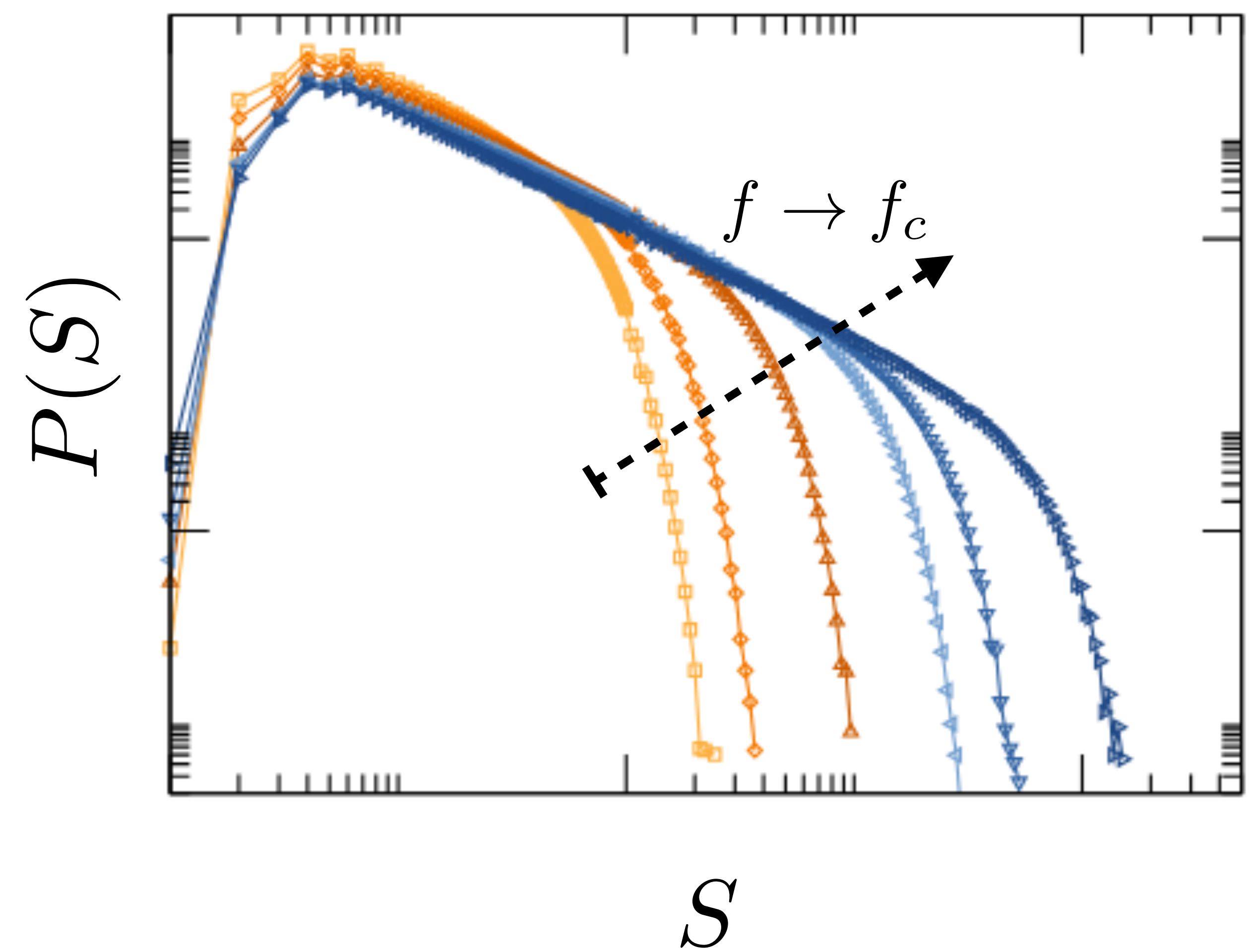
$$x_{j\neq i} \to x_{j\neq i} - \frac{\Delta}{N}$$

Critical exponents (Universal)



Scale invariance: avalanches below threshold





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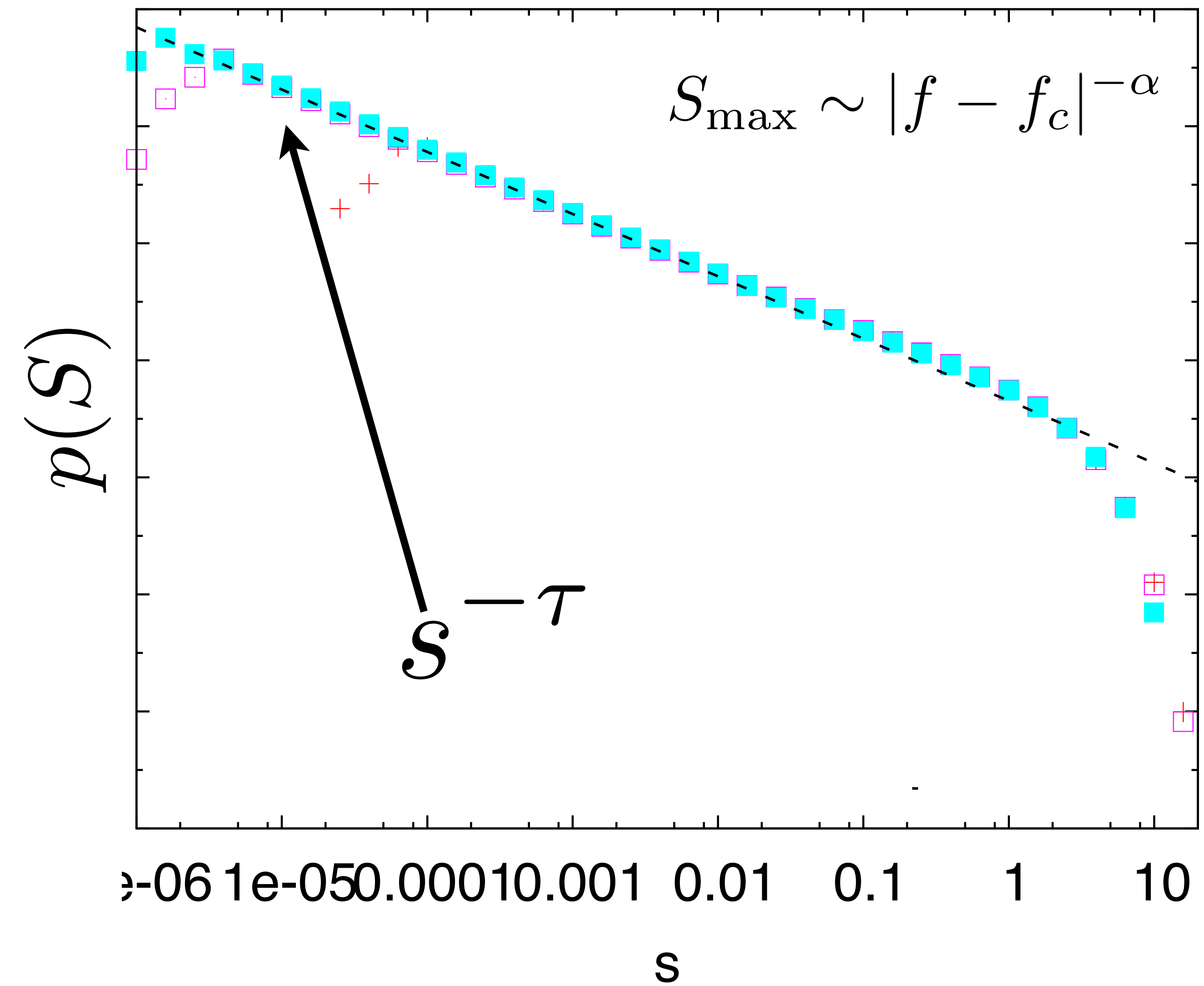
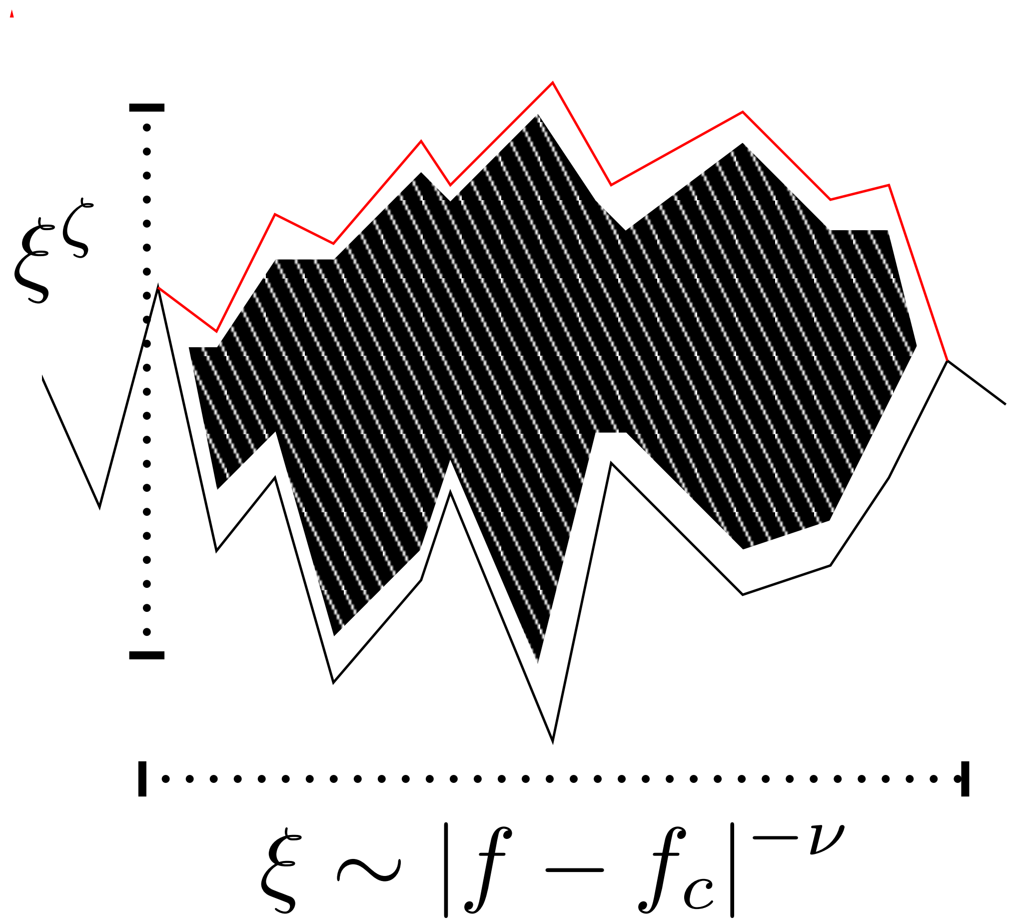
$$S_{\max} \sim |f - f_c|^{-\alpha}$$

Avalanche Dynamics



by Alejandro Kolton (Bariloche)

Finite dimensions: Scaling Relations



$$S_{\max} \sim \xi^{d+\zeta}$$

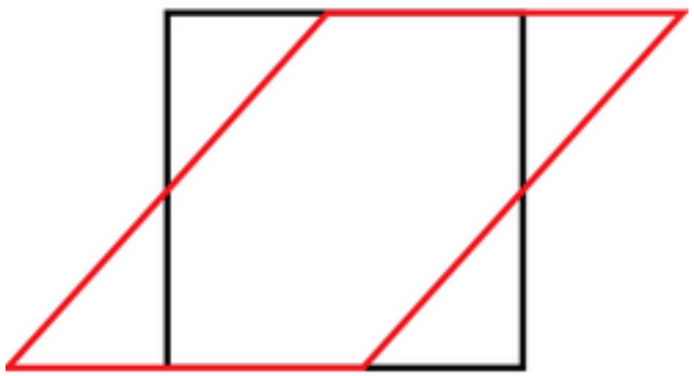
$$\boxed{\alpha = \nu(d+\zeta)}$$

Second (more tricky) relation:

$$\boxed{\tau = 2 - \frac{2}{d+\zeta}}$$

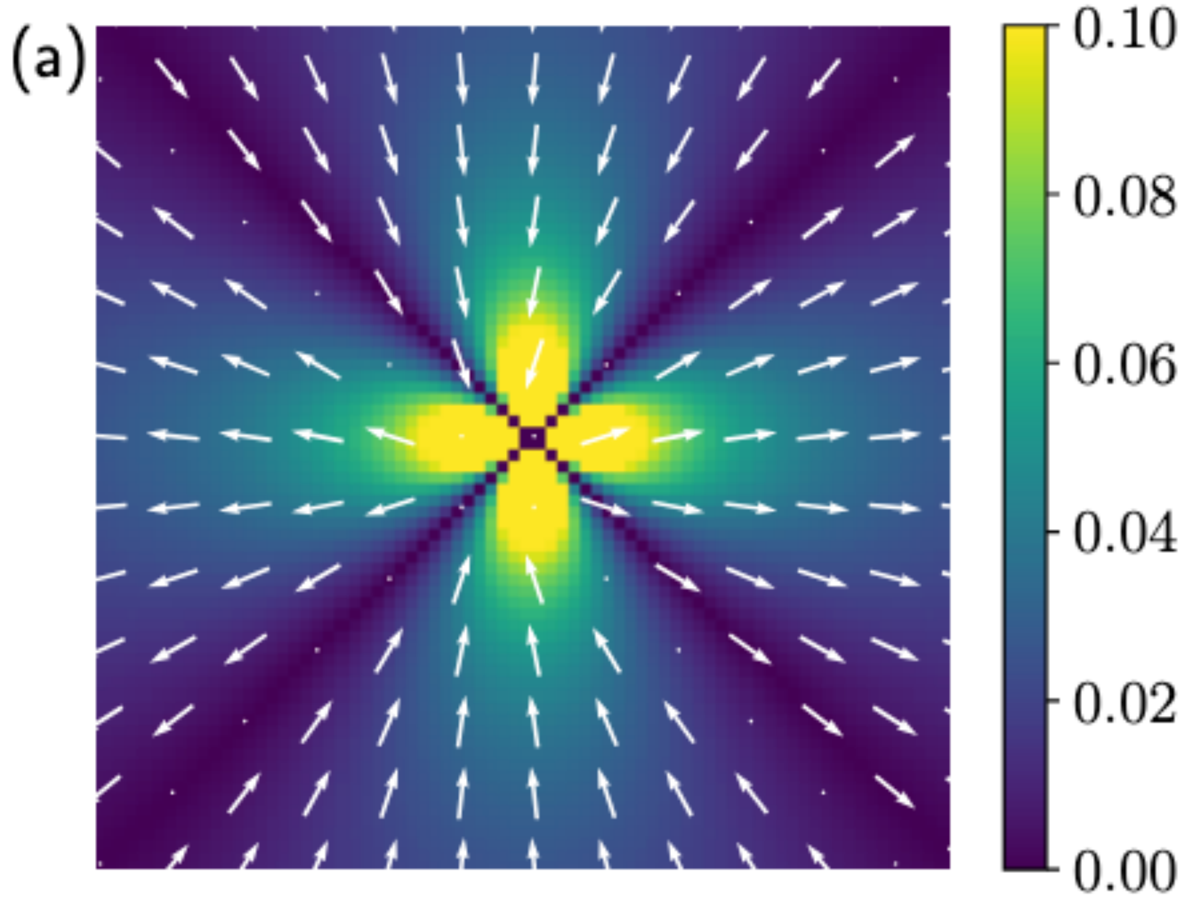
Soft Amorphous Systems: Eshelby Kernel

Simple shear

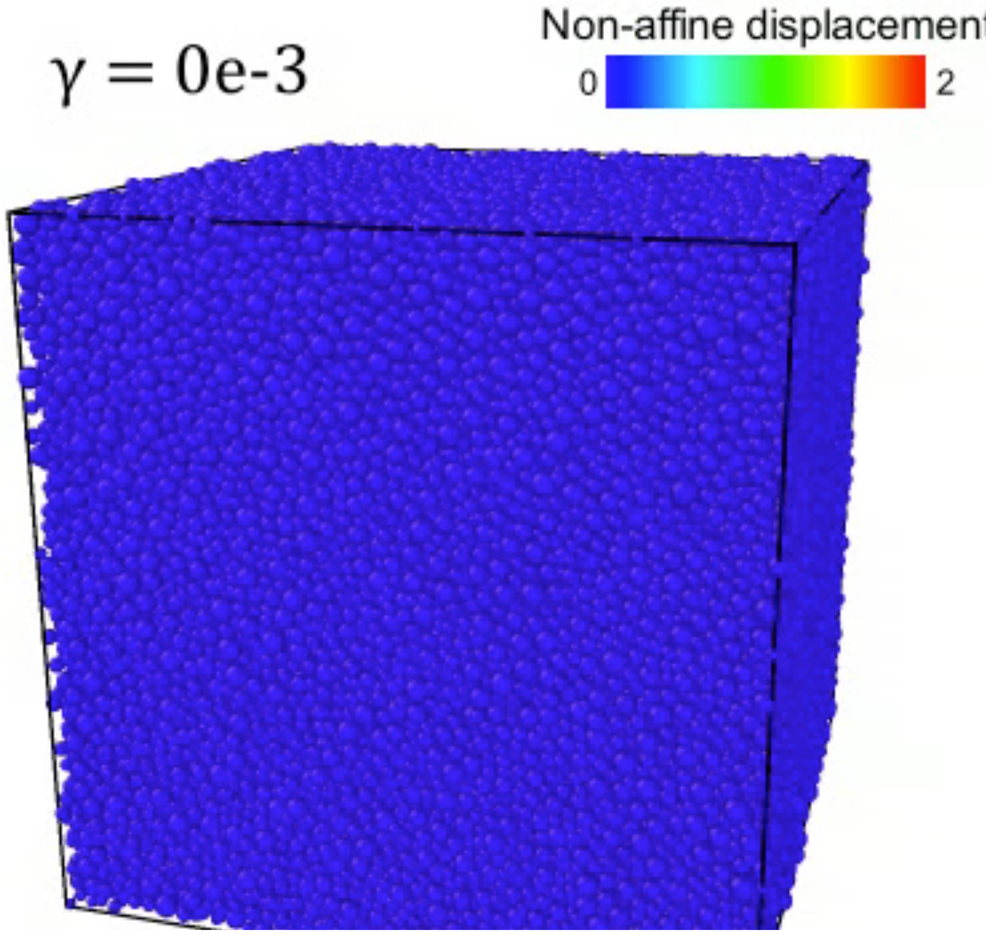


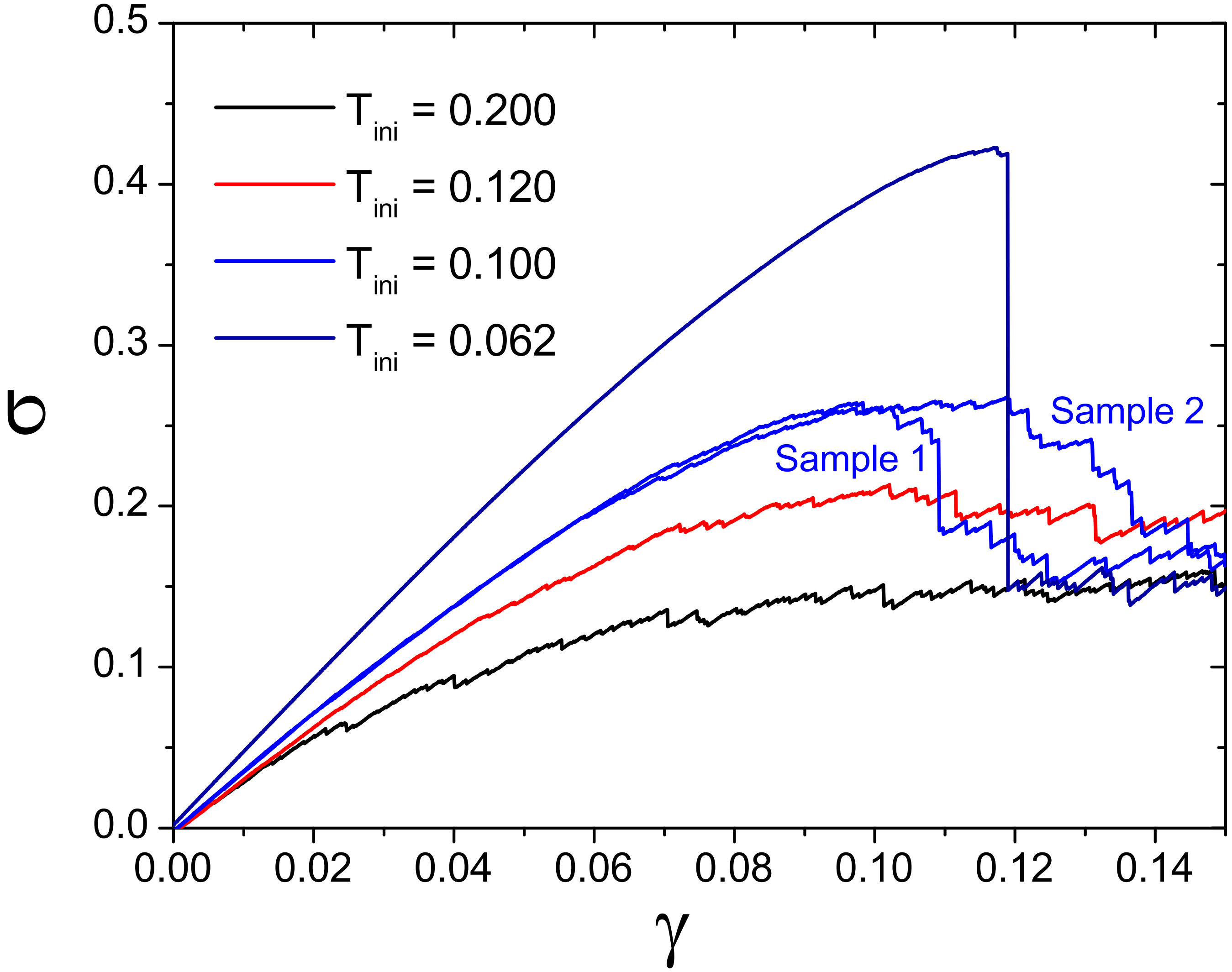
$$x_i \to x_i + \Delta$$

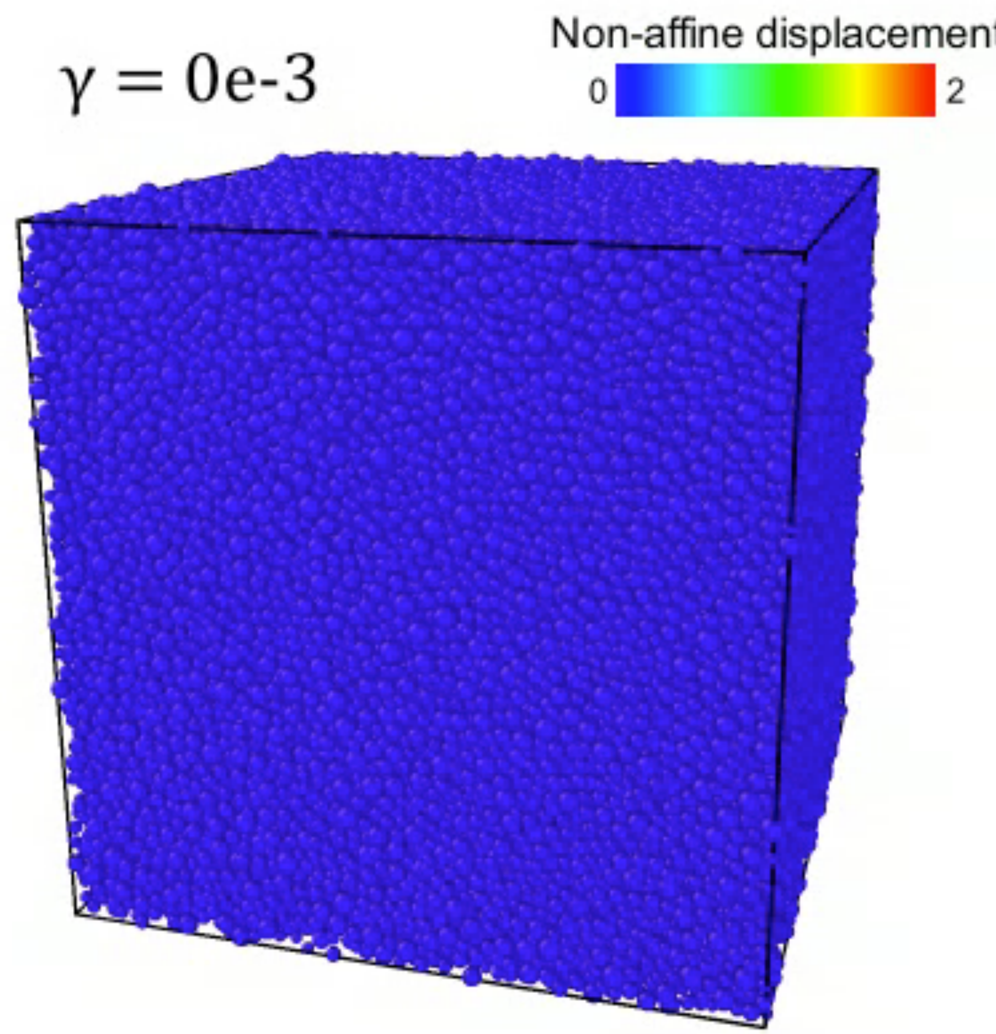
$$x_j \to x_j - \frac{\cos(4\theta_{ij})}{r_{ij}^2}\Delta$$



Brittle Glass







Ductile Foam

by Misaki Ozawa