Globalization, Cultural Drift and Social Networks




Konstantin Klemm Victor M. Eguíluz Raúl Toral Maxi San Miguel

http://www.imedea.uib.es/PhysDept

Axelrod's model of social influence *(J. Conflict Res. 41, 203 (1997))*

Question: "*if people tend to become more alike in their beliefs, attitudes and behavior when they interact, why do not all differences eventually disappear?*"

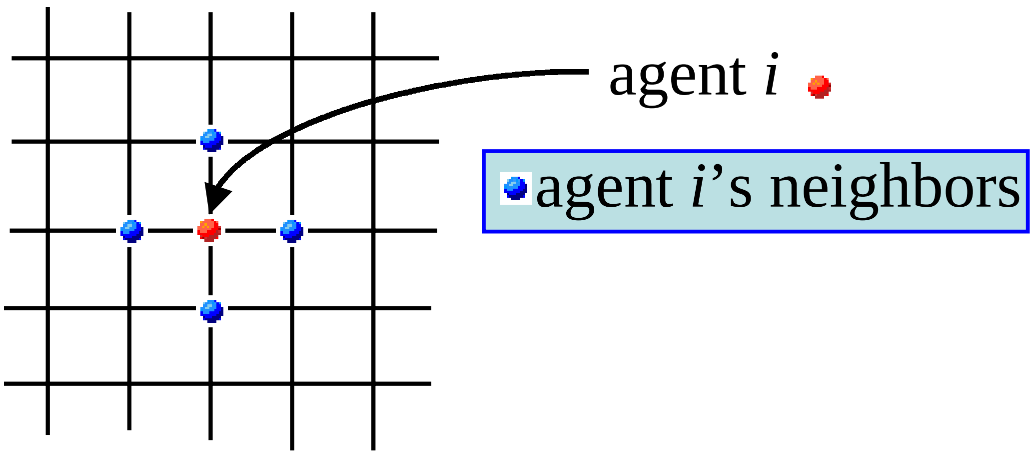
Proposal: Model to explore mechanisms of competition between ***globalization*** and persistence of ***cultural diversity***

- **Definition of culture:** Set of individual attributes subject to social influence
- **Basic premise:** The more similar an actor is to a neighbor, the more likely the actor will adopt one of neighbor's traits (communication most effective between similar people).
- **Novelty in social modeling:** it takes into account interaction between different cultural features.

Physics paradigm:

Cooperative behavior and order-disorder transition.

Axelrod’s agent’s based model: interaction



$$\begin{pmatrix} \sigma_{i1} \\ \sigma_{i2} \\ \vdots \\ \sigma_{iF} \end{pmatrix}$$

F = # **Features**

q = # **Traits** per feature

$\sigma_{if} \in \{0, \ldots, q-1\}$

F=3; q=10

q^F (10^3) *equivalent* cultural options.

$$\begin{pmatrix} 0 \\ 0 \\ 7 \end{pmatrix} \begin{pmatrix} 5 \\ 9 \\ 7 \end{pmatrix}$$

Mechanism of local convergence:

Prob to interact = $\frac{\text{Common features}}{F} = \frac{1}{3}$

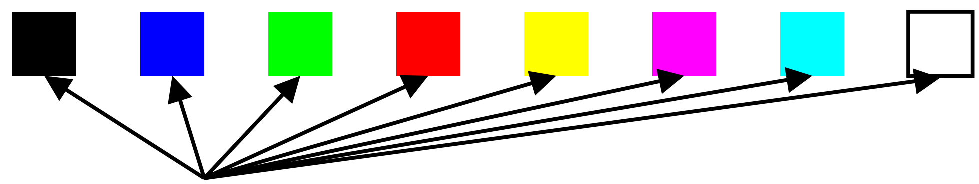
$$\rightarrow \begin{pmatrix} 5 \\ 0 \\ 7 \end{pmatrix} \begin{pmatrix} 5 \\ 9 \\ 7 \end{pmatrix}$$

Visualization of Axelrod´s Dynamics

Color code for

F=3, q=2

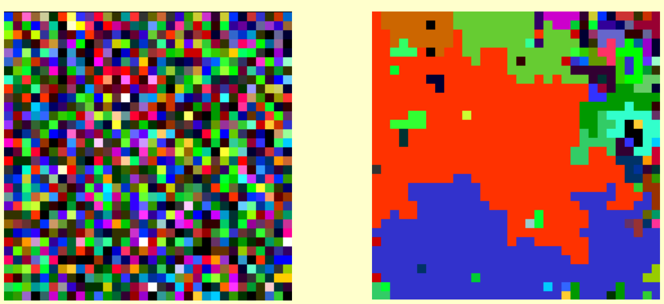
$$\begin{pmatrix}0\\0\\0\end{pmatrix}\begin{pmatrix}0\\0\\1\end{pmatrix}\begin{pmatrix}0\\1\\0\end{pmatrix}\begin{pmatrix}1\\0\\0\end{pmatrix}\begin{pmatrix}1\\1\\0\end{pmatrix}\begin{pmatrix}1\\0\\1\end{pmatrix}\begin{pmatrix}0\\1\\1\end{pmatrix}\begin{pmatrix}1\\1\\1\end{pmatrix}\begin{pmatrix}f=0\rightarrow R\\f=1\rightarrow G\\f=2\rightarrow B\end{pmatrix}$$



We can identify a cultural domain with a given colour.

In general for q >2, q weights the basic colours (**R**,**G**,**B**): $0 \le \sigma_{if}/(q-1) \le 1$

$F = 3,\ q = 10$



$t = 0$ ⟶ System freezes in an absorbing multicultural state

• The model illustrates how **local convergence** can generate **global polarization.**

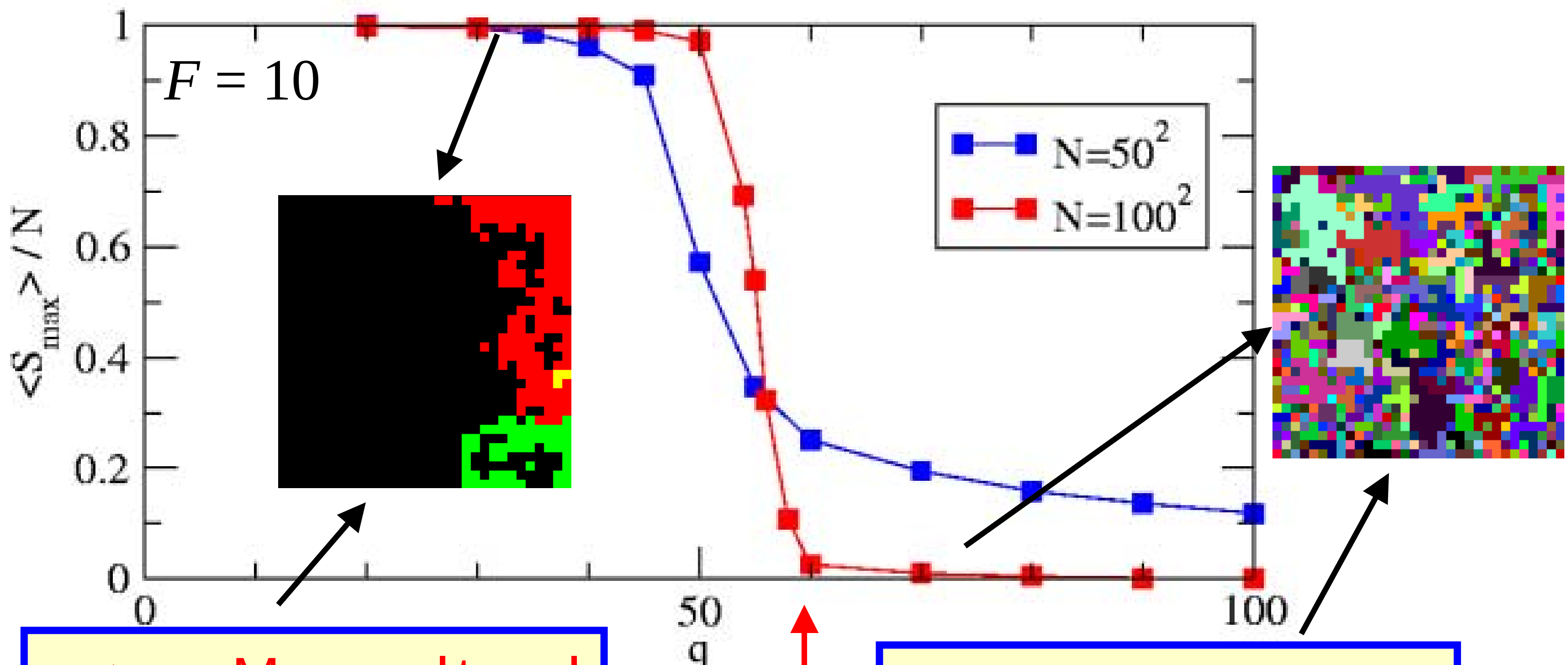
• Number of domains taken as a measure of cultural diversity

http://www.imedea.uib.es/PhysDept research_topics/socio/culture.html

Statistical Physics: a nonequilibrium phase transition

Castellano et al, Phys. Rev. Lett. 85, 3536 (2000)

- Order parameter: S_{max} size of the largest homogeneous domain
- Control parameter: q measures initial degree of disorder.



$q < q_c$: Monocultural

Global culture

q_c

$q > q_c$: Multicultural

Cultural diversity

Global polarization

Transition well defined as N → ∞

Beyond Axelrod's original model

Cultural drift: *"Perhaps the most interesting extension and at the same time, the most difficult one to analyze is cultural drift (modeled as spontaneous change in a trait)."* **R. Axelrod, J. Conflict Res. (1997)**

Questions:
1. Measure of heterogeneity.
2. Time scales of evolution.

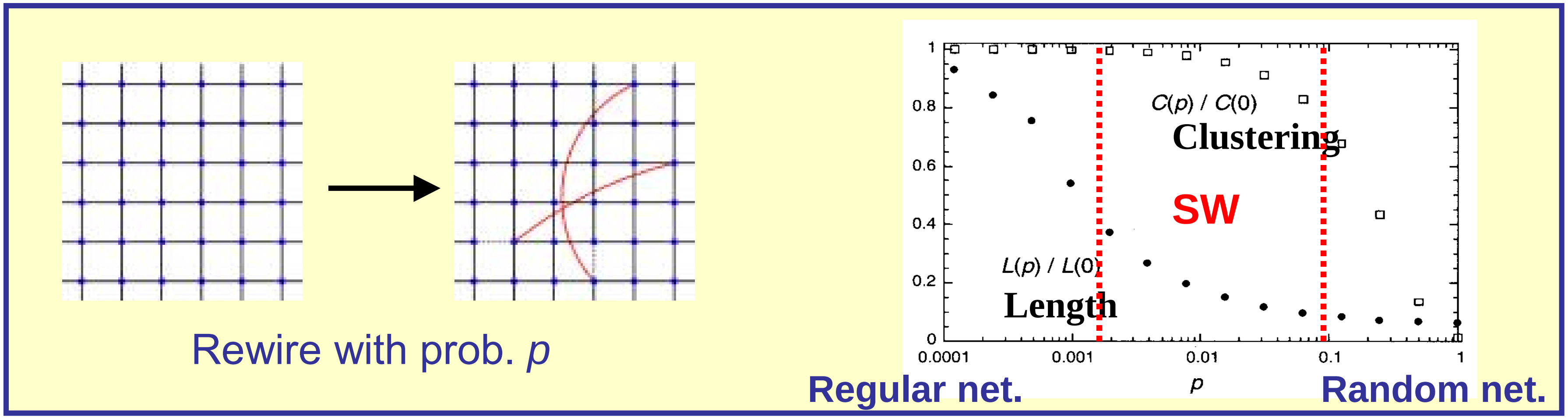
Role of noise?

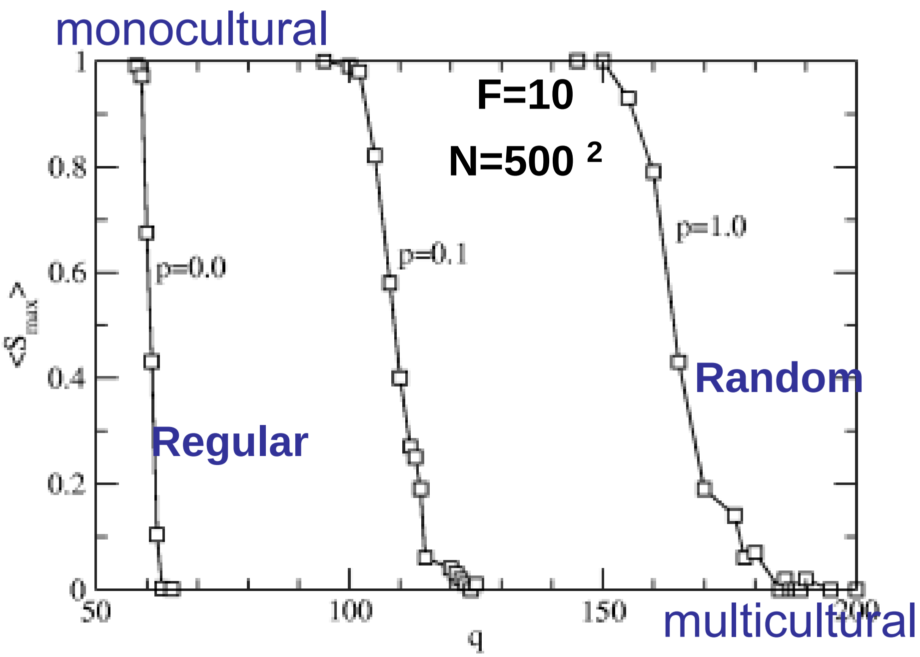
Social cleavages: *"Electronic communication allow us to develop patterns of interaction which are chosen rather than imposed by geography ... Local convergence will be based not on geography, but on emergent patterns of more or less like-minded communication."*
R. Axelrod, J. Conflict Res. (1997)

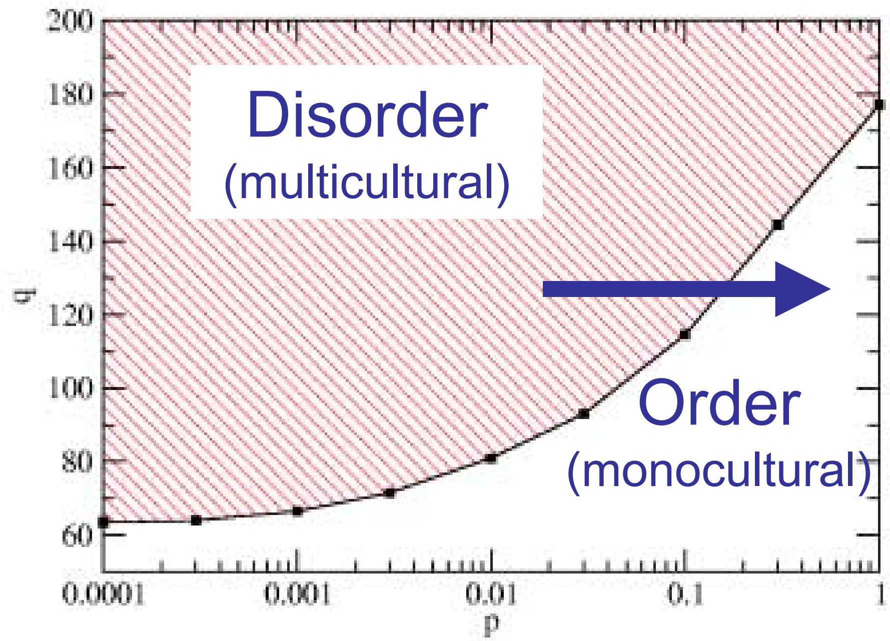
⇒**Network topology**
1. **Small-world networks**
2. **Scale-free networks**

Small-world networks

Watts, Strogatz, Nature 393, 440 (1998)



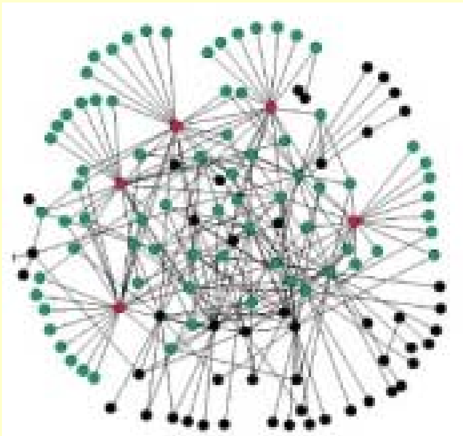




Small world connectivity favors cultural globalization

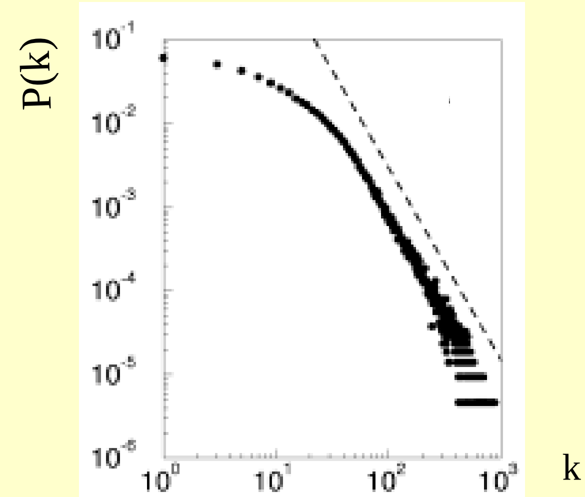
Scale-free networks

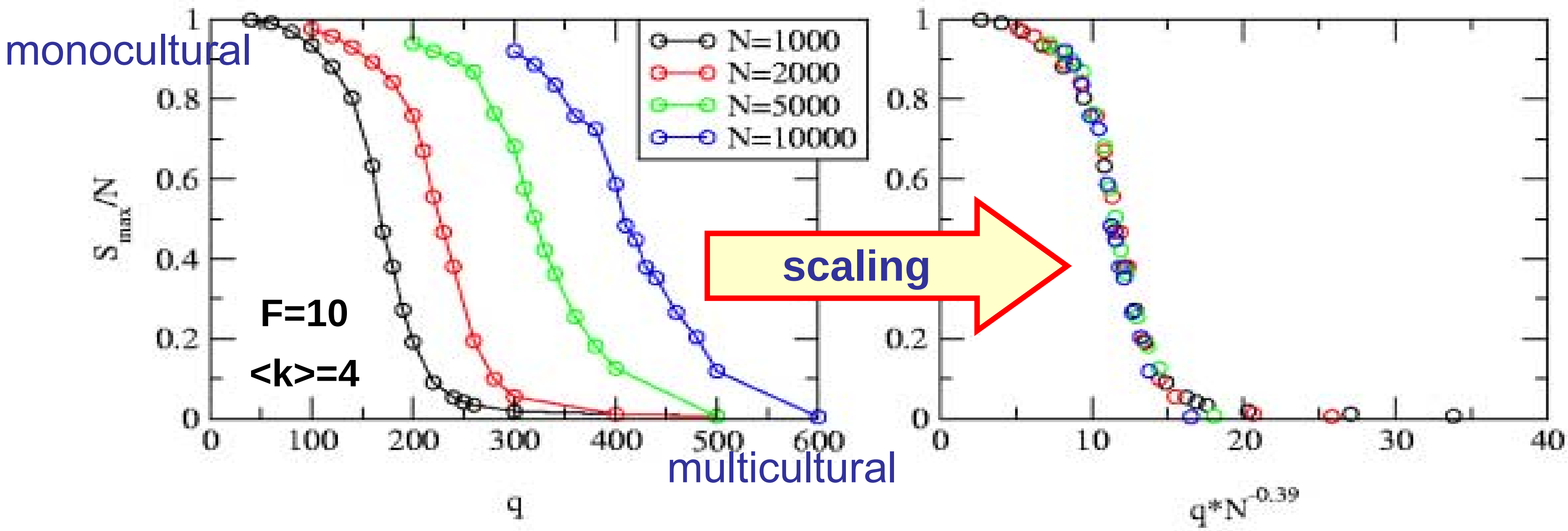
Albert & Barabasi, Rev. Mod. Phys.74, 47 (2002)



Power law for the degree distribution

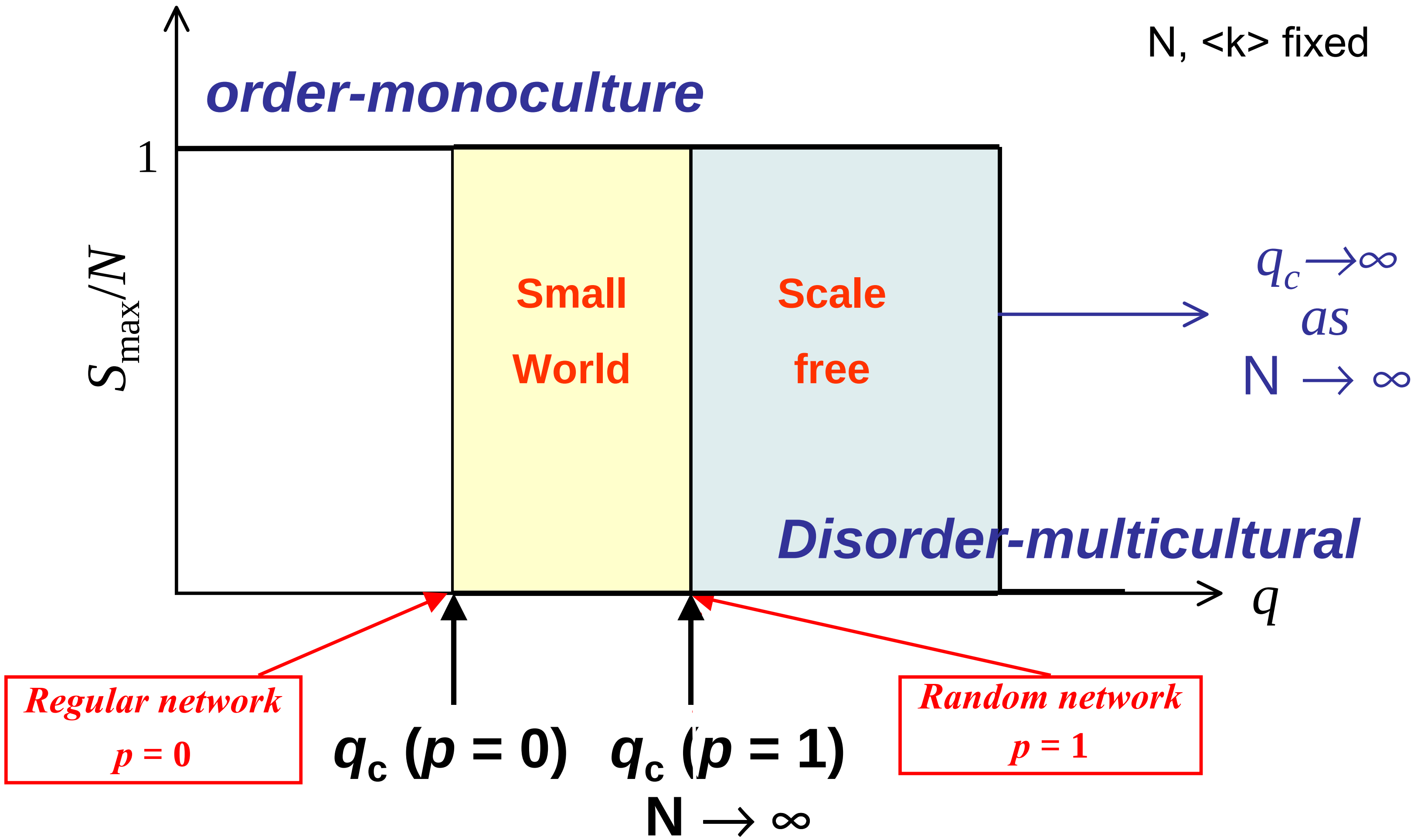
$P(k) \sim k^{-\gamma}, \ \gamma=3$





System size scaling: Global culture prevails for N $\to \infty$

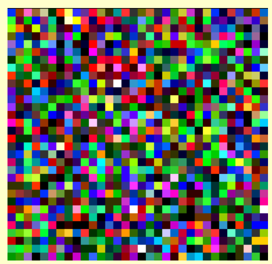
Social Networks and Cultural Globalization



Scale free connectivity is more efficient than random connectivity in promoting global culture

Cultural drift

Cultural drift: *"Perhaps the most interesting extension and at the same time, the most difficult one to analyze is cultural drift (modeled as spontaneous change in a trait)."* **R. Axelrod, J. Conflict Res. (1997)**



$t = 0 \longrightarrow$ System freezes in an absorbing multicultural state

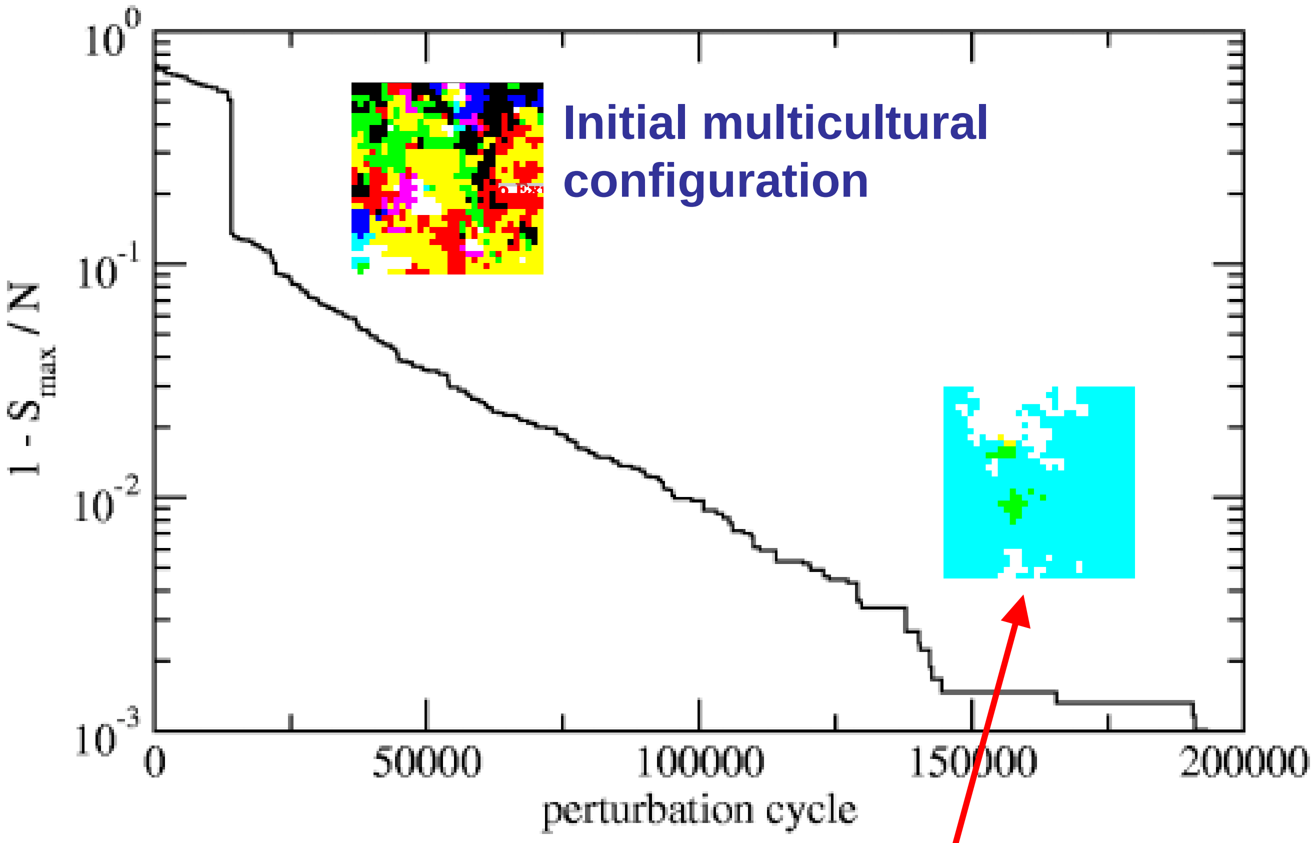
Metastable states

Perturbation-relaxation cycles:

1. Perform ***single feature perturbation***

2. Let the system ***relax*** to an absorbing state.

3. Return to 1.

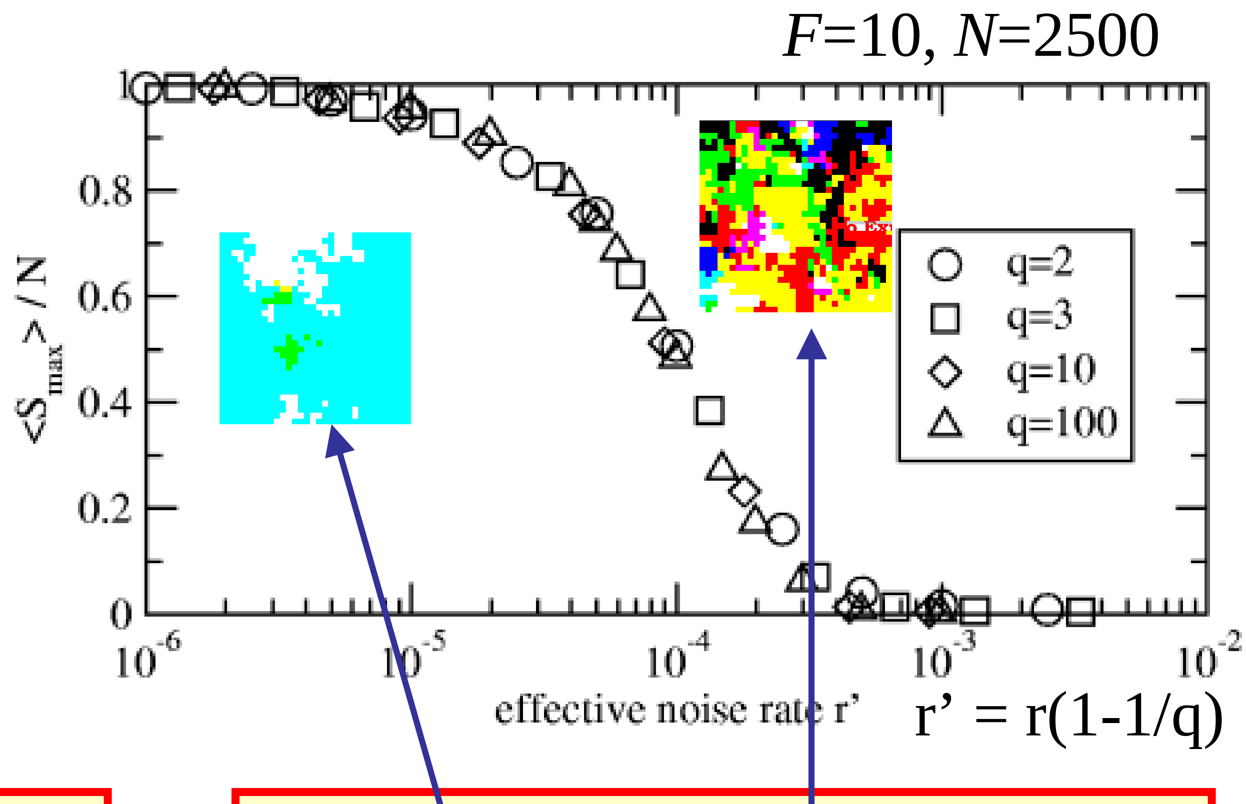


System driven by noise towards a state of global culture

Transition to global culture controlled by noise rate

Cultural drift:

Single feature random perturbation acting continuously at rate r



States of "global culture" for any q as $r \to 0$:

Cultural drift destroys the transition controlled by q that occurs at r=0.

Transition from multicultural to "global culture" states controlled by noise rate r´ with universal *scaling properties* with respect to *q.*

1/q: Probability of configuration unchanged in a perturbation

Why does the noise rate cause a transition?

Competition between noise time scale (1/r) and relaxation time of perturbations T:

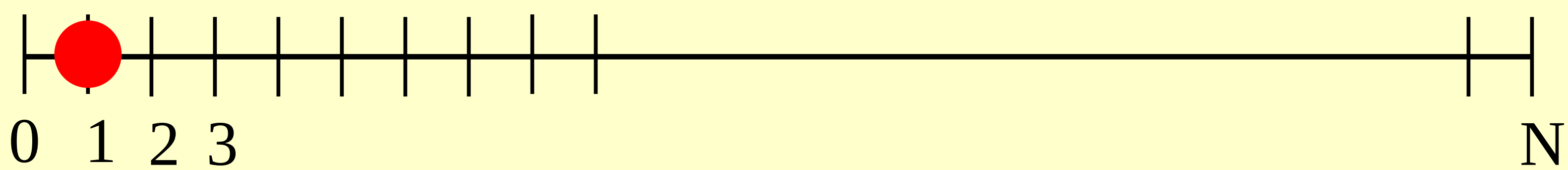
•Small noise rate: There is time to relax and system decays to monocultural state

•Large noise rate: Perturbations accumulate and multicultural disorder is built up

Transition expected for $rT \sim 1$

What is the relaxation time T?

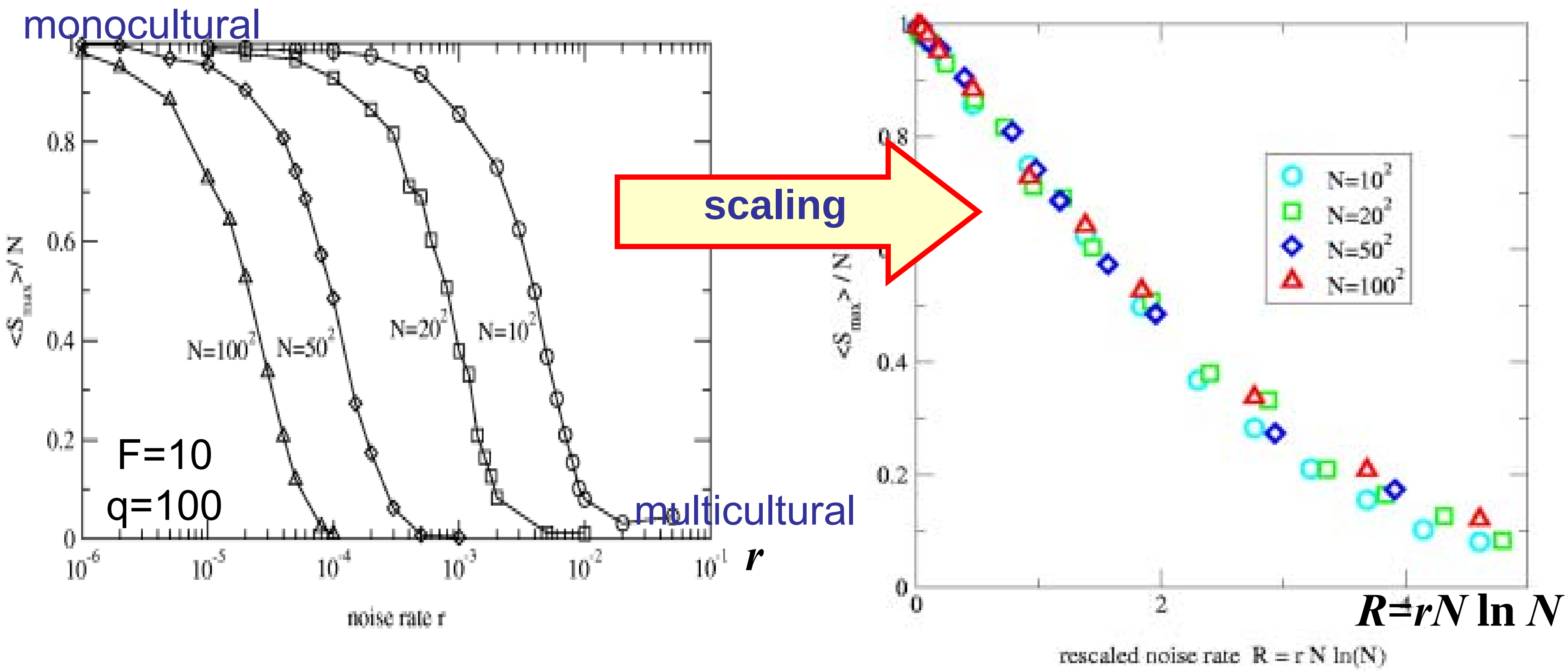
Exit time in *random* walks (mean field)



Damage x(0)=1 reaches x=0 or x=N in a mean exit time

$$T \sim N \ln N$$

System size dependence



- <u>Fixed system size:</u> Universal transition for $rT \sim rN \ln N \sim 1$
- <u>Large systems:</u>

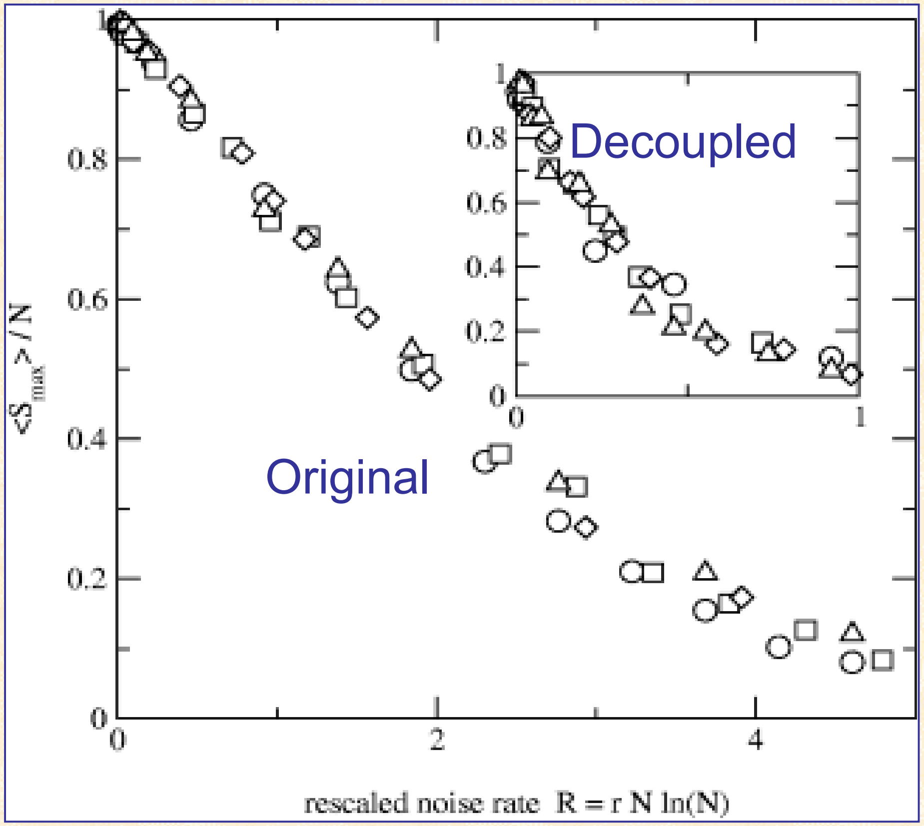
  For $N \rightarrow \infty$ multicultural states prevail at any finite noise rate.

  Global polarization persists, but as a noise sustained state instead of a frozen configuration.

Decoupled model

Motivation: Correct estimates independent of sites overlap

Model: a site always adopts the trait of the chosen neighboring site independently of the number of shared features.



In the presence of cultural drift our main results are insensitive to Axelrod´s basic premise:

Cultural overlap is not essential for local convergence

What is more worrying is that all the models yield more or less the same outcome (N. Gilbert)

Cultural Drift: Summary *cond-mat/0205188*

•**Relevance of time scales:** Noise induced order-disorder transition for $r \sim T^{-1}(N)$. Scaling properties with respect to q and N.

•**Metastability:** Multicultural frozen configurations are metastable and for small noise rate $(r < T^{-1}(N))$ a state of global culture is *induced by noise* independently of the number of traits (q).

•**Size dependence:** For large systems and arbitrarily small noise rate ($r > T^{-1}(N) \rightarrow 0$) the multicultural state prevails: Axelrod's global polarization in spite of local convergence is recovered.

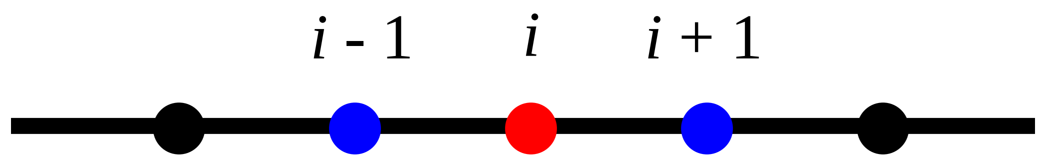
•**Dynamical nature of states:** Ordered state: Jumps among monocultural configurations. Multicultural state: Noise sustained dynamics.

Cultural drift is a crucial ingredient which drastically modifies the dynamics of Axelrod´s model. In particular the basic premise on cultural overlap becomes irrelevant

http://www.imedea.uib.es/PhysDept/research_topics/socio/culture.html

Lyapunov potential in 1-d network

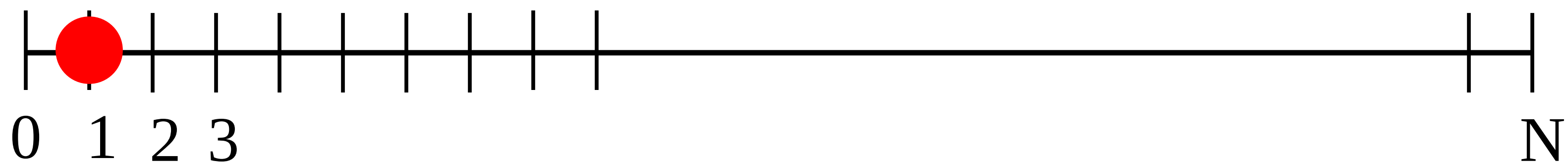
$V = -\Sigma_i\, l(i,i+1)$



- updating *i* with neighbor *i*+1 increases $l(i,i+1)$ by 1.
- at worst $l(i-1,i)$ decreases by 1.
- no other terms in *V* are affected.
- *V* never increases.
- Ground states l(i,i+1)=F ⟹ $V_{min}=-NF$
- All other absorbing states with $V > V_{min}$ are metastable.

What causes the onset of disorder with increasing noise rate? $rT \sim 1$

Exit time in *random* walks (mean field)



- Initial damage x(0)=1
- x(t) is a random walk with diffusion "constant"

$$D(x) = 2\frac{x(N-x)}{N^2}$$

- perturbation has relaxed when damage reaches x=0 or x=N.
- Average relaxation ("exit") time

$$T = N \ln N$$