



IMEDEA



Globalization, Polarization, Cultural Drift and Social Networks



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Nonequilibrium transitions in complex networks: a model of social interaction, Phys. Rev. E 67, 026120 (2003)

Global culture: A noise induced transition in finite systems, Phys Rev. E 67, 045101 (2003), Physica A 327, 1 (2003)

Globalization, polarization and cultural drift, J. Economic Dynamics and Control 29, 321-334 (2005)

Cultural drift and Dynamical networks, unpublished

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 ("polarization")*

• **Definition of culture:** Set of individual attributes subject to social influence

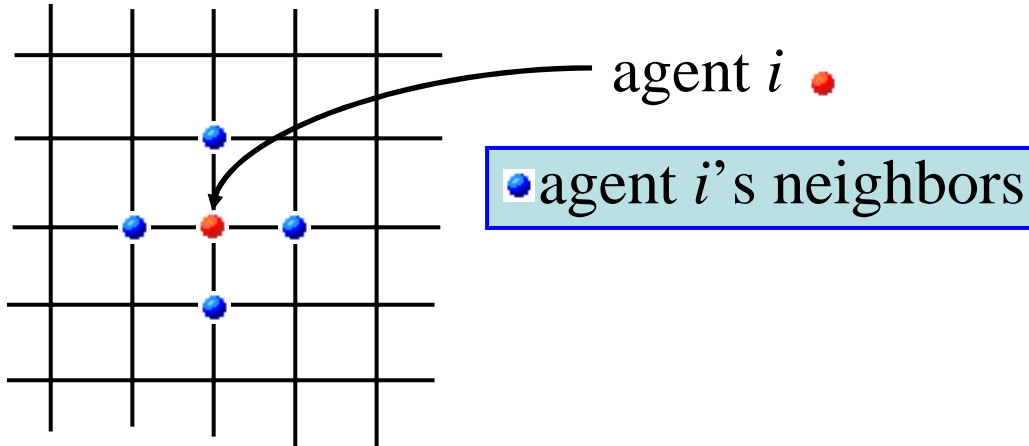
• **Basic premise:** The more similar an actor is to a neighbor, the more likely the actor will adopt one of neighbor's traits (communication most effective between similar people).

• **Novelty in social modeling:** it takes into account interaction between different cultural features.

Physics paradigm: Cooperative behavior and order-disorder transition

"This work is about the mechanisms that translate individual unorganized behavior into collective results" **(T.Schelling, J. Math. Sociology (1971))**

Axelrod's agents based model: interaction

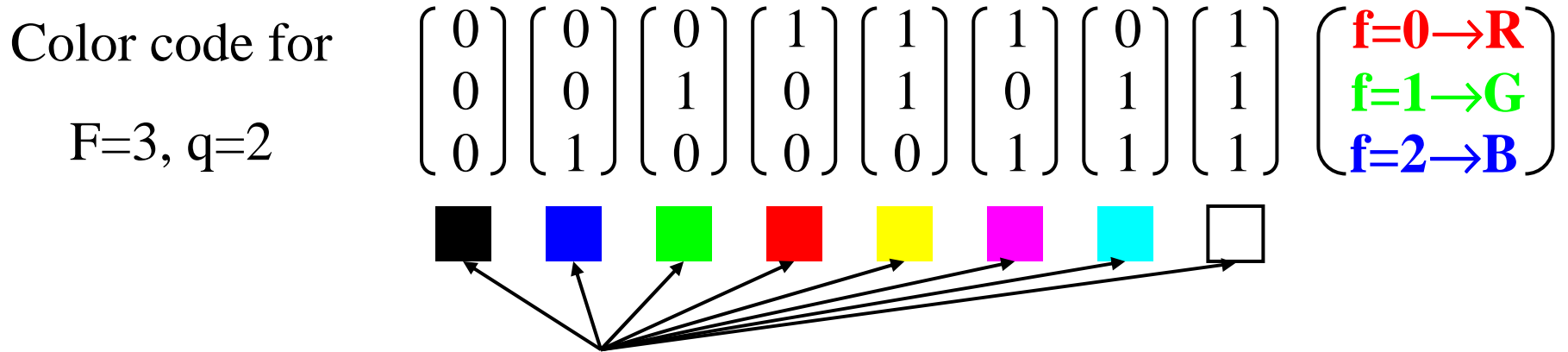


σ_{i1}	$F = \# \text{ Features}$
σ_{i2}	$q = \# \text{ Traits per feature}$
\vdots	
σ_{iF}	$\sigma_{if} \in \{0, \dots, q-1\}$

$F=3; q=10$ $q^F (10^3)$ equivalent cultural options.

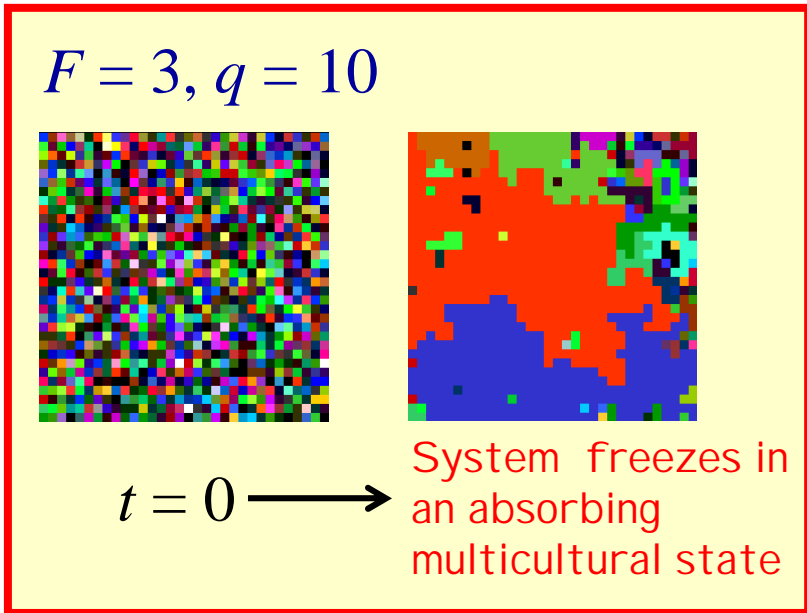
$\left(\begin{array}{c} 0 \\ 0 \\ 7 \end{array} \right)$	$\left(\begin{array}{c} 5 \\ 9 \\ 7 \end{array} \right)$	<p>Mechanism of local convergence:</p> <p>Prob to interact =</p> <p>Common features = $\frac{1}{3}$</p> <p style="text-align: center;">F</p>	$\left(\begin{array}{cc} 5 & 5 \\ 0 & 9 \\ 7 & 7 \end{array} \right)$
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Visualization of Axelrod's Dynamics



We can identify a cultural domain with a given colour.

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



- The model illustrates how **local convergence** can generate **global polarization**.
- Number of domains taken as a measure of cultural diversity
- Uniform state always prevails without similarity rule (*Kennedy 1998*)

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

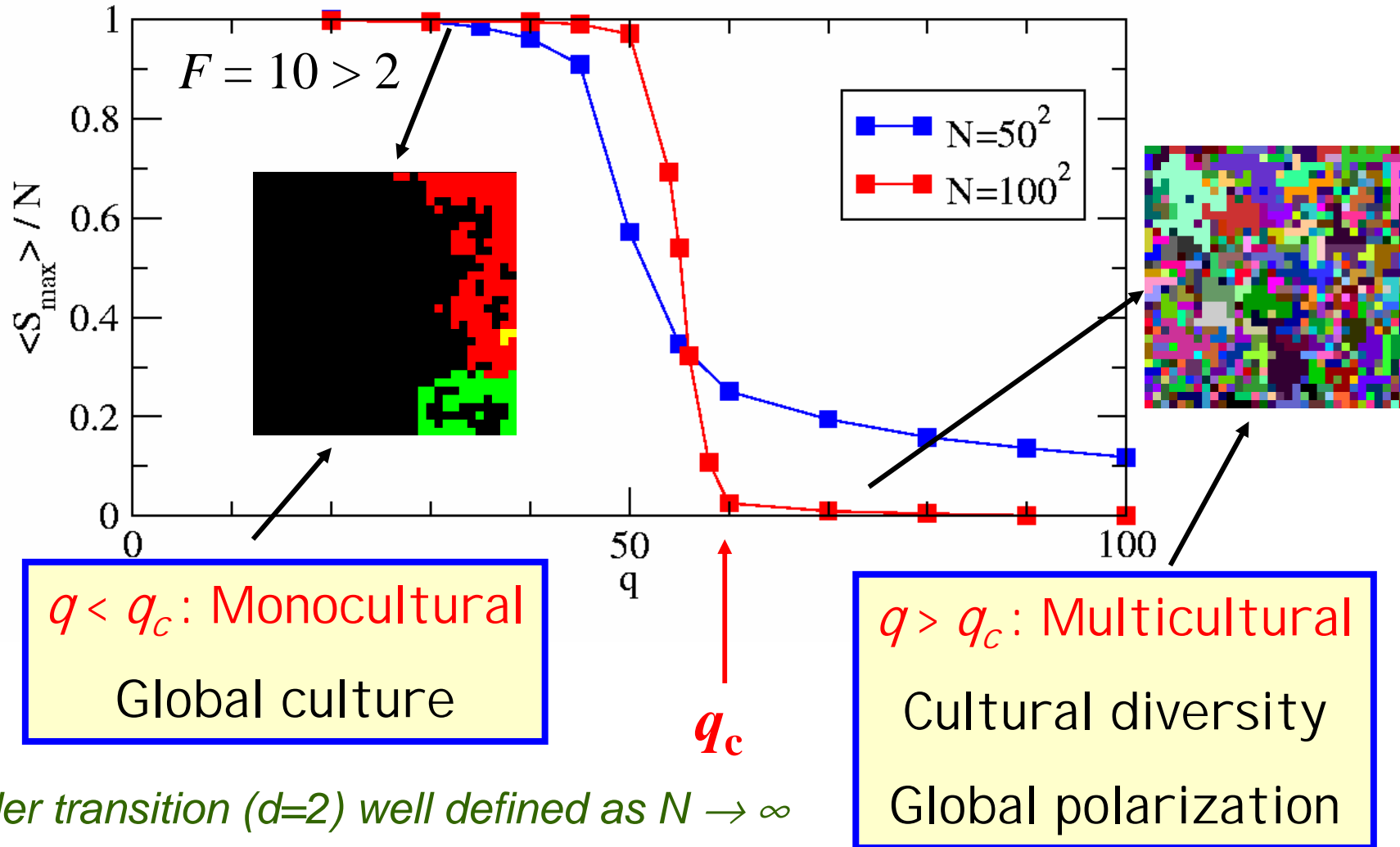
Statistical Physics: a nonequilibrium phase transition

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

- Order parameter: S_{\max} size of the largest homogeneous domain

Lewenstein et al (1992)

- Control parameter: q measures initial degree of disorder.



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?

B. Latane et al., Behav. Science (1994)

 **Beyond T=0**

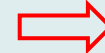
Social cleavages: *"Electronic communication allow us to develop patterns of interaction which are chosen rather than imposed by geography ... With random long distance interactions, the heterogeneity sustained by local interactions cannot be sustained."*

R. Axelrod, J. Conflict Res. (1997)

⇒ Network topology

1. Small-world networks

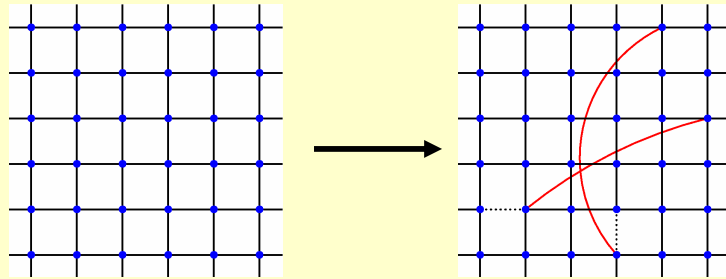
2. Scale-free networks



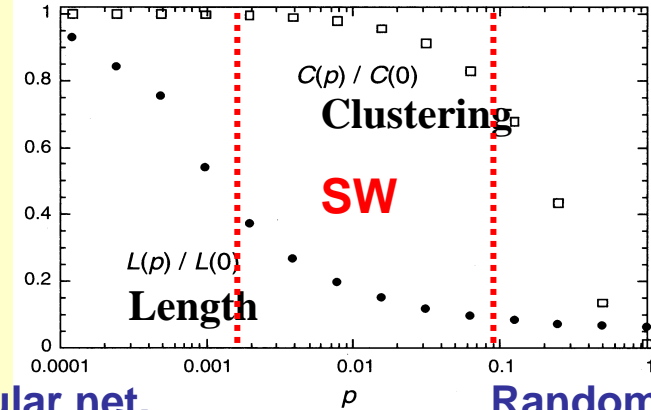
**Structured
scale-free**

Small-world networks

Watts, Strogatz, *Nature* 393, 440 (1998)

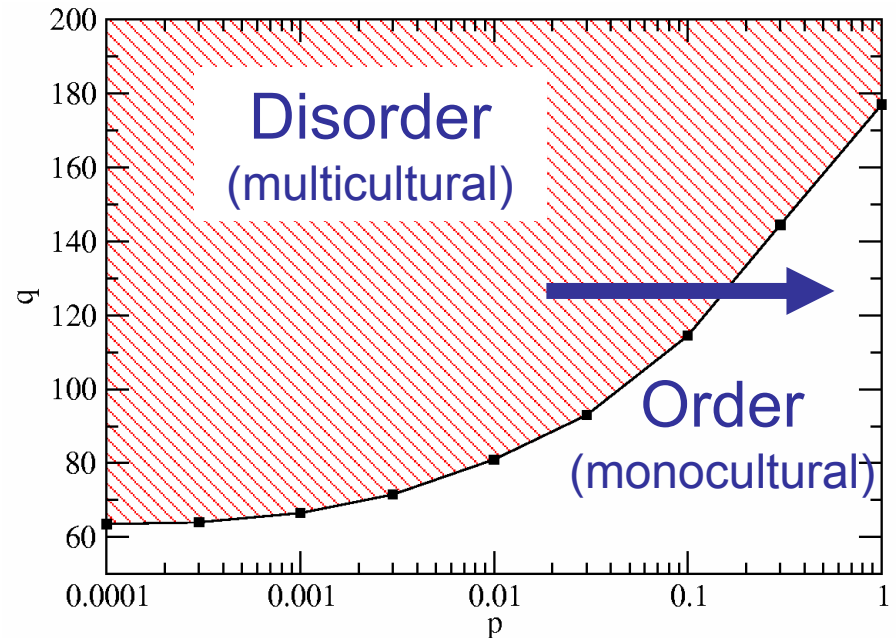
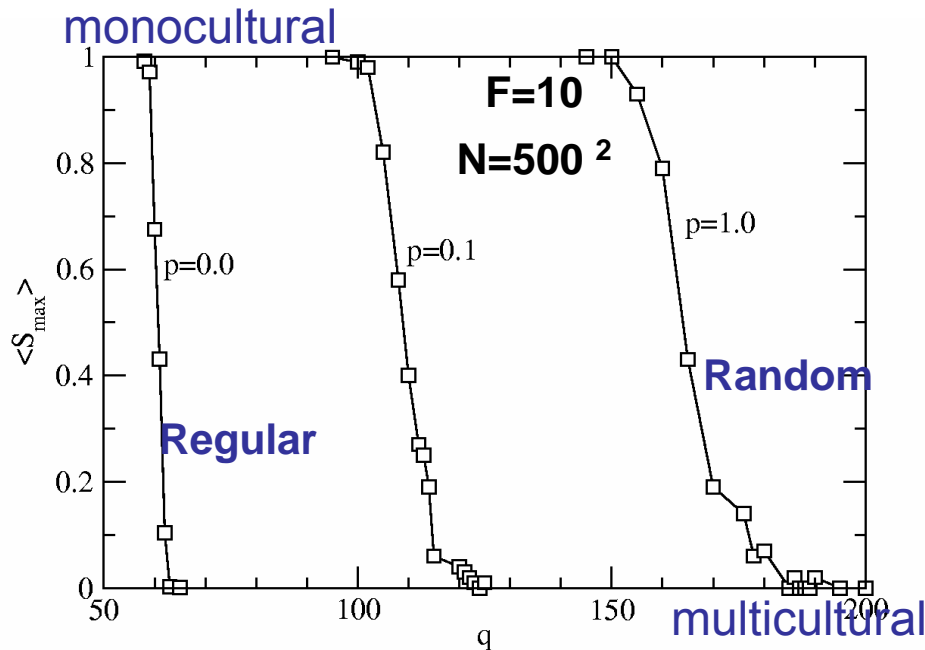


Rewire with prob. p



Regular net.

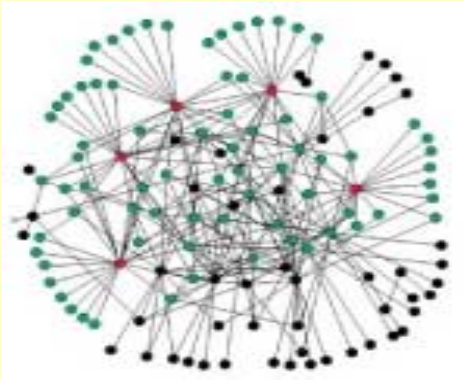
Random net.



Small world connectivity favors cultural globalization

Scale-free networks

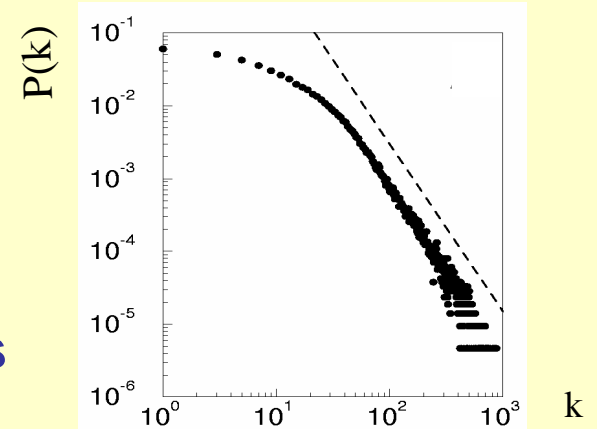
Albert & Barabasi, *Rev. Mod. Phys.* 74, 47 (2002)



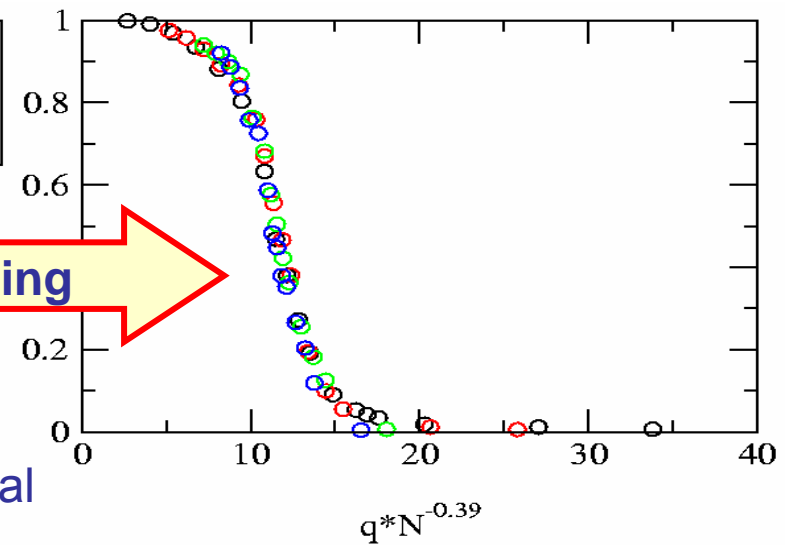
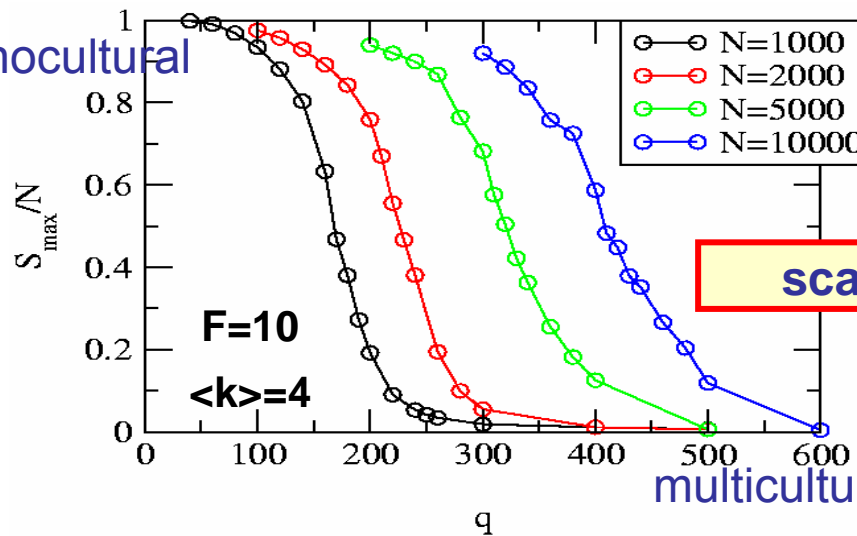
Power law for the degree distribution

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

Importance of hubs



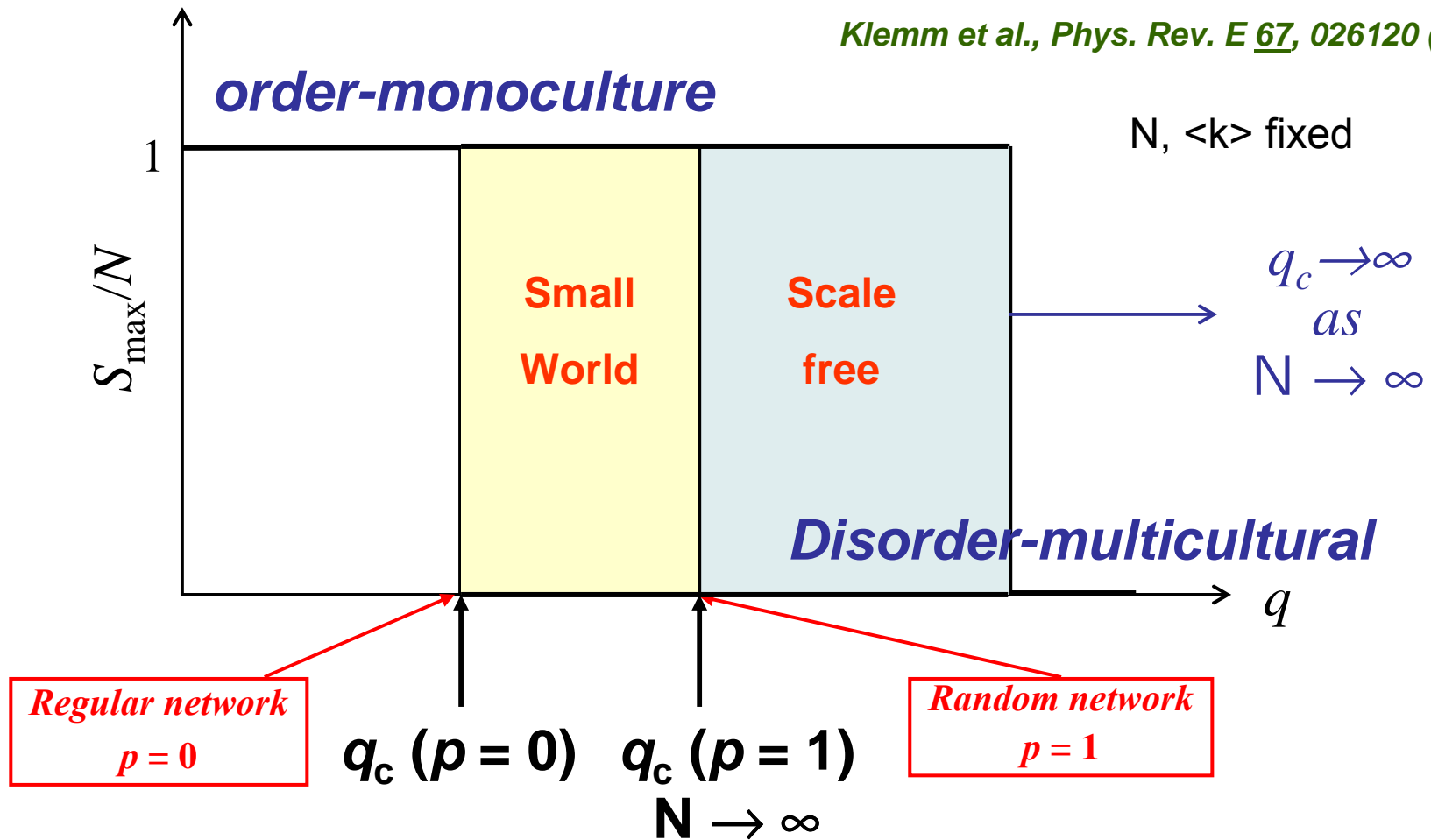
LINK UPDATE!: See voter model and conservation laws, *KS, VME, MSM, Europhys. Lett.* 69, 228 (2005)



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

Social Networks and Cultural Globalization

Klemm et al., Phys. Rev. E 67, 026120 (2003)



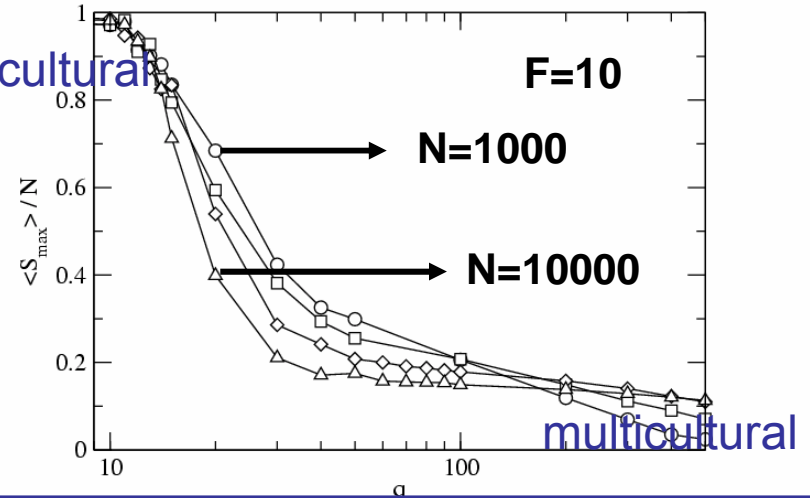
Scale free connectivity is more efficient than random connectivity in promoting global culture

Structured scale-free networks

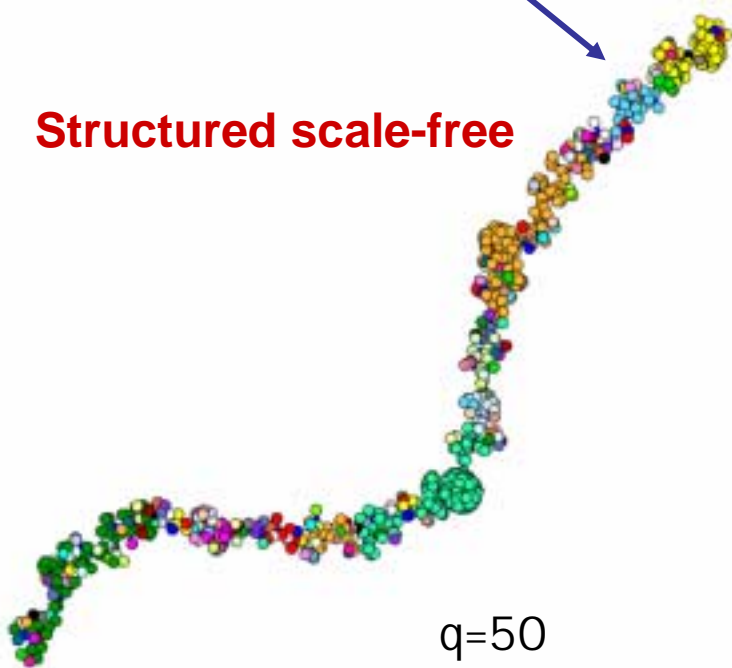
Nonrandom scale free :
High clustering, $C \sim N^0$

- Transition for $N \rightarrow \infty$.
- Hubs create ordered clusters in disordered state

monocultural

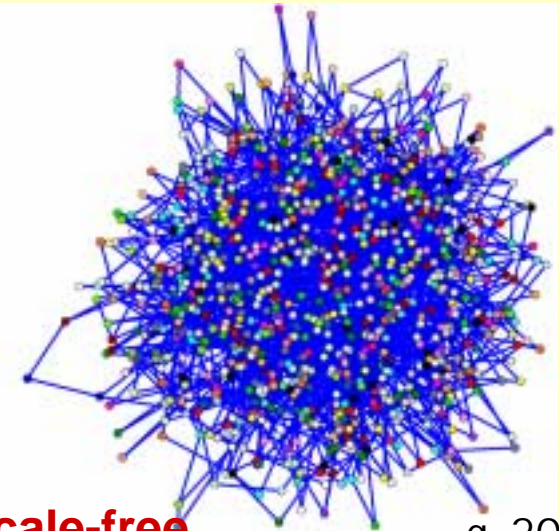


Structured scale-free



Disordered multicultural states

$N=1000$
 $F=10$

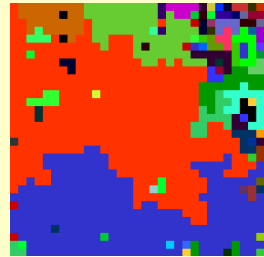
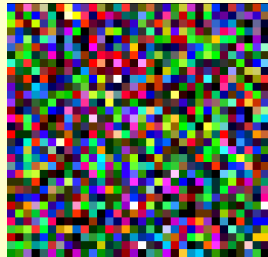


Random scale-free

$q=200$

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)



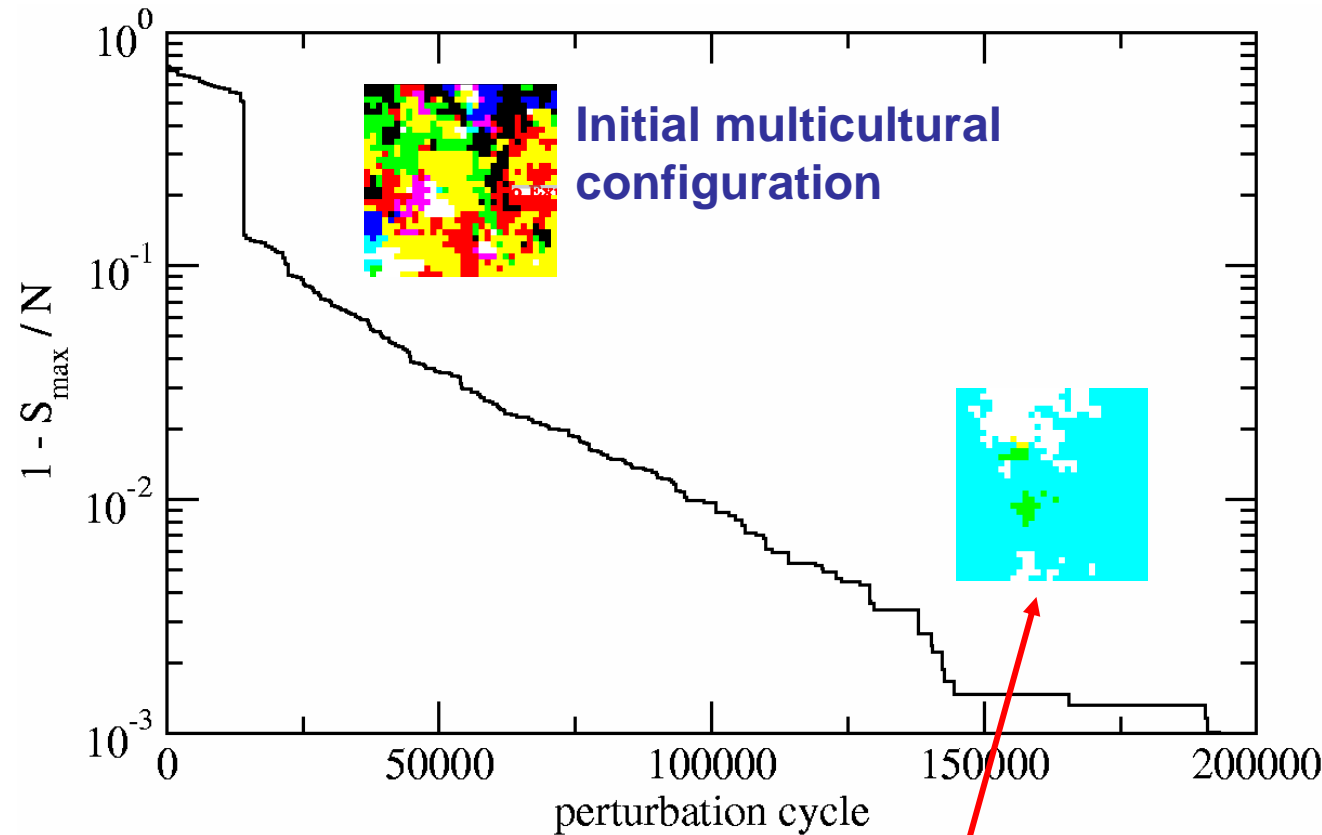
$t = 0 \longrightarrow$

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.



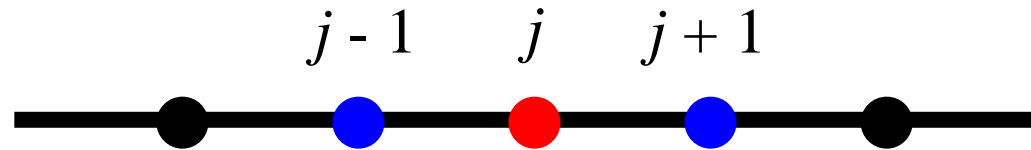
System driven by noise towards a state of global culture

$d=1$: Lyapunov potential exists

Lyapunov potential in 1-d network

Klemm et al. J. Economic Dynamics and Control 29, 321 (2005)

$$L = -\sum_i l(i, i+1)$$



$$L(t) \geq L(t+1)$$

$l(i, j)$ = overlap: number of shared features

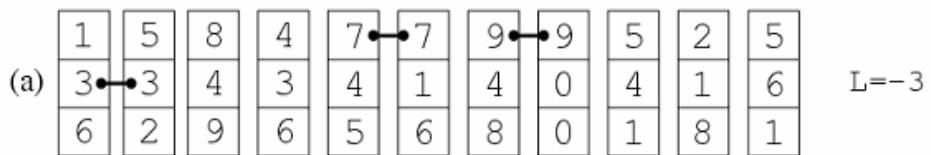
STABILITY

- Homogeneous configurations are equivalent global minima of L ($L_{\min} = -(N-1)F$). They are **metastable** states.
- All other absorbing states are **NOT** minima of L . There are always neighboring configurations with the same or lower value of L .
Marginally stable or **unstable** states.

DYNAMICS

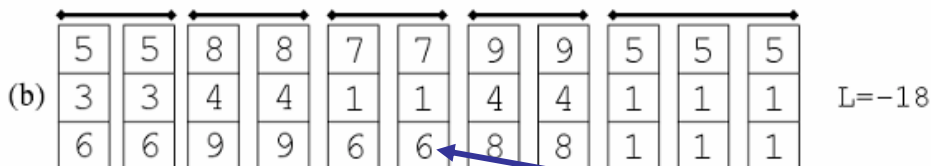
Change of L from initial random configuration to an absorbing state is **NOT small**. L_{\min} is not reached because of proximity in the value of L : Genuine nonequilibrium dynamics. Not an optimization dynamics

Lyapunov description: Attractors



Random initial condition, $F=3$, $q=10$, $N=11$

$$\langle L \rangle_0 = -(N-1)F/q$$

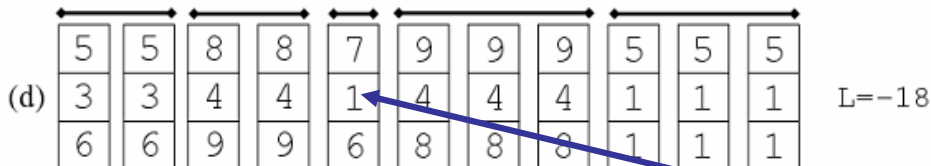


1st attractor reached by dynamics:

Marginally stable

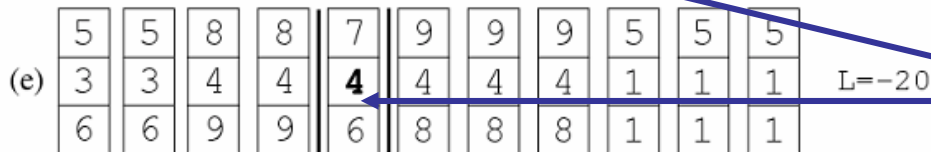


Single perturbation: L unchanged

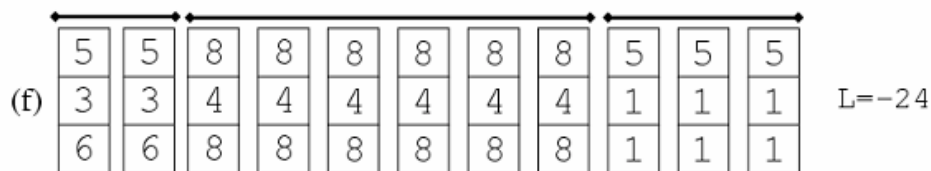


Next attractor reached by dynamics:

Unstable



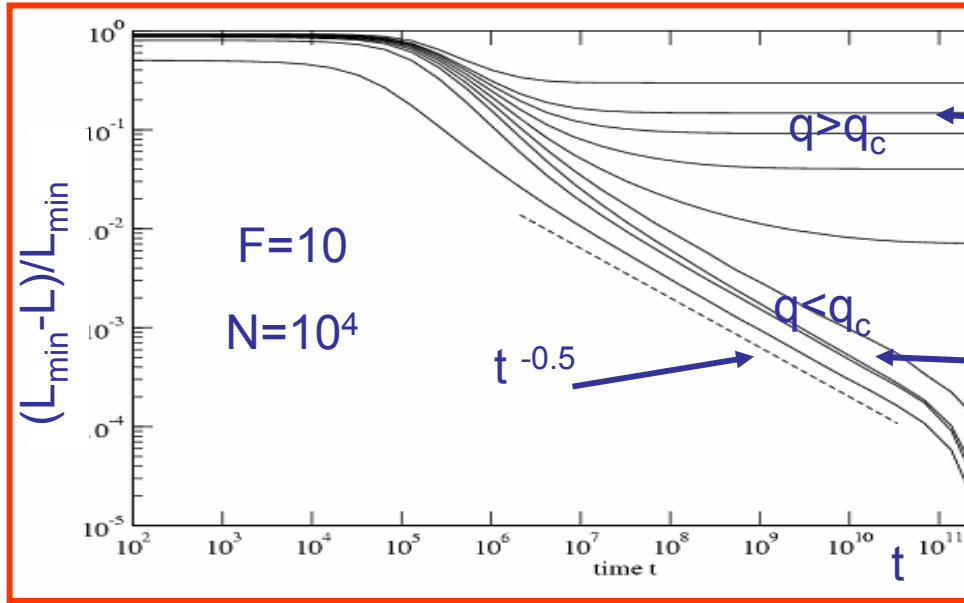
Single perturbation: L diminishes



Next attractor reached by dynamics:

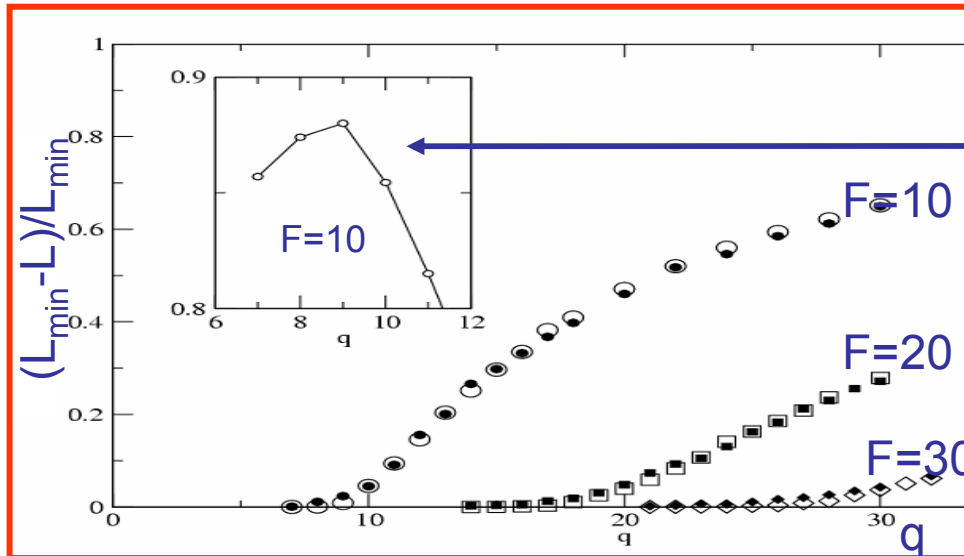
Smaller value of L and
smaller number of domains

Lyapunov description: Transition



L saturates to a finite value for $q < q_c$

L decays to L_{\min} as a power law for $q > q_c$



Normalized difference between initial L and value of L at absorbing state is large

Transition in $d=1$
 for $F \sim q$
Vilone et al. Eur. Phys. J. B 30, 399 (2002)

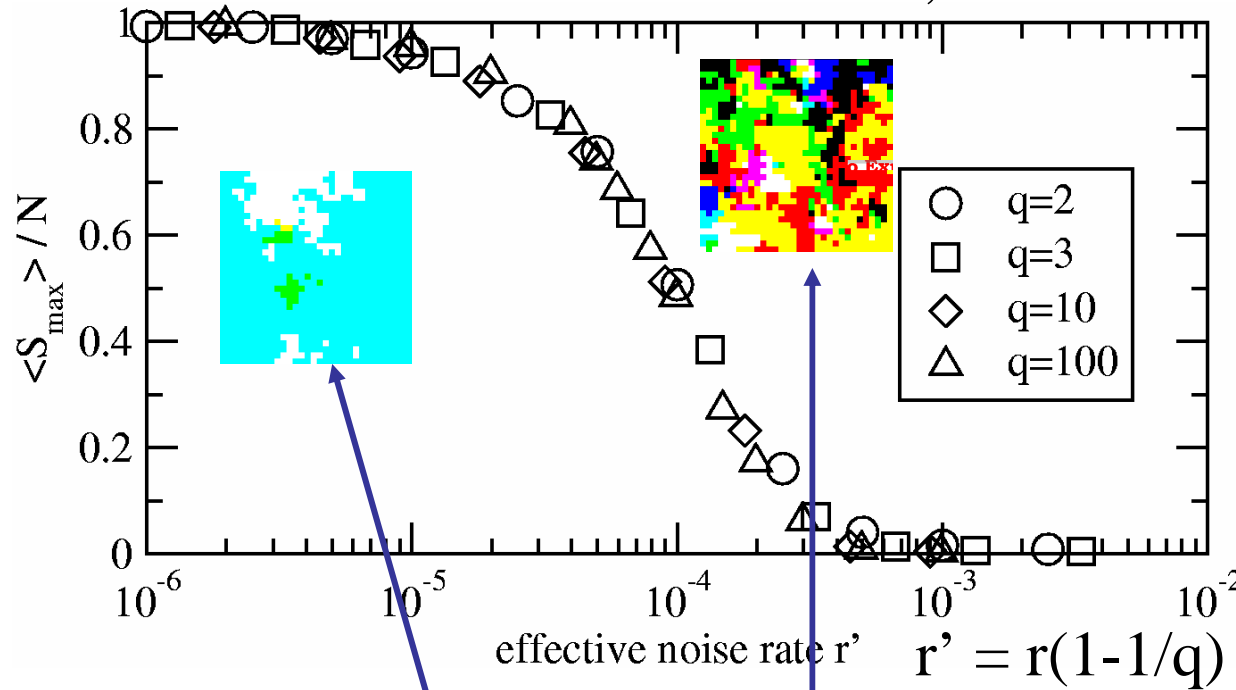
Transition to global culture controlled by noise rate

$d=2$

$F=10, N=2500$

Cultural drift:

Single feature random perturbation acting continuously at rate r



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

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?

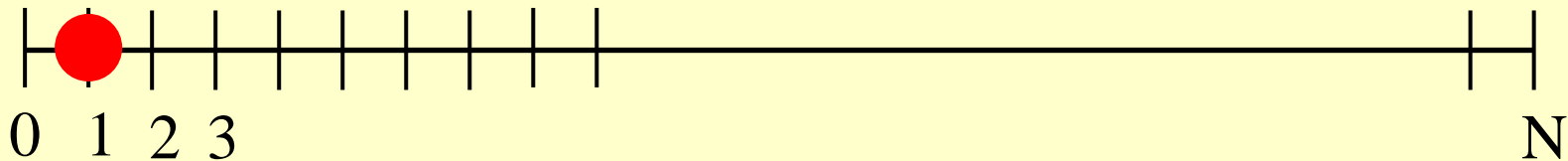
Competition between noise time scale ($1/r$) and relaxation time of perturbations T :

- 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)

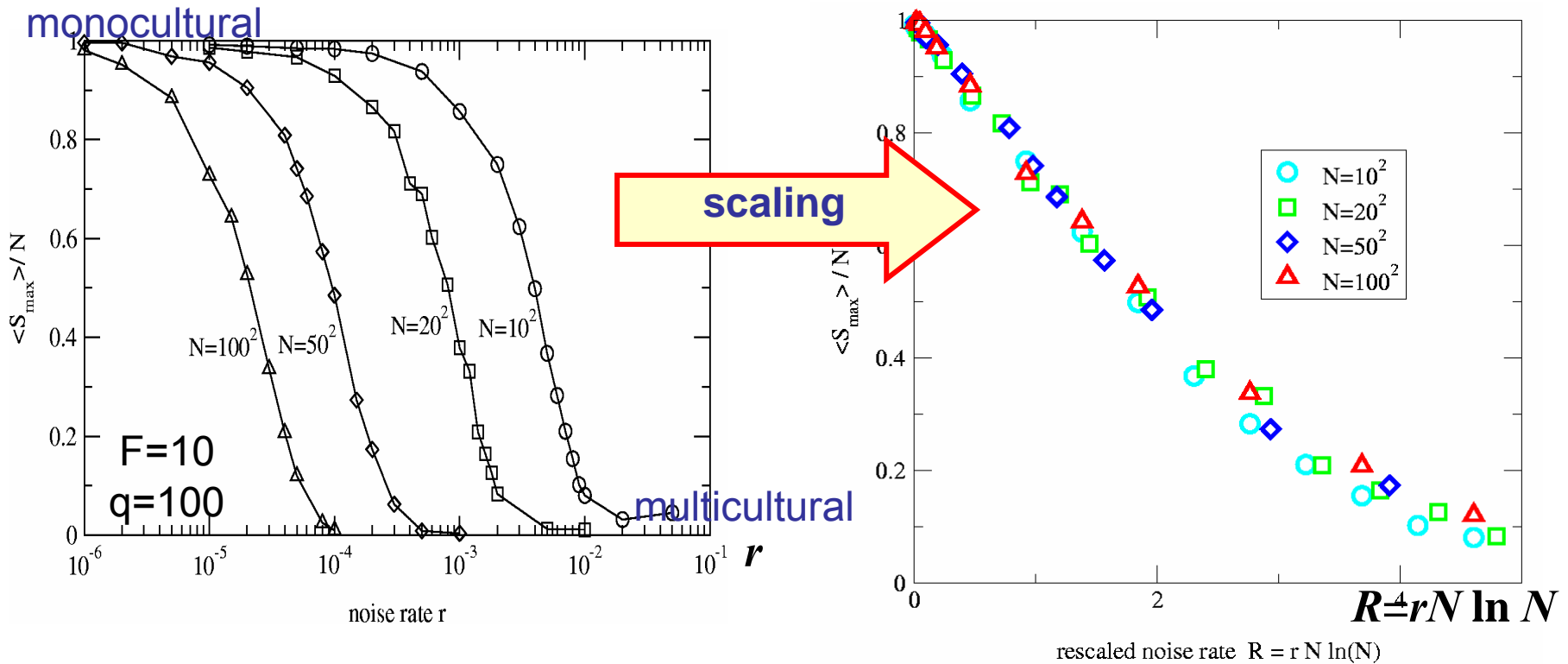


Damage $x(0)=1$ reaches $x=0$ or $x=N$ in a mean exit time

$$T \sim N \ln N$$

$$(d=1, T \sim N^2)$$

System size dependence



- Fixed system size: Universal transition for $rT \sim rN \ln N \sim 1$
 $\langle S_{\max}(r, q, N) \rangle = \langle S_{\max}(\alpha) \rangle$, $\alpha = r(1 - 1/q)N \ln N$
- Large systems:

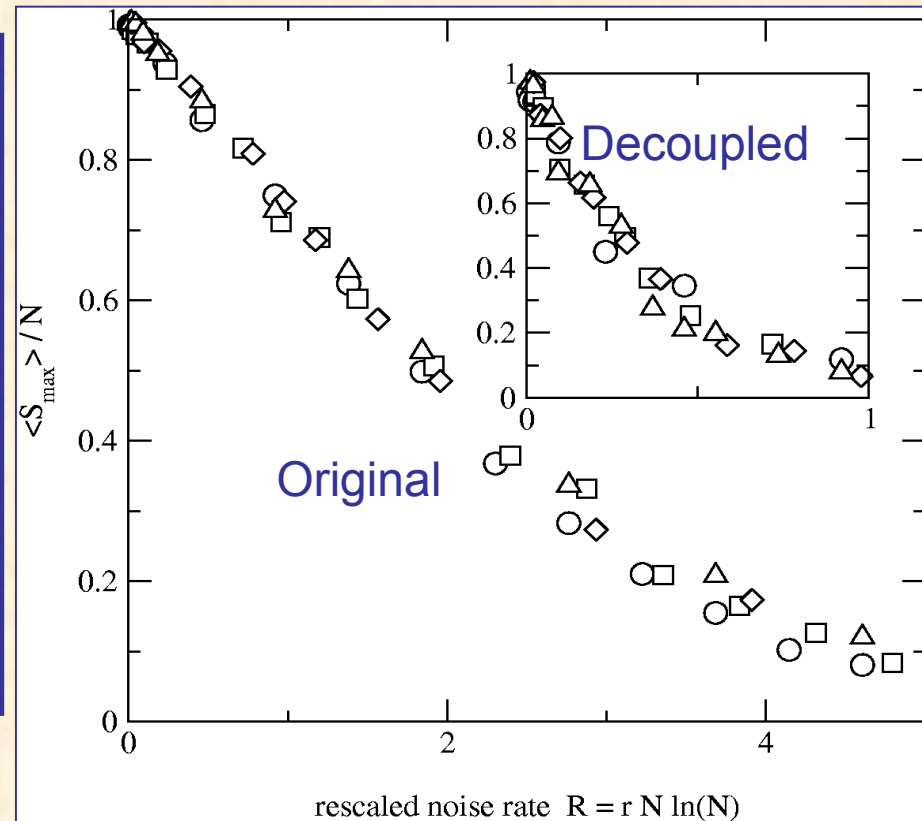
For $N \rightarrow \infty$ multicultural states prevail at any finite noise rate.

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

Cultural Drift: Summary

Phys Rev. E 67, 045101 R (2003)

- Relevance of time scales: Noise induced order-disorder transition for $r \sim T^{-1}(N)$. Scaling properties with respect to q and N .
- Stability: Multicultural frozen configurations are not stable 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 (Metastable states). 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

Revisiting Axelrod's question and conclusion

Principle of Homophily: Promotes interaction between similar.

"like attracts like"

Principle of Social Influence: Promotes cultural similarity. *The more two interact the more similar they become. But they become more unlike that someone else*: Cleavages.

Axelrod: Combination of homophily and social influence produces and sustains polarization (cultural diversity)

Cultural drift: Destroys diversity for N finite and small noise rate $r \ll 1$

- Question: Can stable cultural diversity emerge from local processes of homophily and social influence in an imperfect world (cultural drift)?
- Answer: **YES!** With a proper specification of homophily: Social network is not fixed.

Principle of CO-EVOLUTION of agents and network: Social structure evolves in tandem with the collective action that makes it possible.

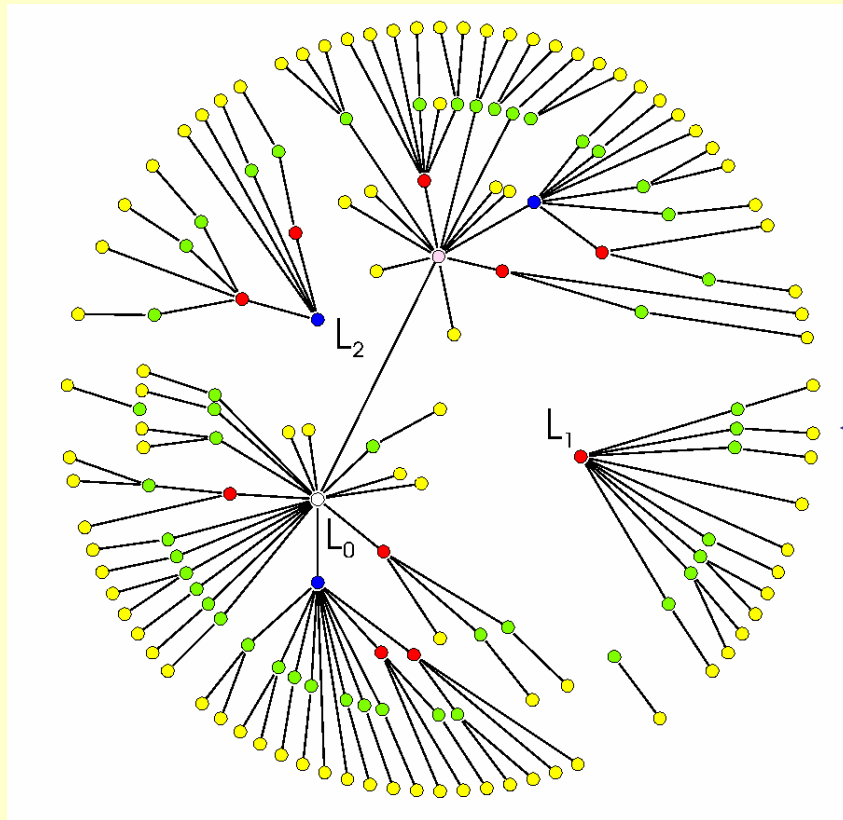
Dynamic and adaptive networks Zimmermann et al, *Phys. Rev. E.* **69**, 065102-6 (2004)

Example of co-evolution: Process of social differentiation

V. Eguíluz et al. Am. J. Soc. 111 (2005)

Spatial Prisoner's Dilemma Game: Cooperation maintained by local interactions
(M. A. Nowak and R. M. May, *Nature* 359, 826 (1992))

Network Dynamics (Choosing partners): Unsatisfied Defectors break any link with neighbouring Defector and establishes a new link in the network



Social differentiation: Emergence of

Leaders

Conformists

Exploiters

Imitation network of Cooperators

Absolute leader L_0 :

Largest pay-off in the network

and

largest number of links

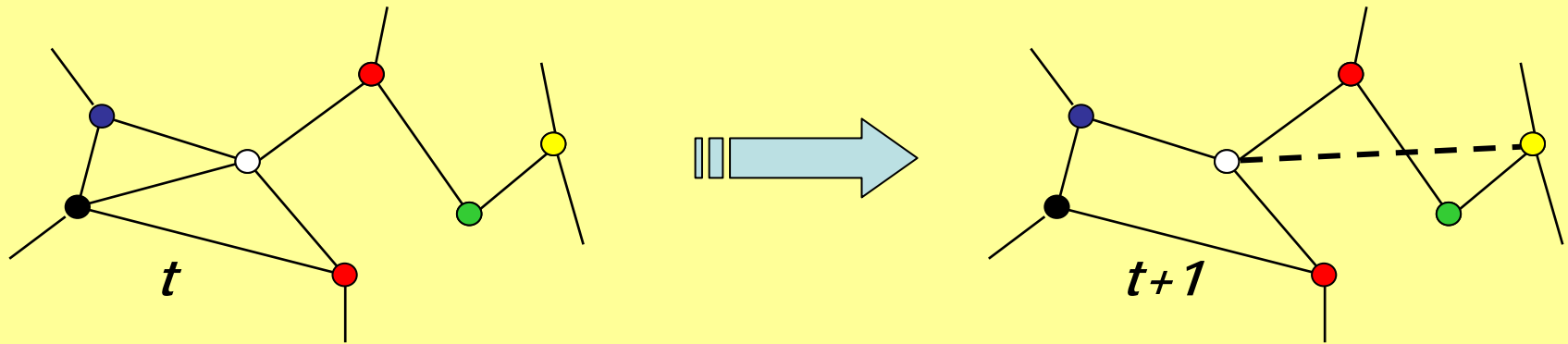
Axelrod's model in a Dynamic Network

Step 1: Choose randomly a link connecting two agents and calculate the overlap (number of shared features). Probability of interaction is proportional to the overlap (if overlap is not maximum)

Step 2: Social influence dynamics: interaction results in one more common trait

Step 3: NETWORK DYNAMICS: New homophily specification

A link with zero overlap (cleavage-link) is dropped + new link established

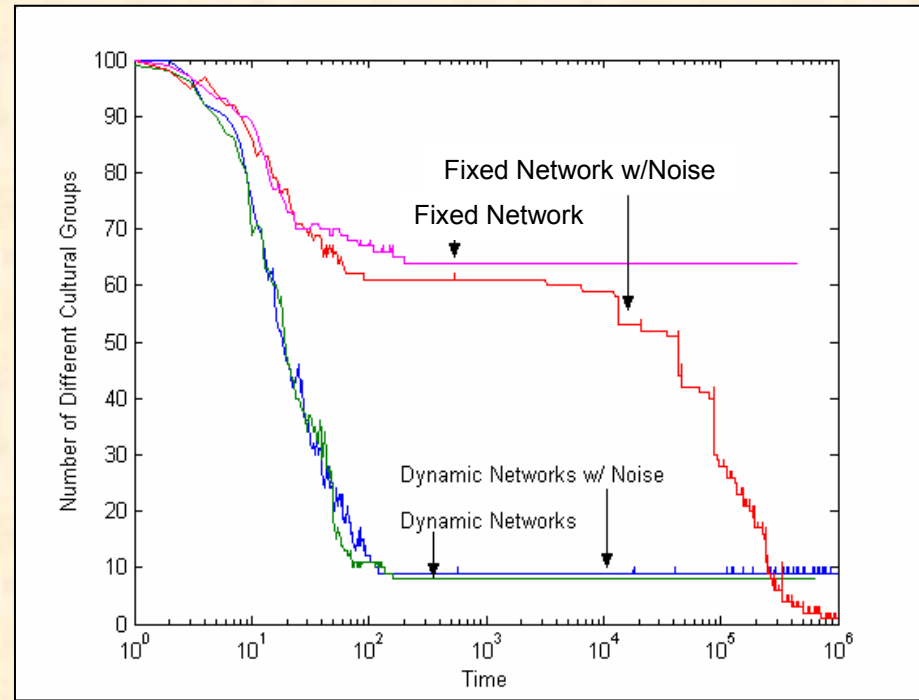
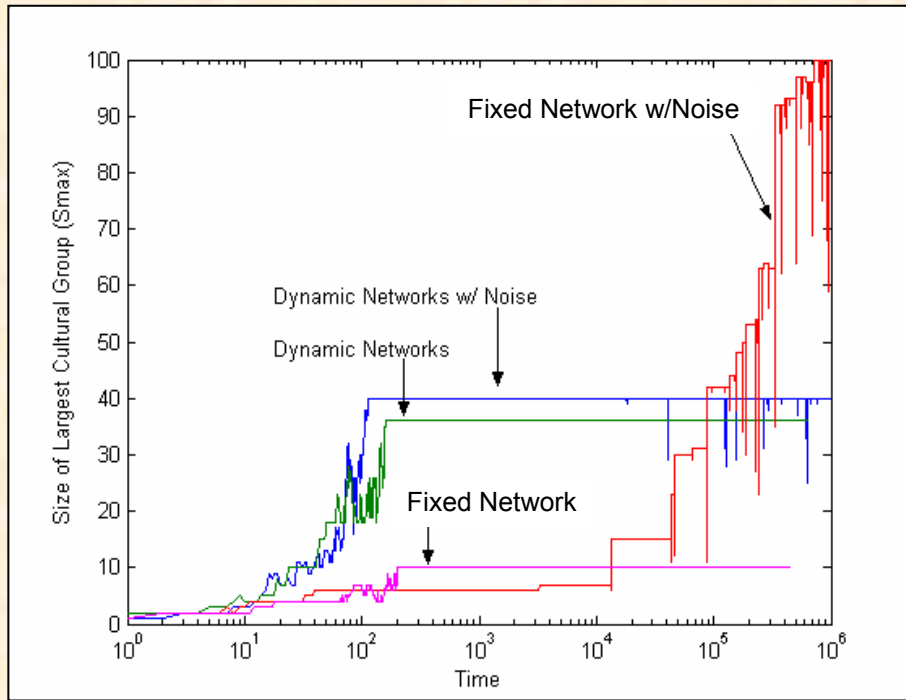


Step 4: Cultural drift:

Single feature perturbation with probability r



Cultural drift in a Dynamic Network

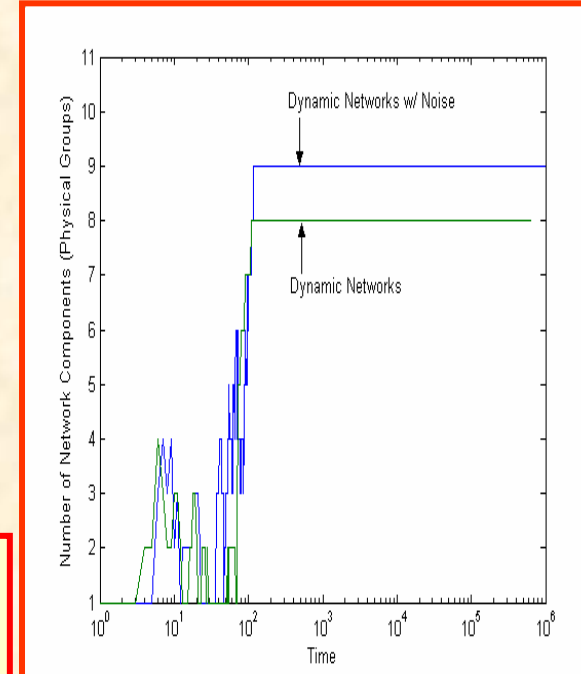
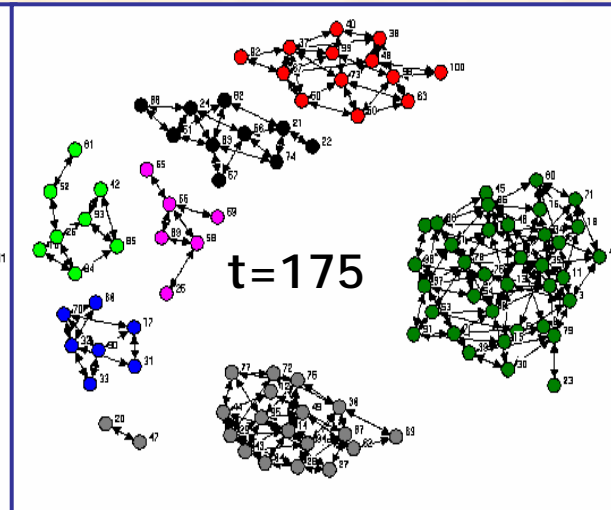
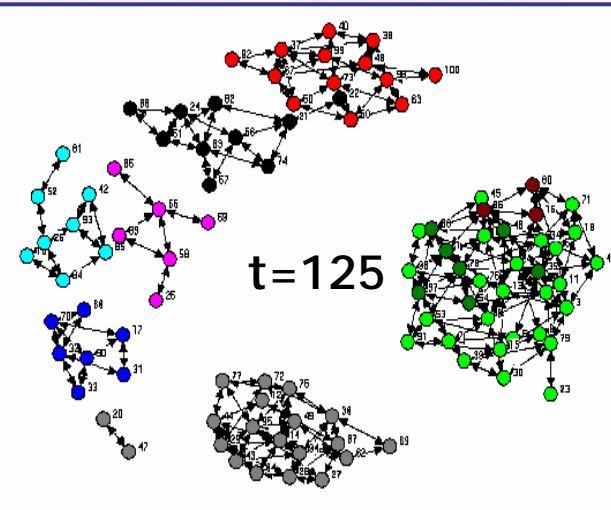
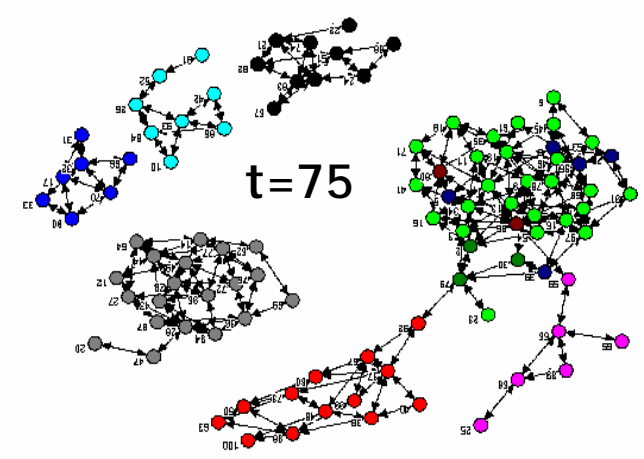
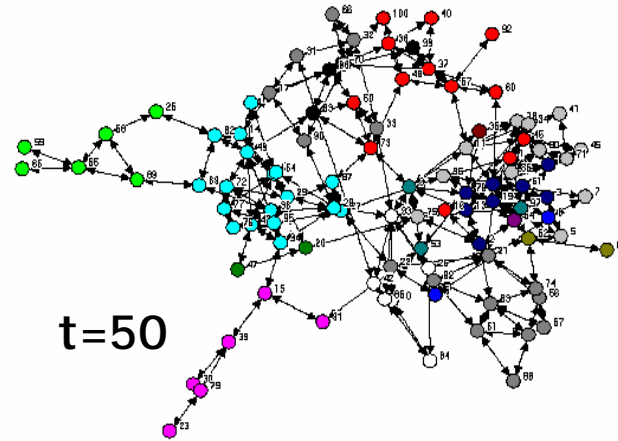
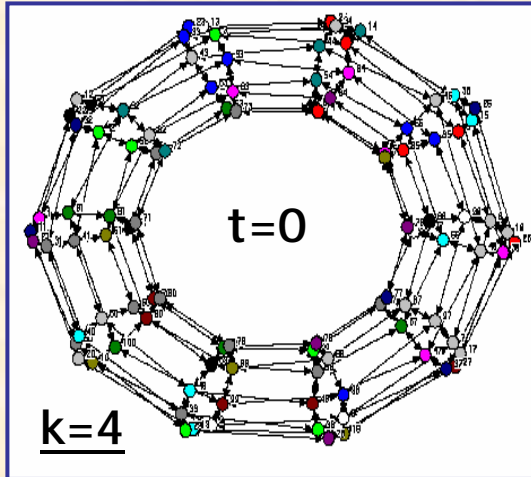


$$d=2, k=4, F=3, q = 20 > q_c, N=100 (r_c=10^{-2}), r=10^{-3}$$

Dynamical network maintains polarization in spite of cultural drift of slow rate: Insensitive to noise

Noise is not efficient to produce globalization in a dynamical network during large time scales: **WHY?**

Physical groups in a Dynamic Network: Cleavages vs. Noise



Dynamics of the network leads to static physical groups
Each group evolves independently becoming a cultural group
Cultural drift only efficient within a group

Summary

- Basics: Interaction of several cultural features based on homophily and social influence produces a transition between global culture and polarization.
- Fixed networks: Long range links and degree heterogeneity favor globalization. High clustering restores polarization in scale free networks.
- Cultural drift in fixed networks: Essential \longrightarrow Qualitative changes. q -independent, N -dependent noise induced transition between metastable global culture and noise dominated polarized state.
- Dynamic networks: Stable polarization due to formation of physical groups. Cultural drift of slow rate becomes inefficient.

Some open questions:

- * Hierarchy of features
- * Mass media effects
- * System size in dynamic networks
- * Competition of degree heterogeneity with cultural drift