Globalization-polarization transition, cultural drift, co-evolution and group formation



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Axelrod's model of social influence

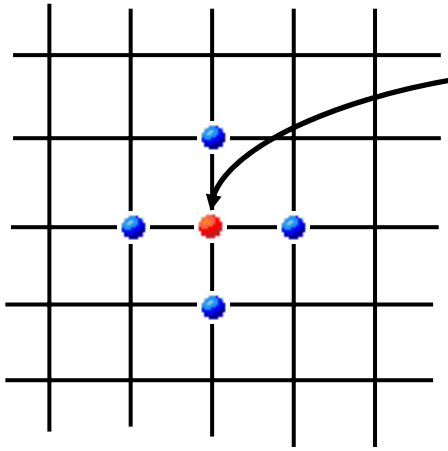
(J. Conflict Res. 41, 203 (1997))

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.

Axelrod's agents 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.

0	5
0	9
7	7

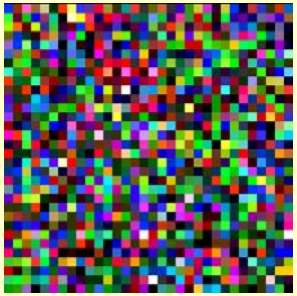
Mechanism of local convergence:

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

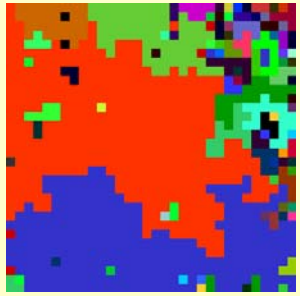
5	5
0	9
7	7

Visualization of Axelrod´s Dynamics

$F = 3, q = 10$



$t = 0 \longrightarrow$



System freezes in an absorbing multicultural state

http://ifisc.uib.es/research_topics/socio/culture.html

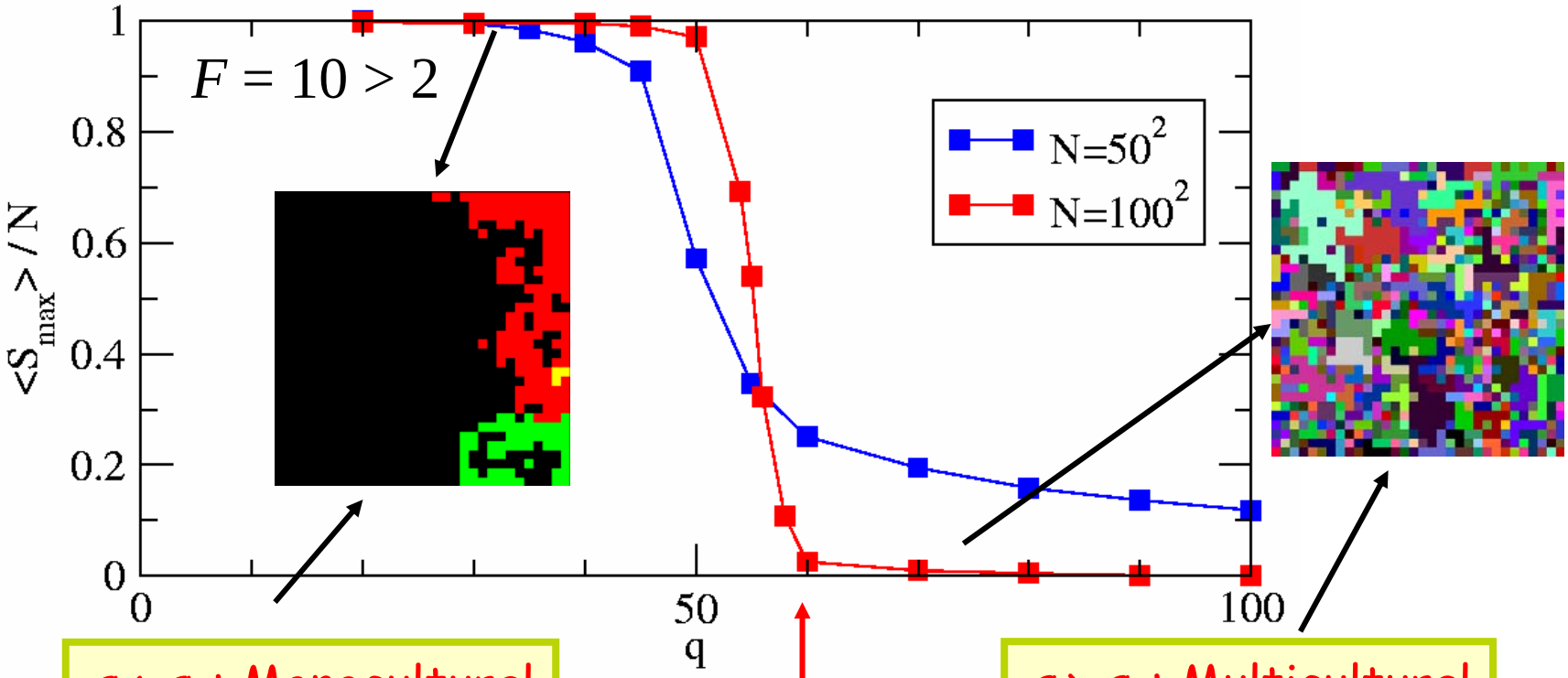
- The model illustrates how **local convergence** can generate **global polarization.**
- Number of domains taken as a measure of cultural diversity
- Uniform state always prevails without similarity rule *(Kennedy 1998)*

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.

Lewenstein et al (1992)



$q < q_c$: Monocultural

Global culture

q_c

$q > q_c$: Multicultural

Cultural diversity

Global polarization

Beyond Axelrod's original model

1.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)

*Klemm et al., Phys Rev. E **67**, 045101R (2003); J. Economic Dynamics and Control **29**, 321 (2005)*

2. Social structure: *" With random long distance interactions, the heterogeneity sustained by local interactions cannot be sustained."*

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

*San Miguel et al., Computing in Science and Engineering **7**, 67 (2005)*

3. Co-evolution of agents and network: *Group formation*

"Circumstances make men as much as men make circumstances"

*F. Vázquez et al., Phys. Rev. E **76**, 046120(2007); D. Centola et al. J. of Conflict Resolution (Dec. 2007)*

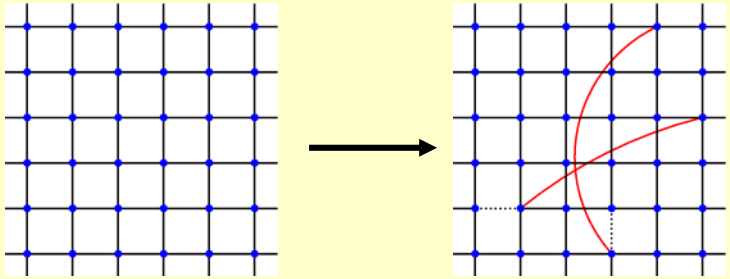
4. The function of mass media:

Information feedback trough agents: *Shibanai et al., J. Conflict Resolution. **45**, 80 (2001)*

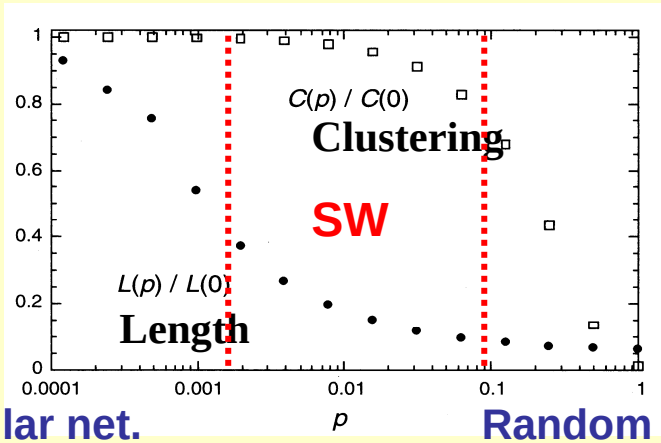
*J.C. González-Avella et al., Phys. Rev. E **73**,046119 (2006); JASSS **10**, 1-17 (2007)*

Small-world networks

Watts, Strogatz, Nature 393, 440 (1998)

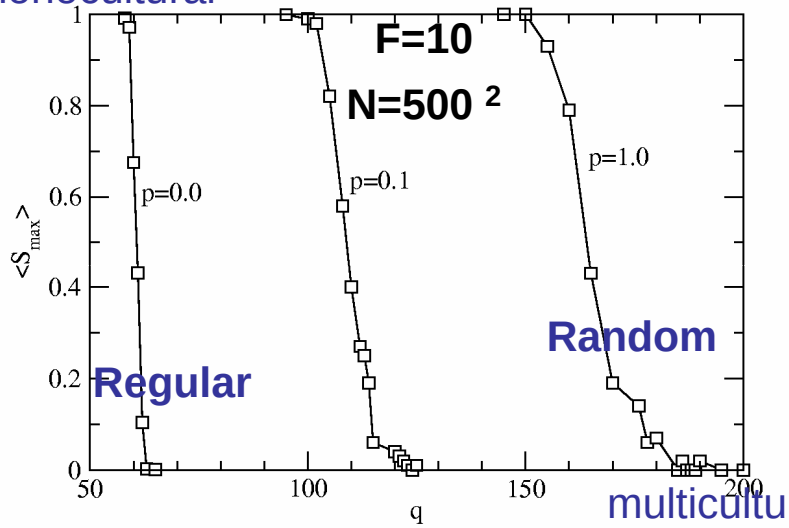


Rewire with prob. *p*

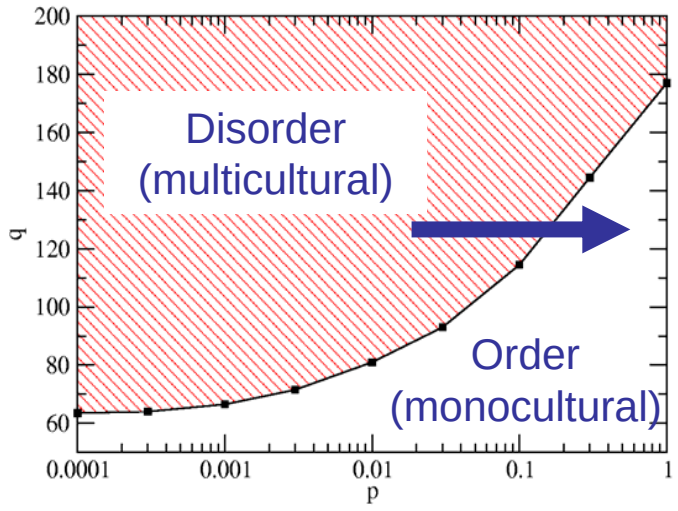


Regular net. **Random net.**

monocultural



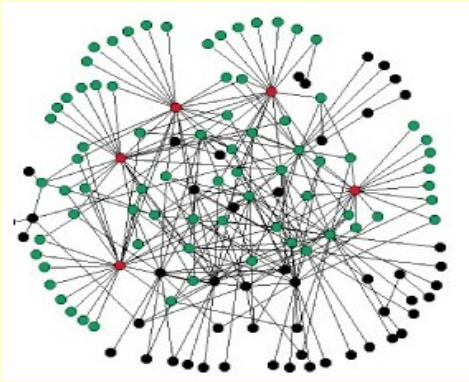
multicultural



Small world connectivity favors cultural globalization

Scale-free networks

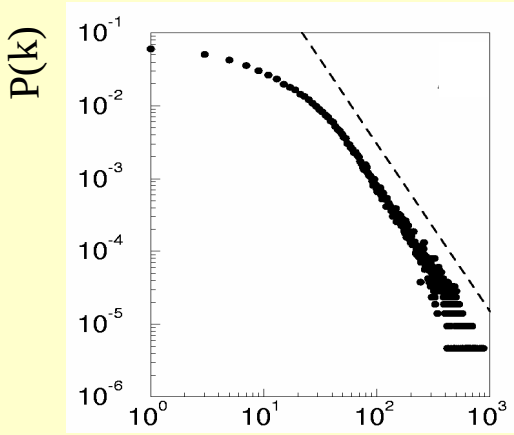
Albert & Barabasi, Rev. Mod. Phys.74, 47 (2002)



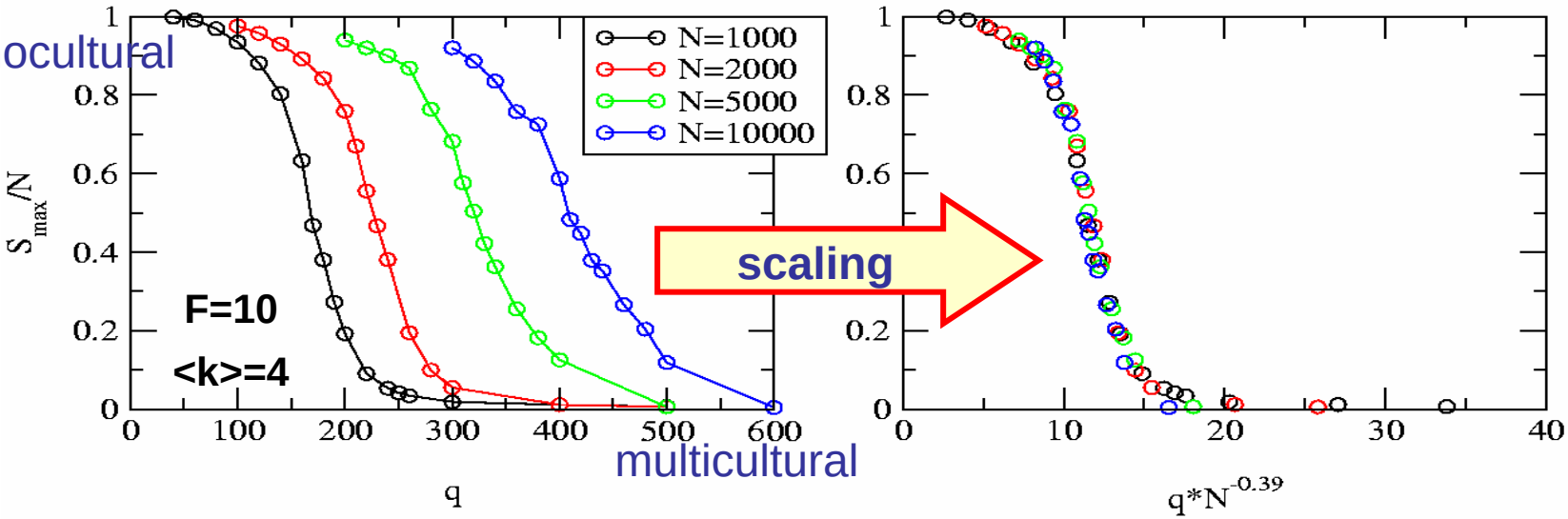
Power law for the degree distribution

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

Importance of hubs

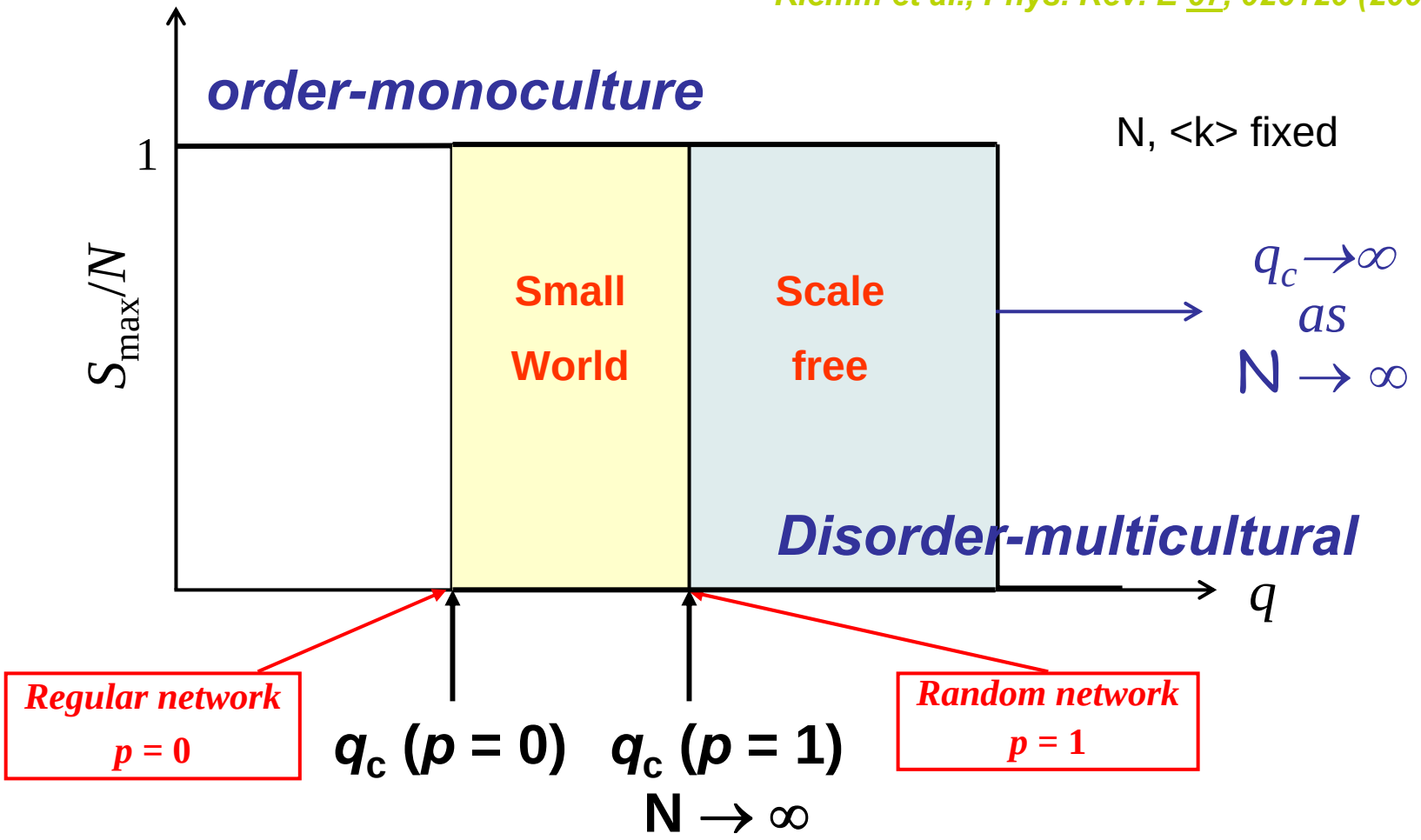


monocultural



System size scaling: Global culture prevails for N → ∞

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



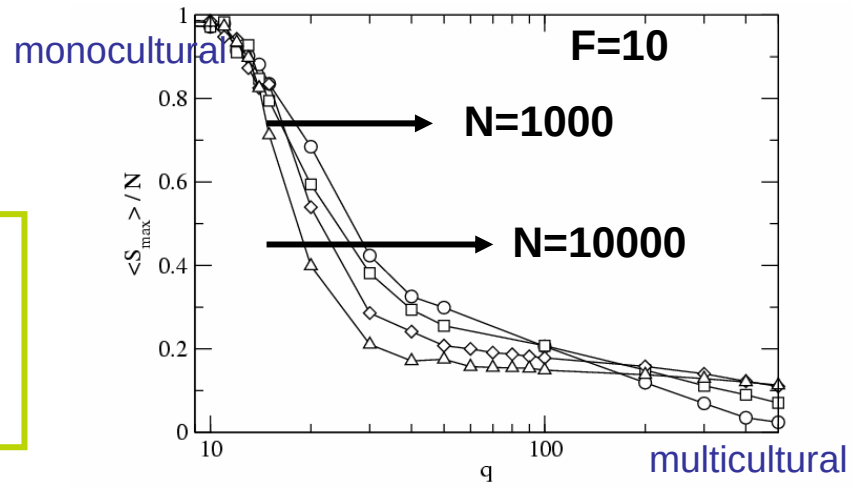
Scale free connectivity is more efficient than random connectivity in promoting global culture

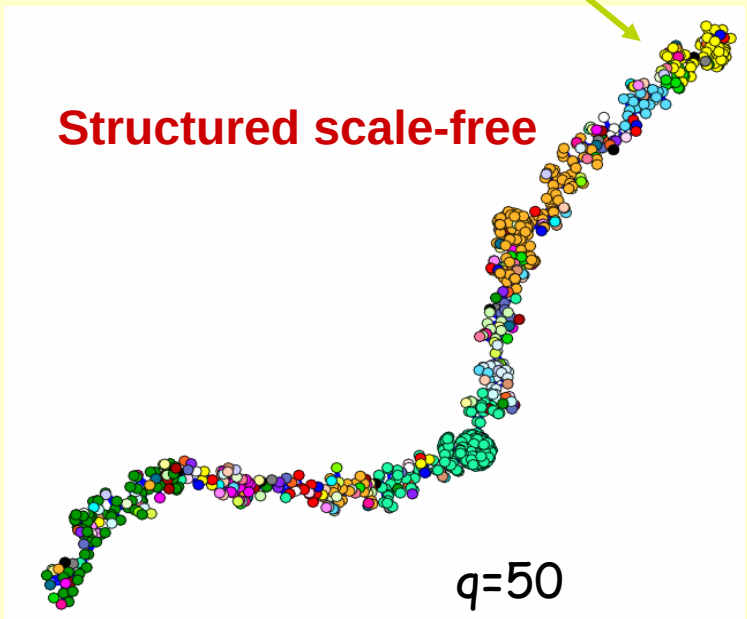
Structured scale-free networks

Klemm & Eguiluz, Phys. Rev. E 65, 036123 (2002)

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

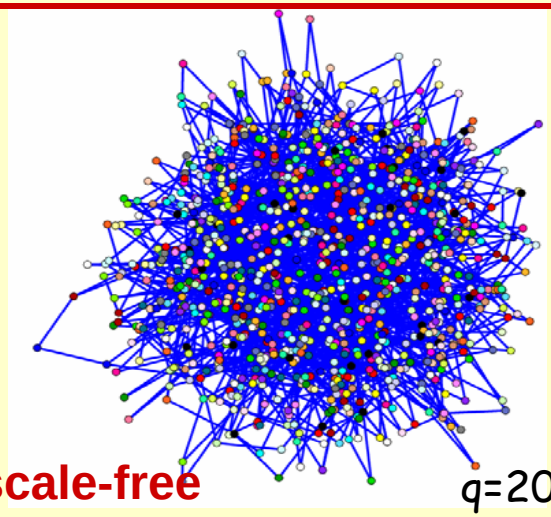
- Transition for $N \to \infty$.
- Hubs create ordered clusters in disordered state



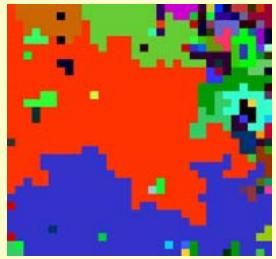


Disordered multicultural states

N=1000
F=10



Robustness and Cultural Drift



Frozen states stable against perturbations?

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

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**

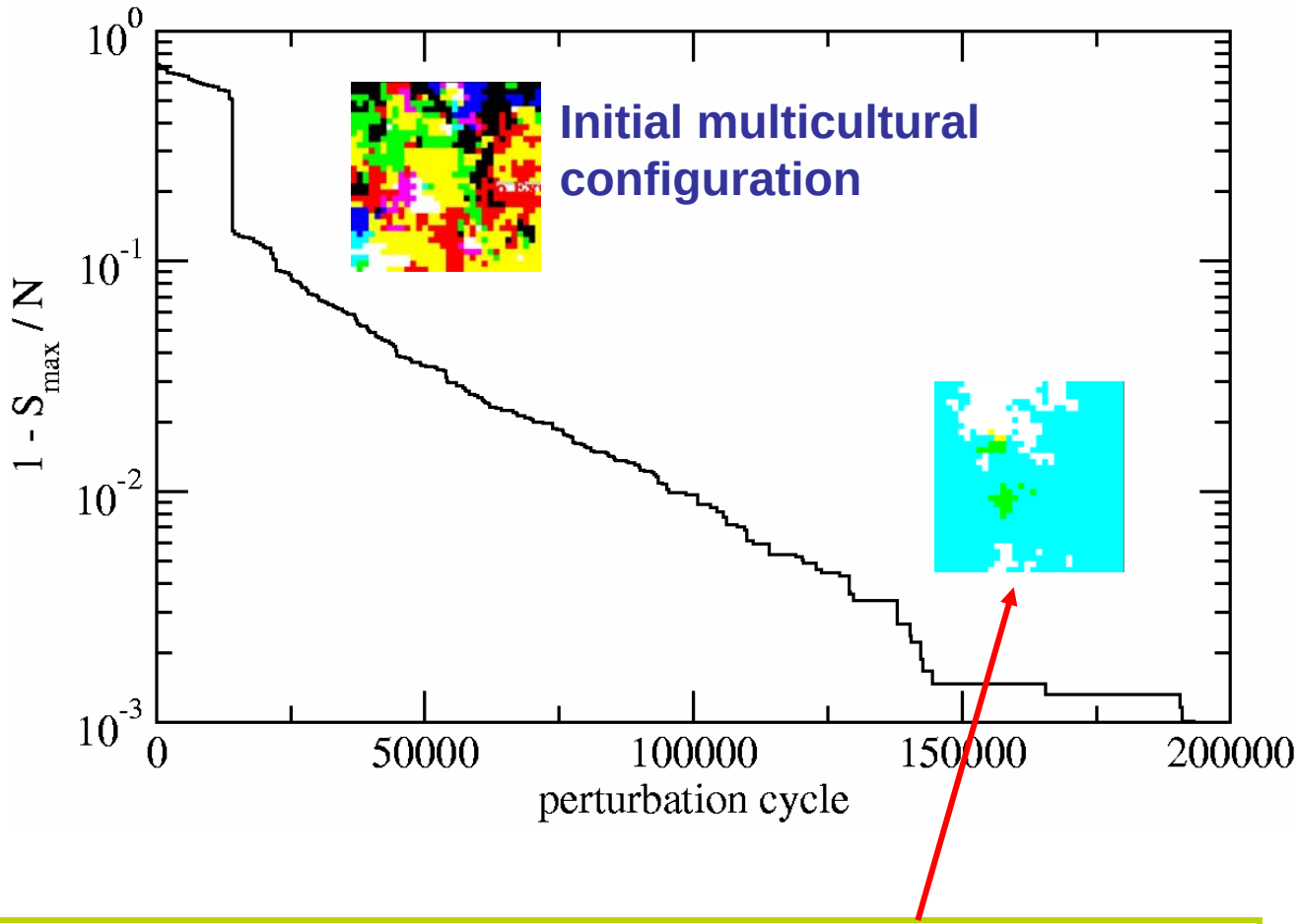
Metastable states?

Perturbation-relaxation cycles:

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

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

3. Return to 1.

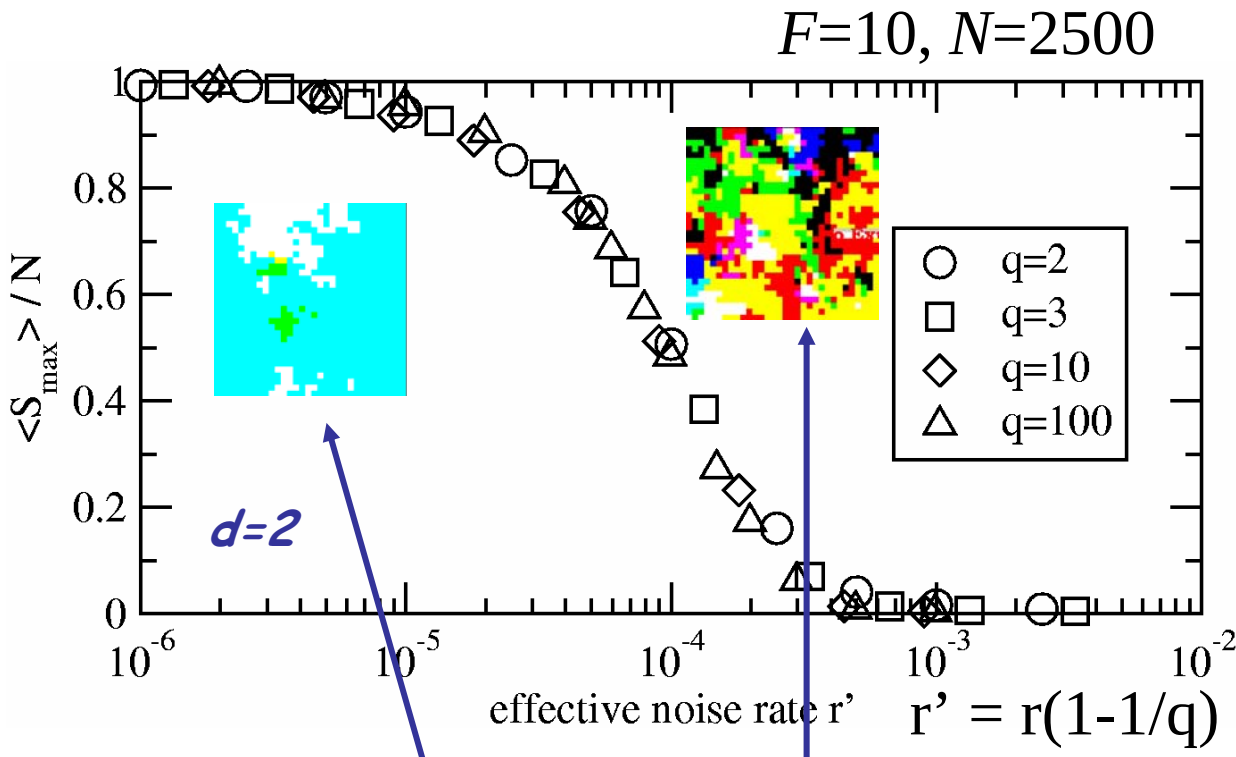


System driven by noise towards a state of global culture

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

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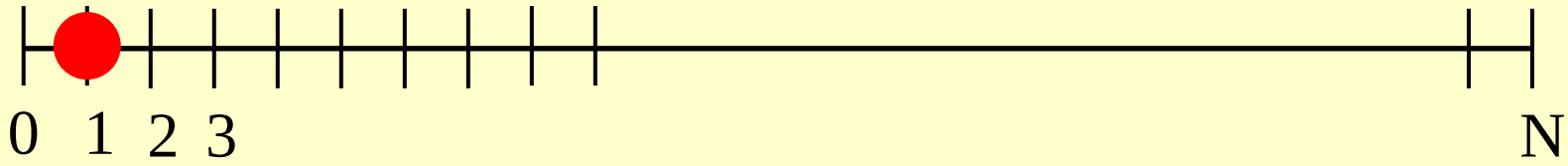
Competition between noise time scale (1/r) and relaxation time of perturbations T:

- 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?

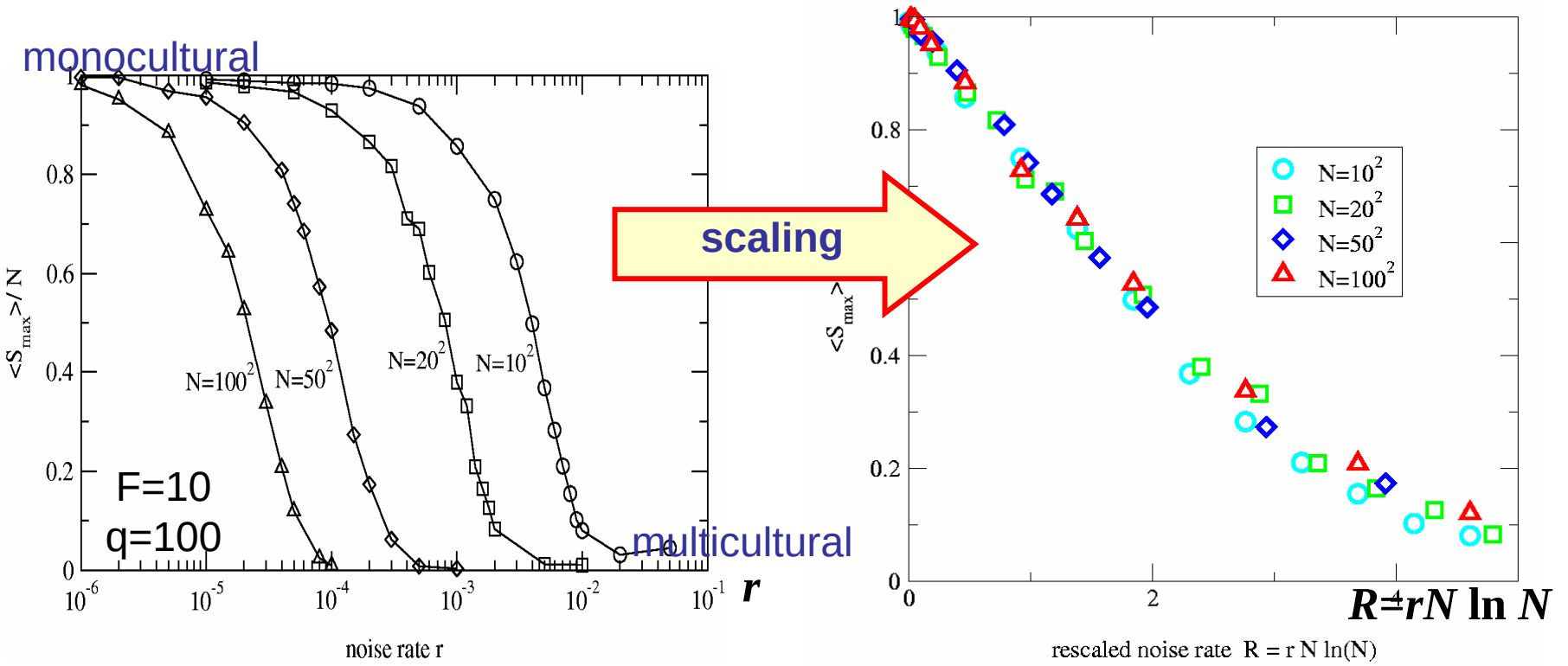
Exit time in *random* walks (mean field)



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

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

System size dependence



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

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

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

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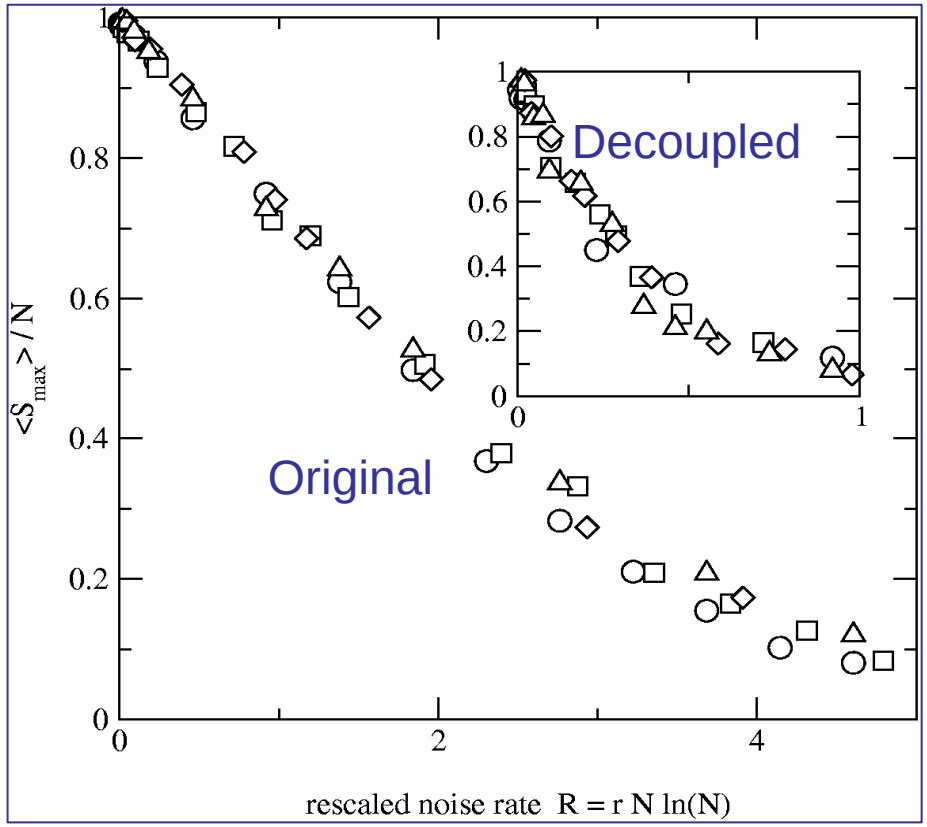
Decoupled model

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

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<<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 *Eguíluz et al. American J. Sociology 110, 977 (2005)*

Zimmermann et al, in " Economics with Heterogeneous Interacting Agents" Lecture Notes in Economics and Mathematical Systems 503, pp.73-86 (2001)

CO-EVOLUTION

Dynamics of Networks:

1. Dynamics of network formation: Structure created by individual choices/actions ← *Rightwing view*

2. Dynamics on the network: Actions of individuals constrained by the social network ← *Leftwing view*

3. Co-evolution of agents and network :

Circumstances make men as much as men make circumstances

..new research agenda in which the structure of the network is no longer a given but a variable.....explore how a social structure might evolve in tandem with the collective action it makes possible (Macy, 1991)

Key ingredients.

a) Going beyond co-evolution models in which:

- -Network evolution is decoupled from the evolution of agents actions
- -Complete network redefined at each time step

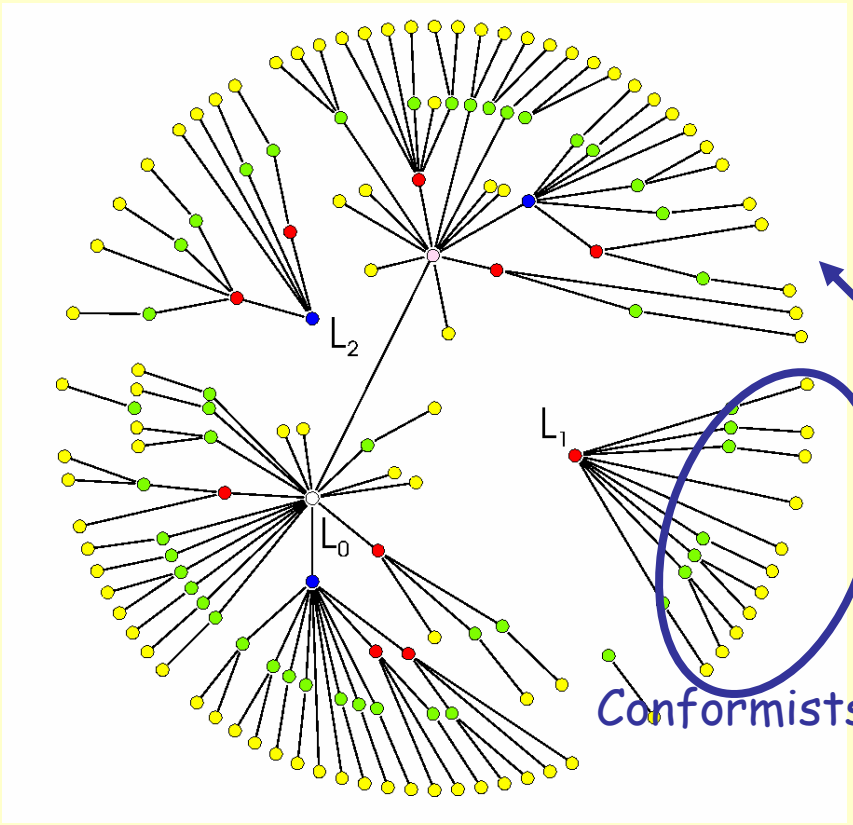
b) Social plasticity as ratio of time scales of evolution of network and action

Example of co-evolution

V. Eguíluz et al. American J. Sociology 110 , 977 (2005)

Spatial Prisoner´s Dilemma Game: Cooperation maintained by local interactions (M. A. Nowak and R. M. May, Nature 359, 826 (1992); B. Huberman and S. Glance, PNAS 90, 7716 (1993))

Network Dynamics (Choosing partners): **Unsatisfied** Defectors break (probability *p*) 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

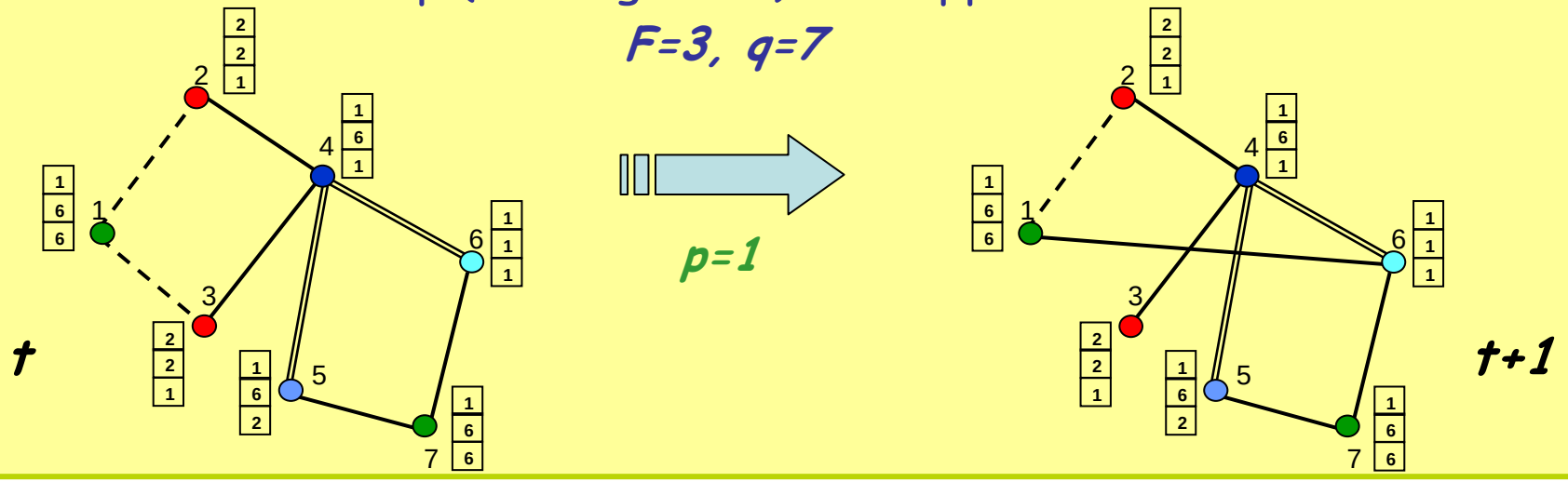
largest number of links

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)

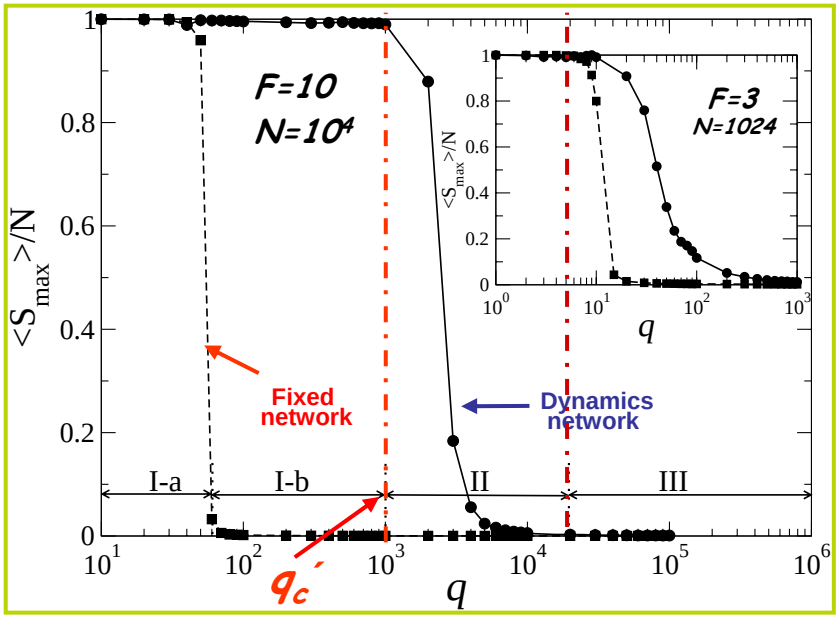
Step 2: **Social influence dynamics:** interaction results in one more common trait

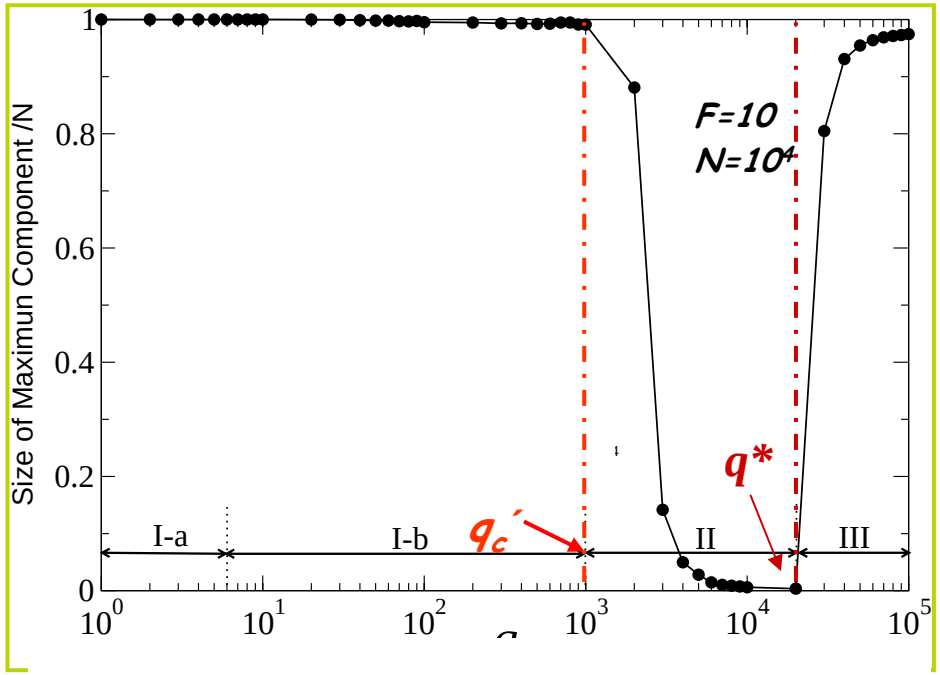
Step 3: ***NETWORK DYNAMICS:*** New homophily specification

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



Polariza





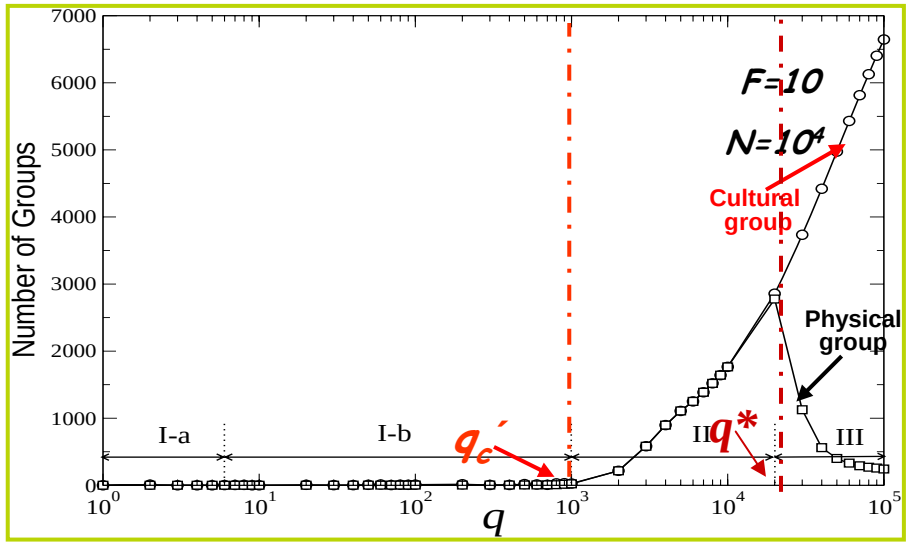
I) $q < q_c'$ (frozen)
Monocultural state in giant network component

I ⟶ II: Network breaks in physical groups

II) $q_c' < q < q^*$ (frozen)
Disordered multicultural states
Equal number of physical and cultural groups

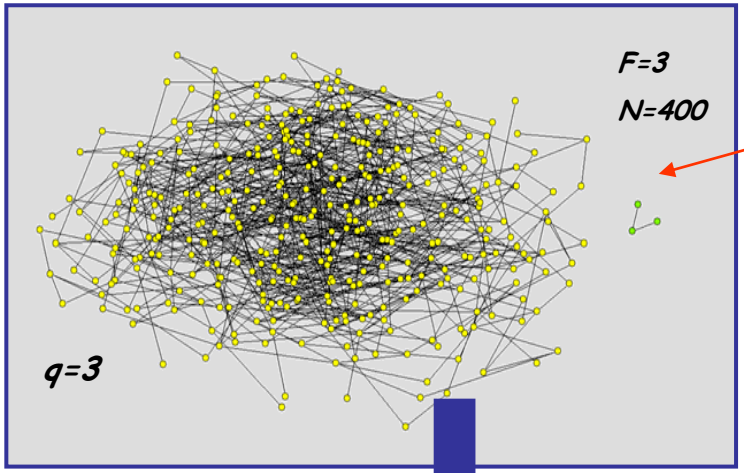
II ⟶ III: Network and cultural dynamics decouple

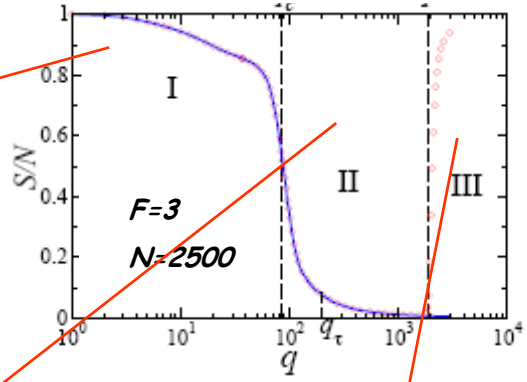
III) $q > q^*$ (dynamic configuration)
Continuous break of links and search of new partners
Giant network component
Cultural and physical groups do not coincide.



Network fragmentation and recombination

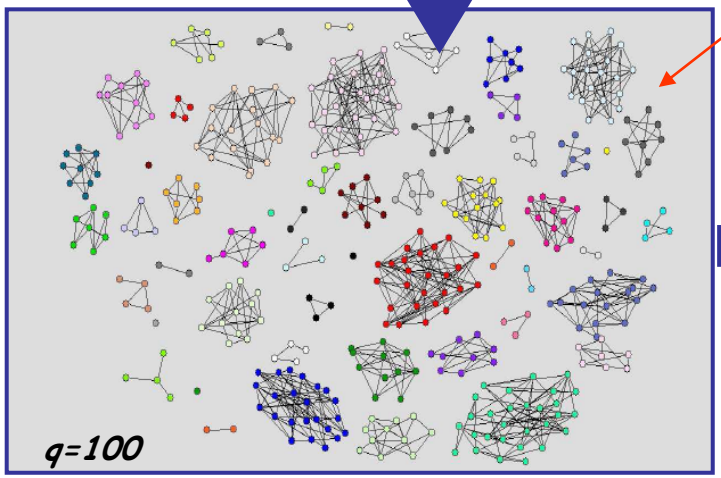
Region I (frozen configuration)





Fragmentation

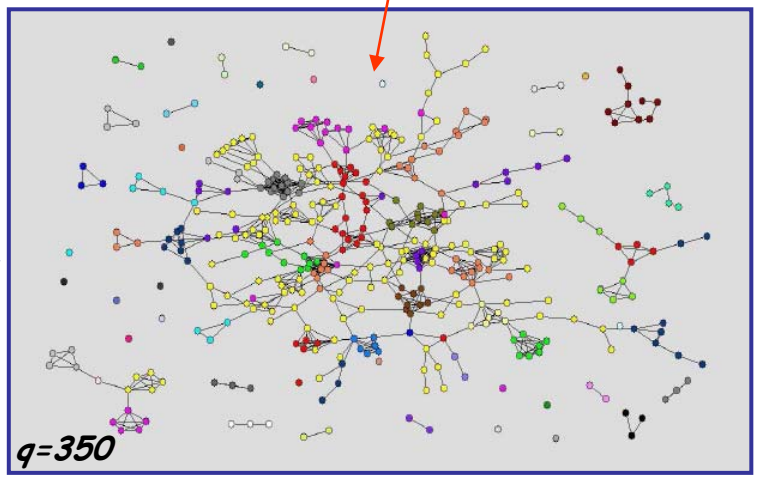
Region II (frozen)



Recombination

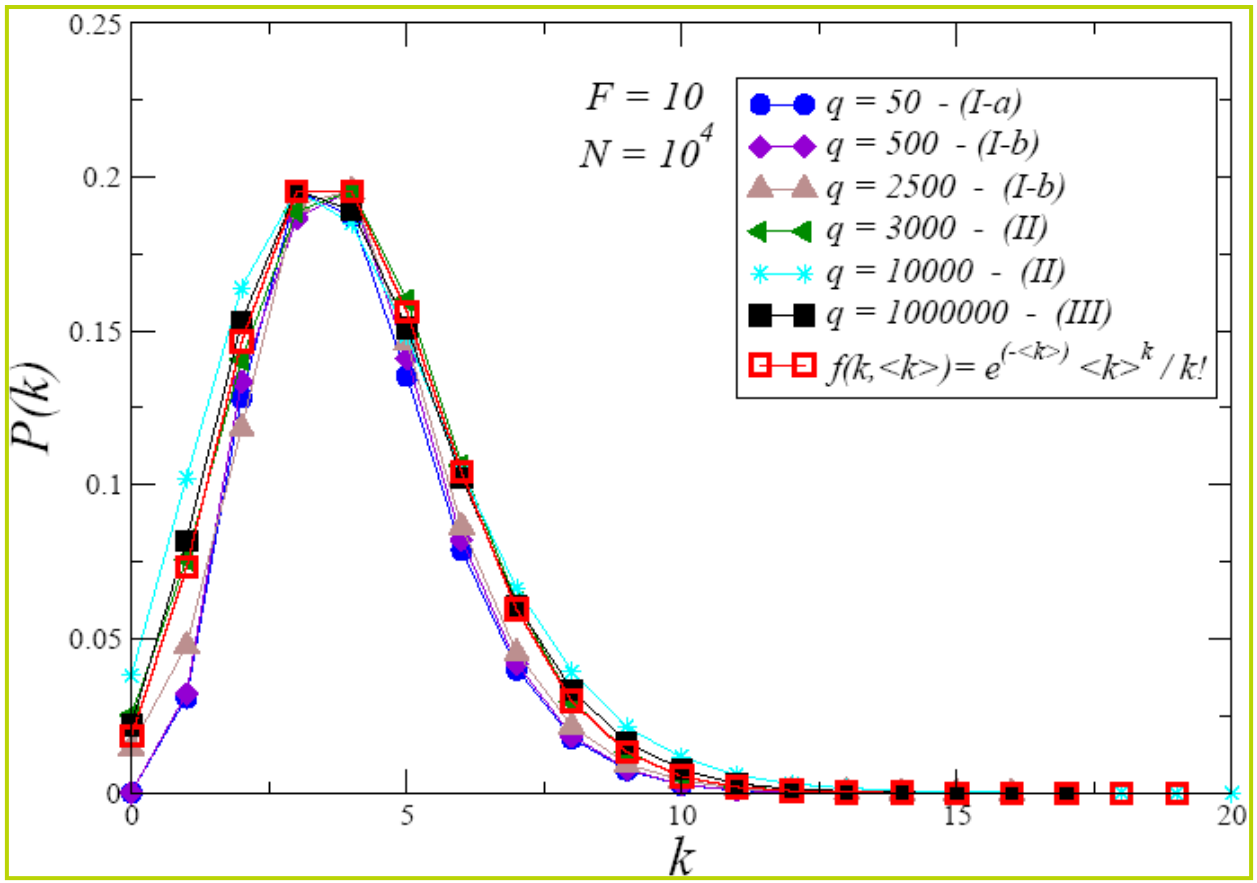
$$q^* \cong \frac{NF}{< k >}$$

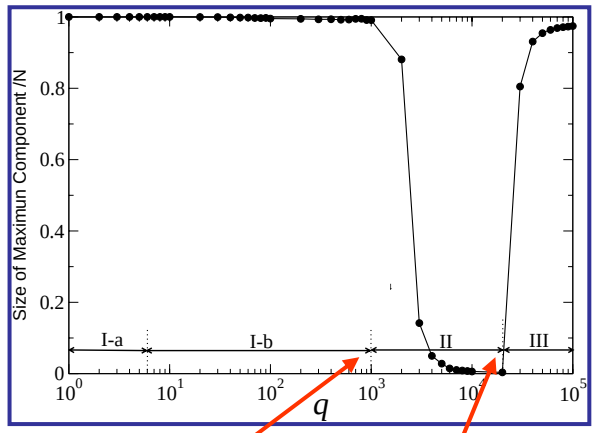
Region III (dynamic frustrated configuration)



Degree Distribution

Random network with Poisson distribution





$q_c' = 2500$

$q^* = 2\ 10^4$

$\langle k \rangle = 4$

Network fragmentation transition

F. Vázquez et al. Phys. Rev. E (2007)

Region I

giant network component

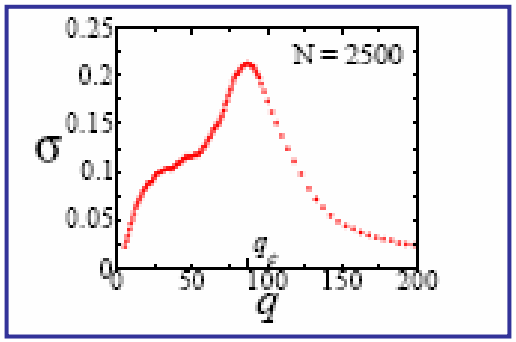
q_c'

Region II

many small network components

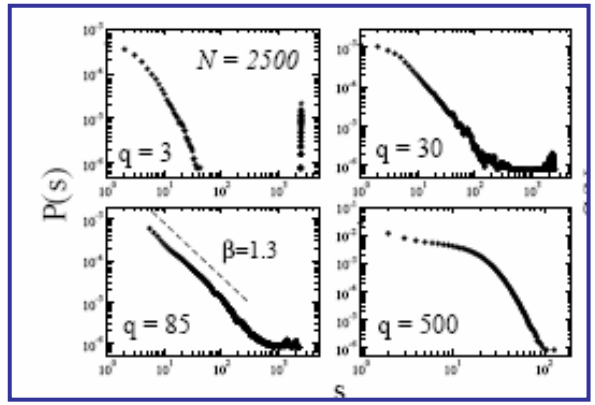
Maximum of fluctuation in S

F=3



$q_c' = 85$

Power law distribution for size components



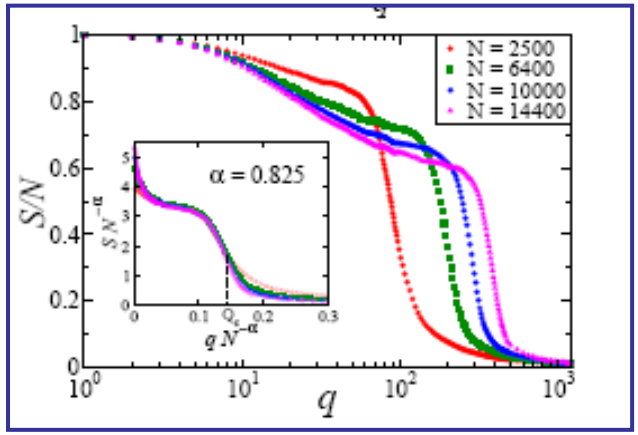
$$P(s) \sim s^{-\beta}$$

Finite size scaling

$$S = N^{\alpha} f(N^{-\alpha} q) \text{ for } q < q_c.$$

$$q_c \sim N^{\alpha} \to \infty$$

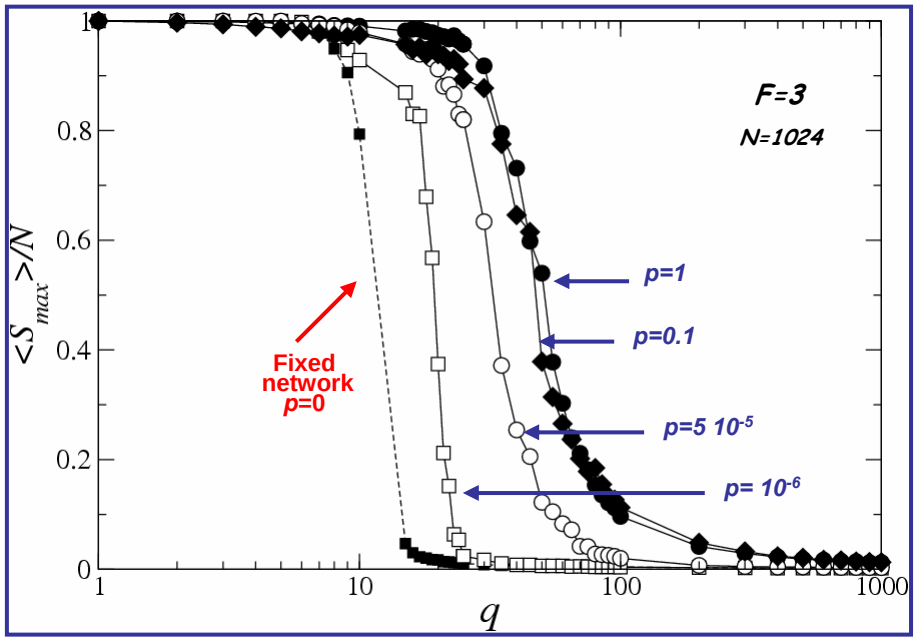
$$S/N \sim N^{\alpha - 1} \to 0 \quad \text{as} \quad N \to \infty$$

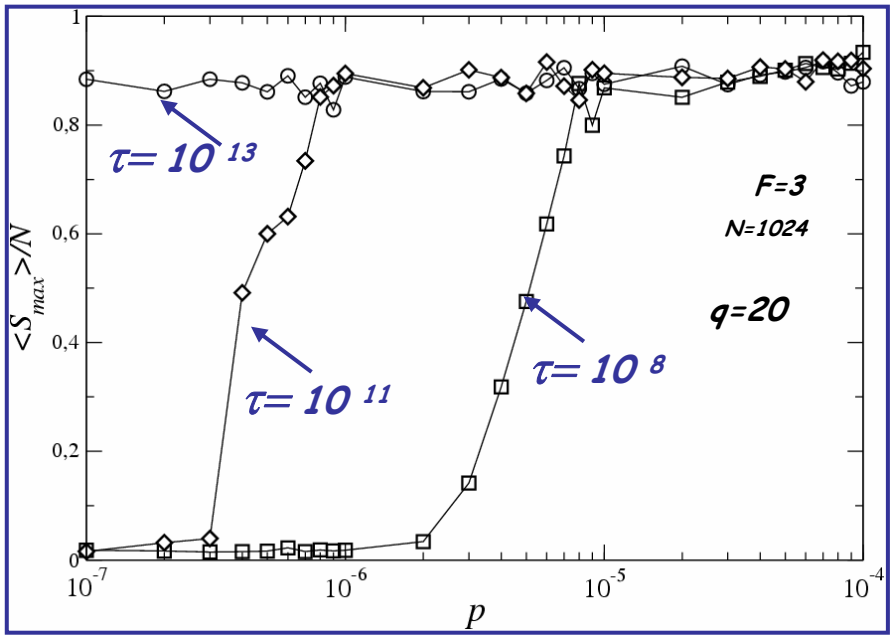


Transition becomes continuous and diasappears in the large N limit

Social plasticity?

Rewiring with probability p





Fixed observation time $\tau = 10^8$

Different observation times

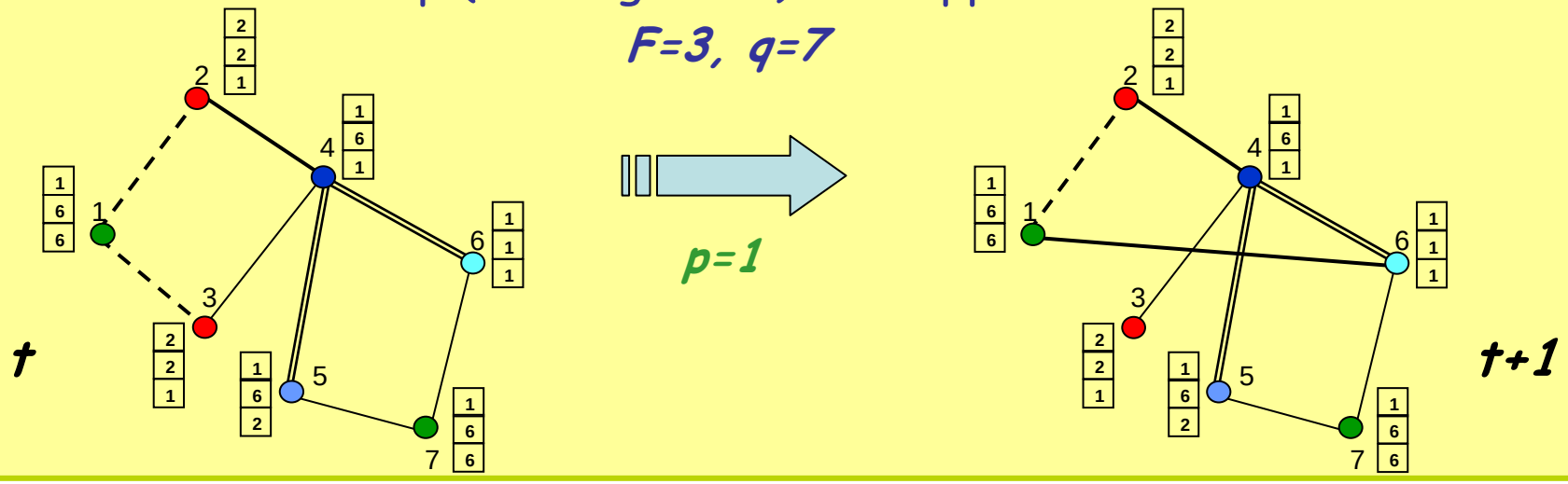
Discontinuity at p=0: Fixed transition shift for any finite p and long enough observation time

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

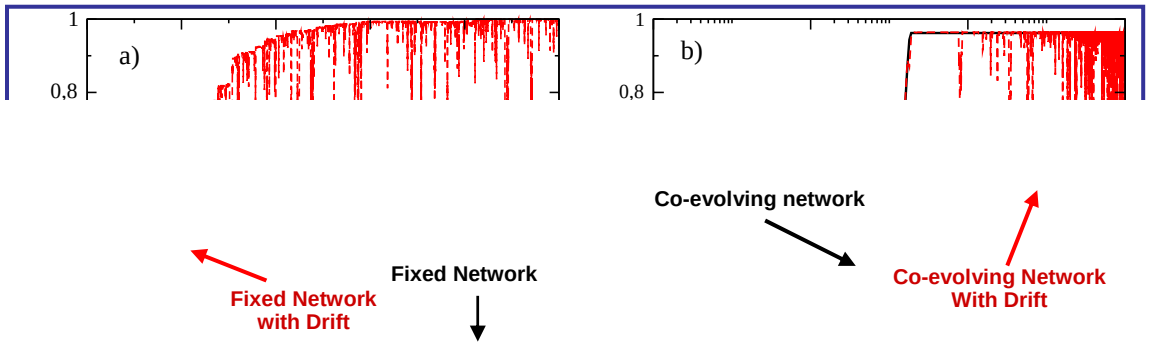
A link with zero overlap (cleavage-link) is dropped + new link established



Step 4: **Cultural drift:**

Single feature perturbation with probability r

F=3, N = 1024, r = 10^{-5}, q =20 > q_c =15: Region Ib



Region Ib

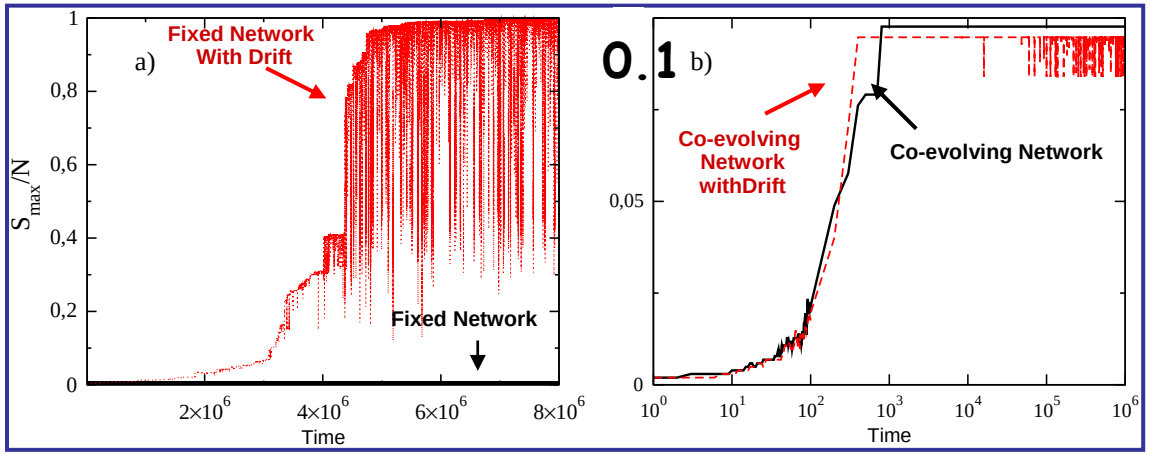
Fixed network:

Cultural drift takes the system to a global monocultural state

Co-evolving network:

Remains in global monocultural state under cultural drift

F=3, N = 1024, r = 10^{-5}, q =100 > q_c´: Region II



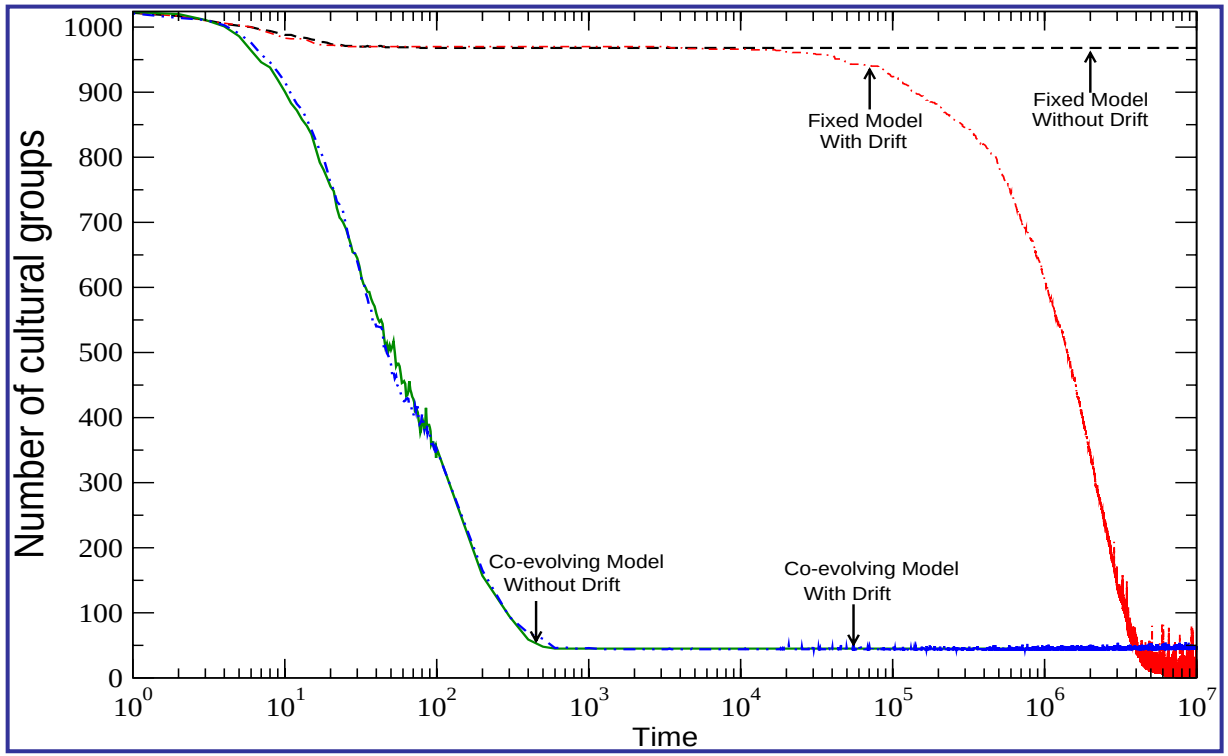
Region II

Fixed network:

Same than region I

Co-evolving network:

Cultural drift does not order the system. It is not able to take it away from the multicultural disordered state.



Region II

F=3, q=100

N=1024

r=10^{-5}

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

Noise is not efficient to produce globalization in a co-evolvig network during large time scales

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 with large number of nodes.

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

- **Cultural drift in fixed networks:** Essential ⟶ Qualitative changes. q-independent, N-dependent noise induced transition between metastable global culture and noise dominated polarized state.

*Klemm et al., Phys. Rev. E **67**, 045101 (2003); J. Econ. Dyn. Control **29,** 321(2005)*

Co-evolution (Dynamic networks):

- Network Fragmentation and recombination transitions

*F. Vázquez et al., Phys. Rev. E **76**, 046120(2007)*

- Stable cultural polarization: Cultural drift of slow rate becomes inefficient.

D. Centola et al. J. of Conflict Resolution (Dec. 2007)

Mass media effects on cultural dynamics

"The mass media (plurality information feedback), ***contrary to lay beliefs of their strong uniforming power, would rather contribute to creating differences in the long run"***

Shibanai et al., J. Conflict Resolution. ***45****, 80 (2001)*

General question: Identify the mechanisms, and their efficiency, by which different forms of mass media modifies processes of cultural dynamics based on local agent interaction

Specific questions to be addressed:

Q1. What is a more important influence in making up your mind: what your acquaintances tell you (viral marketing) or TV and newspapers ?

Q2. Are you influenced by mass media messages on, say perfumes, if you do not use perfumes?

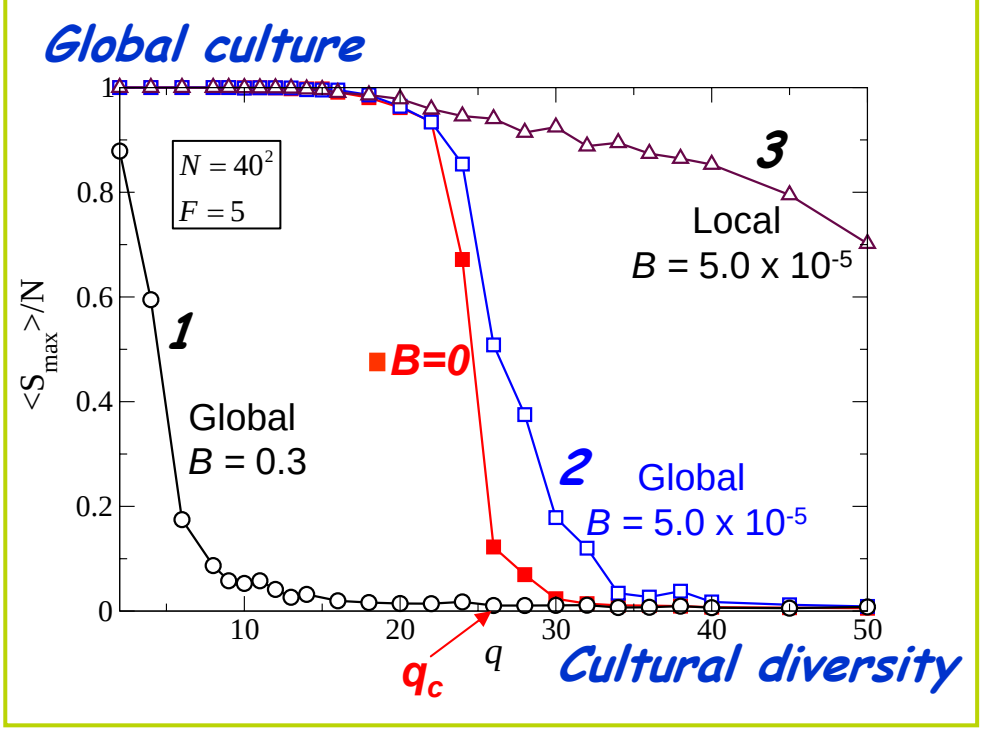
Q3. Do you follow insistent and recurrent mass media messages or occasional apparently weak messages are more influential?

Q4. What is more efficient in producing cultural homogeneity, local mass media (narrowcast) or global mass media (broadcast)?

Mass media effects: Summary

J. C. González-Avella et al., J. ARTIFICIAL SOCIETIES SOCIAL SIMULATION 10, 1-17 (2007)

http://ifisc.uib.es/eng/lines/APPLET_Axelrod/Culture.html



1) Polarization caused by strong media ($B>B_c$)

* Competition of similarity rule applied to agent-agent and agent-media interactions

* Limiting case B=1: agent-agent interaction negligible and no agent-media interaction for zero overlap. No mechanism of cultural dissemination at work

2) Cultural homogenization is caused by weak media

3) Local media (feedback at regional levels) are more efficient in the cultural globalization path.

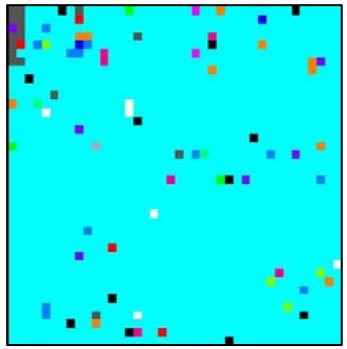
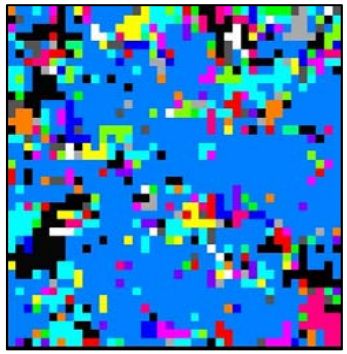
Mass media is only efficient in producing cultural homogeneity in conditions of weak broadcast of message, so that agent-agent interactions can be still effective in constructing some cultural overlap with the mass media message. Strong media messages do not homogenize because agent-agent interactions become inefficient:

The power of being subtle (and local)

Mass media effects: multicultural states $(q > q_c)$

http://ifisc.uib.es/eng/lines/APPLET_Axelrod/Culture.html

Dynamics of cultural homogenization for weak* (B=0.0005) *mass media:

B=0	Local	Global	External
			
t = 1000	*t = 60000*	*t = 49000*	*t = 36000*

F=5, q=30

Mass Media: Answers

Q1. What is a more important influence in making up your mind: what your acquaintances tell you (viral marketing) or TV and newspapers ?

A1. Delicate compromise and feedback processes: Mass media reflects local or global cultural trends created by local interactions. Media information processed by agent interaction in a social structure.

Q2. Are you influenced by mass media messages on, say perfumes, if you do not use perfumes?

A2. Present modeling requires cultural overlap with the message for the interaction with the agent to be possible.

Q3. Do you follow insistent and recurrent mass media messages or occasional apparently weak messages are more influential?

A3. Weak coupling to the message is more efficient: ***The power of being subtle***

Q4. What is more efficient in producing cultural homogeneity, local mass media or global mass media ?

A4. Local mass media (regional TV) appear to be more effective in producing cultural homogeneity than global uniform broadcasts (CNN).