Mathematical Modelling of Social Dynamics

A physicist perspective

Maxi San Miguel

IFISC

CSIC

Universitat de les Illes Balears

Outline:

1. Physics, Complexity, and Social Sciences: Sociophysics?
2. Axelrod´s model for cultural dissemination
3. Schelling´s model of segregation
4. Game Theory. Social and strategic interactions

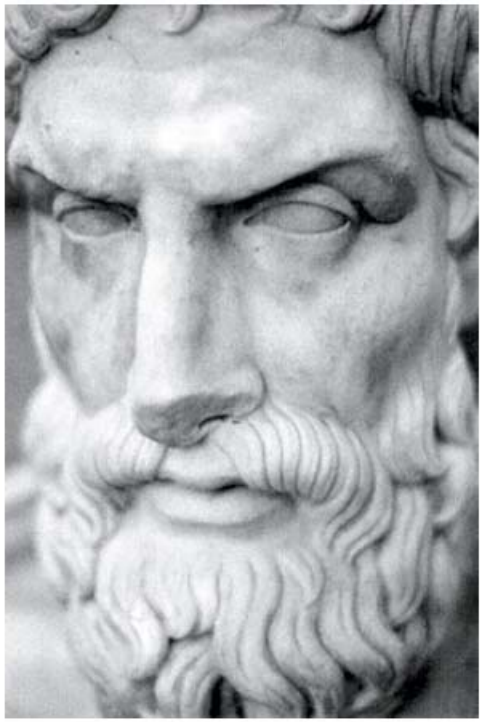

Two Cultures?
DON QUIJOTE

PHYSICS and SOCIAL SCIENCES

- What is Physics? Natural Sciences?
- H. A. Simon: *Sciences of the artificial*

Maxwell:

The peculiar function of Physical Sciences is to take us to the limits of understanding



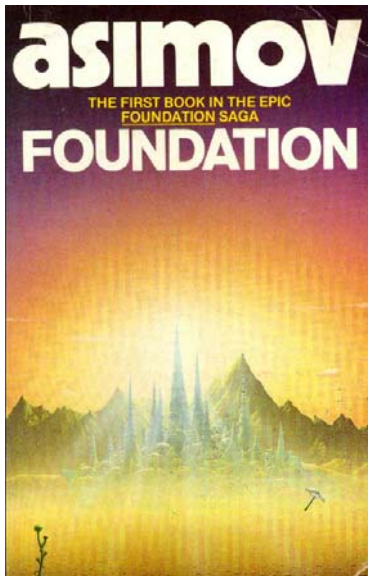
We must hold that to arrive at accurate knowledge of the cause of things of most moment is the business of natural science, and that happiness depends on this.

Epicurus (341 AC - 270 AC)
"Letter to Herodotus"

Quetelet was keenly aware of the overwhelming complexity of social phenomena, and the many variables that needed measurement. His goal was to understand the statistical laws underlying such phenomena as crime rates, marriage rates or suicide rates. He wanted to explain the values of these variables by other social factors. These ideas were rather controversial among other scientists at the time who held that it contradicted a concept of freedom of choice.

His most influential book was *Sur l'homme et le développement de ses facultés, ou Essai de physique sociale*, published in 1835. In it, he outlines the project of a social physics and describes his concept of the "average man" (l'homme moyen) who is characterized by the mean values of measured variables that follow a normal distribution.

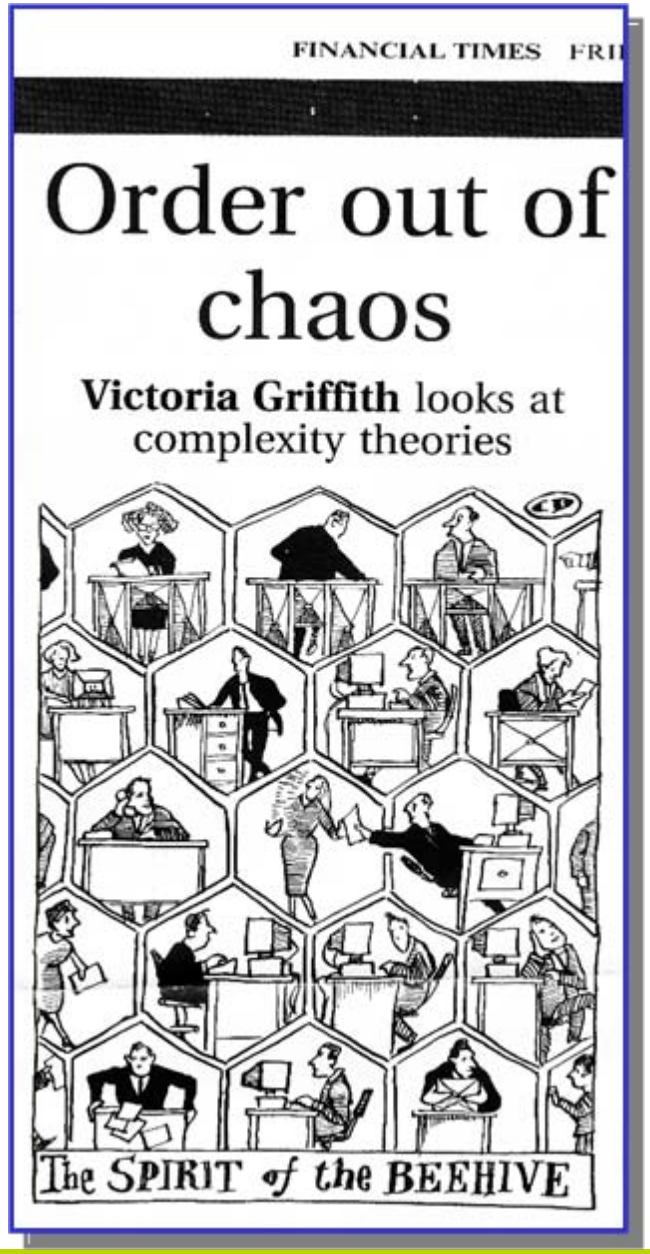
Individual → *Society*



Psycohistory: H. Seldon

EMERGENCE IS NOT STATISTICS!!

*W. Weaver, Science and Complexity, American Scientist **36**, 536 (1948)*



P. Ball, The Physical Modelling of Human Social Systems, *Complexus 2004*

One of the core assumptions in the study of complex systems is that there exist 'universal' features analogous to those that characterize the notion of universality in statistical physics. That is to say, sometimes the details do not matter: certain aspects of complex behaviour transcend the particularities of a given system, and are to be anticipated in any system of a multitude of simultaneously interacting components. There can be no tougher test of this idea than that posed by the nature of human social systems. Can there really be any similarities between, say, a collection of inanimate particles in a fluid interacting via simple, mathematically defined forces of attraction and repulsion, and communities of people each of whom is governed by an unfathomable wealth of psychological complexity? The traditional approach to the social sciences has tended to view these psychological factors as irreducible components of human social interactions. But attempts to model society using the methods and tools of statistical physics have now provided ample reason to suppose that, in many situations, the behaviour of large groups of people can be understood on the basis of very simple interaction rules

P. Ball, The Physical Modelling of Human Social Systems, *Complexus 2004*

If the case is going to be made that physics can contribute to an understanding of the social sciences, that is not going to be done by any crucial experiment or theory. Rather, the argument will have to be cumulative, arising on a case by case basis.

I would argue that their primary value is often to challenge entrenched preconceptions about how human society works. Policy makers are all too prone to linear thinking: they assume that if we understand how an individual tends to think or behave, we can understand what a population will do. It is surely time to move beyond this “ideal gas” position and to acknowledge the interactive nature of society makes it truly complex and non-linear system.

T. Schelling

The Bank of Sweden Prize in Economic Sciences in Memory of Alfred Nobel 2005

"for having enhanced our understanding of conflict and cooperation through game-theory analysis"

Robert J. Aumann

1/2 of the prize

Israel and USA

Center for Rationality, Hebrew University of Jerusalem
Jerusalem, Israel

b. 1930
(in Frankfurt-on-the-Main, Germany)

Thomas C. Schelling

1/2 of the prize

USA

Department of Economics and School of Public Policy,
University of Maryland
College Park, MD, USA

b. 1921

<u>Physics paradigm:</u> Collective behavior and order-disorder transitions

This work is about the mechanisms that translate individual unorganized behavior into collective results

Micromotives and Macrobehavior

And long time ago I discovered, somebody told me that, there were some physical models, I think something in crystal formation. Somebody was referring to ISING model, which was a well-known model of, I think, crystal formation. And it seemed to be reminiscent of what I did, and they were interested in whether if examined in detail the analogy would be preserved at the local detail of the molecules of whatever it was.

Schelling´s residential seggregation model =

Kinetic Ising model at T=0, with exchange dynamics and vacancies

Emergence in social systems

The behavior of large and complex aggregates of elementary particles, it turns out, **is not to be understood in terms of a simple extrapolation of the properties of a few particles**. Instead, at each level of complexity entirely new properties appear

P. Anderson

More is different, Science (1972).

T. Schelling

Micromotives and Macrobehavior (1978)

We usually have to look at the system of interaction between individuals and their environment, that is, between individuals and the collectivity. And sometimes the results are surprising. Sometimes they are not easily guessed. Sometimes the analysis is difficult. Sometimes it is inconclusive. ***But even inconclusive analysis can warn against jumping to conclusions about individual intentions from observations of aggregates, or jumping to conclusions about the behavior of aggregates from what one knows or can guess about individual intentions.***

Micro-macro and emergence

D. Watts, Everything is obvious. How common sense fails, 2011

Micro-macro: How do we get from the micro choices of individuals to the macro phenomena of the social world?

Something like the micro-macro problem comes up in every realm of science, often under the label of "emergence": How is it, for example that one can lump together a collection of atoms and somehow get a molecule? How is that one can lump together a collection of molecules and somehow get amino acids? How is it that one can lump together a collection of aminoacids and other chemicals and somehow get a living cell? How is that one can lump together a collection of living cells and somehow get complex organs like the brain? And how is that one can lump together a collection of organs and somehow get a sentient being that wonders about its eternal self? (P.W.Anderson, *More is differrent,* Science (1972))

Seen in this light, sociology is merely at the tip of the pyramid of complexity that begins with subatomic particles and ends with global society. And a each level of the pyramid, we have essentially the same problem-how do we get from one "scale" of reality to next?

The Future of Physics

W. Heisemberg: Have we reached the end of Physics? (1970)

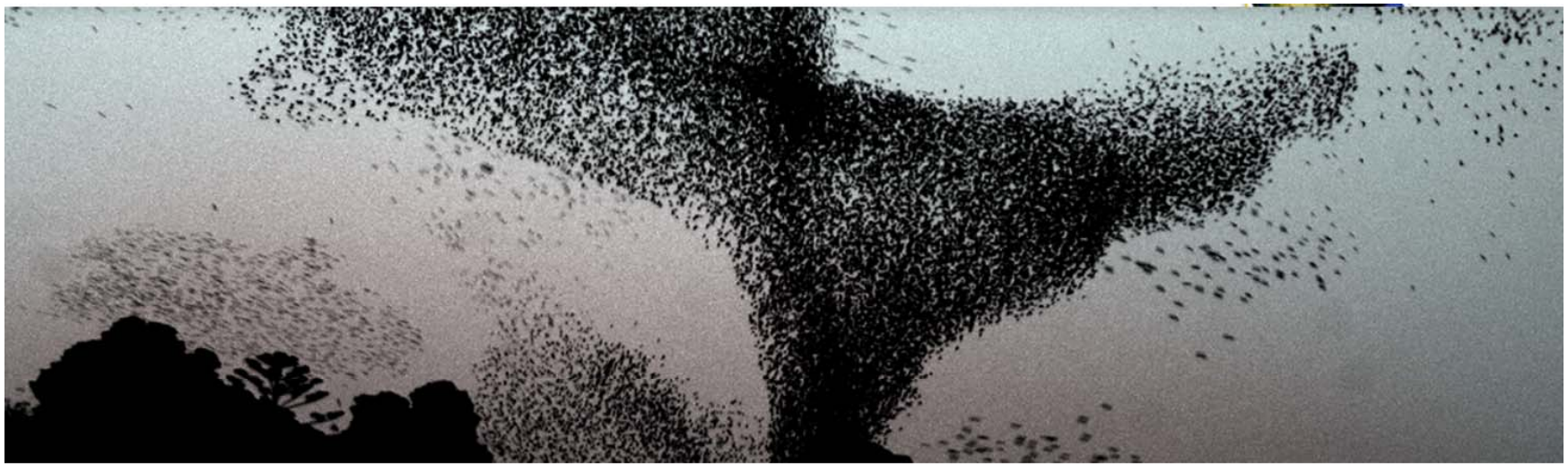
Physics would now remain as a "closed science". But the limits between Physics and nearby sciences are so fluid that Physics can never be a closed science

What is Physics? ***Physics is what physicists do*** (*Sam Edwards, David Gross…*)

M. Buchanan (2008):

The future of physics really may lie mostly outside of physics.

The greatest contribution physics can make to the rest of science is the good sense of starting simple



IDEAS | SCIENCE PRACTICE

Why Physics Is Not a Discipline

Physics is not just what happens in the Department of Physics.

BY PHILIP BALL
APRIL 21, 2016

Ernst Mayr's (2004) *What Makes Biology Unique*.

Physics according to Mayr: essentialist, deterministic, reductionist!
Quantum, chaos, complexity and emergence ?

Pursuing arrogant simplicities *Nature 416, 247 (2002)*

Multidisciplinary research in biology *requires the patience to distinguish untutored crassness from deceptively simple insights*, and awareness from all participants of just how complex is even the simplest life-form.

Commenting on the impact of physicists on biology after the Second World War, the physicist-turned-biologist Leo Szilard said: "What physicists brought to biology is not any skills acquired in physics, but rather an attitude: the conviction that few biologists had at that time, that mysteries can be solved." Physicists always tend to start simple. Is that wise, when confronting life?

Let no one underestimate the irritation that hypothetical simplicity can engender. Just consider the reactions to 'Daisyworld' ....

Especially in a multidisciplinary project, *it's important to be able to distinguish between ignorant simple-mindedness and the simplicity of true insight*. This is easily said but less easily done

S. Galam: Le Monde, 26 Febrero, 2005

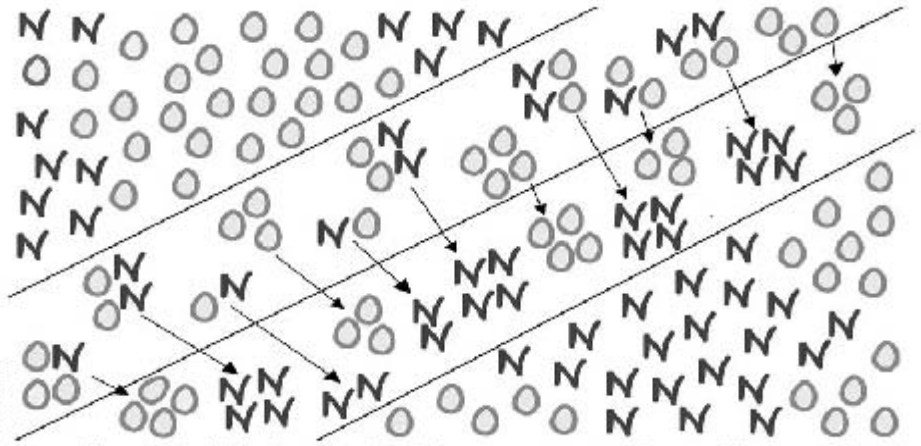
Elaboré par un sociophysicien, un modèle décrit comment une opinion qui était au départ minoritaire peut finir par l'emporter

Les mathématiques s'invitent dans le débat européen

« LE "NON" ... é constitutionnel européen ... importer... Je le crains. » L... qui formule ce pronostic n'est pas un politologue, ne dirige pas un institut de sondages et ne lit pas davantage dans une boule de cristal. Il est chercheur et utilise, pour tout outil de travail, des modèles mathématiques.

Serge Galam, physicien de formation, spécialiste des théories du désordre, œuvre au rapprochement de sa discipline d'origine et des sciences humaines au sein du Centre de recherche en épistémologie appliquée (Ecole polytechnique-CNRS) de Paris. Ce « sociophysicien » s'intéresse, en particulier, aux mouvements d'opinion (*Le Monde* du 28 mars 2000).

L'un de ses modèles, décrivant *« la propagation d'opinions minoritaires en milieu démocratique »* s'appli-



SERGE GALAM

Au terme d'un seul cycle de discussion, 25 « oui » et 12 « non » peuvent se transformer en 20 « non » et 17 « oui ».

sant que, sur 100 Français, 70 sont au départ favorables au « oui » au référendum, ils ne sont plus que 67 après le premier round de discussion, 63 après le deuxième, puis, la machine s'emballant, 56, 45, 30, 12, 2 et, pour finir, 0. Quatre cycles suffisent pour rendre le « oui » minoritaire, et huit pour l'éliminer complètement. Il faudrait que les partisans du « oui » soient 80 pour qu'ils finissent par convaincre les 20 défenseurs du « non », au bout de quatorze cycles de discussion.

Un tel scénario, qui réduit à néant une opinion au départ largement majoritaire, n'est évidemment guère vraisemblable. Cette construction arithmétique a en effet ses limites. Elle ne tient pas compte, en particulier, de tous les facteurs externes – interventions politiques, campa-

COLLECTIVE SOCIAL DYNAMICS

LA OLA

Millenium Bridge, London

Jamaraat Bridge, Mecca

IFISC

COLLECTIVE SOCIAL DYNAMICS

London 2011

COOPERATION

Torok et al,
Physical Review Letters ***110*** *(2013)*

acampadasol democraciarealya 15m yeswecamp notenemosmiedo nonosvamos spanishrevolution nolesvotes

Instituto Universitario de Investigación Biocomputación y Física de Sistemas Complejos Universidad Zaragoza

http://15m.bifi.es/index_en.php

31 days, May 2011, 87,569 users

581,749 messages

- Agent characterization: state
- Interaction rules among angents
- Network of interactions: Who interacts with whom?
- Activity patterns: When interactions occur

What makes James Bond an agent? He has a clear goal, he is autonomous in his decisions about achieving the goal and he adapts these decisions to his rapidly changing situation

(V. Grimm et al, Science (2005))

- **Who defines the questions? Who decides the good models?**

Some problems: Competition and Cooperation, Consensus vs Polarization, Opinion formation, Social structure and group formation, Cultural dissemination, Language Competition, Information aggregation, Social learning, Innovation Adoption, Sociotechnical Systems

Tools: Statistical and Nonlinear Physics, Complex Networks, Game Theory

Basic issue in modelling: People do not behave like particles?

Ising like variables → Game theory → Emotions

(no strategies) (rational agents, bounded rationality) ?

social *homo economicus*

What are "*RELEVANT*" social ingredients?

Differences between social and physical systems

-Heterogeneity

-Local Optimization vs Global (Physics)

-Strategic interactions. Expectations. No reciprocity (Newton´s third law fails)

-Meaning

-La vida no es lo que uno vivió, sino lo que uno recuerda y cómo lo recuerda para contarla (Gabriel García-Márquez)

-Second-order emergence:

-Humans can recognise and react to the emergent global structure

-Circumstances make men as much as men make circumstances

-Feedback processes in which the elementary units of the system react to the collective behaviour redefining micro-level interaction processes

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Axelrod's model of social influence

J. Conflict Resolution 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")*

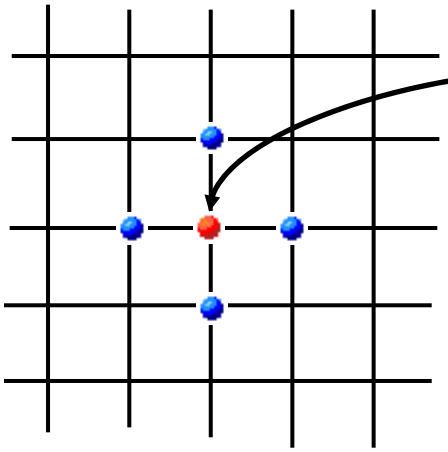
Definition of culture: Set of individual attributes subject to social influence

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.*

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

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.

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

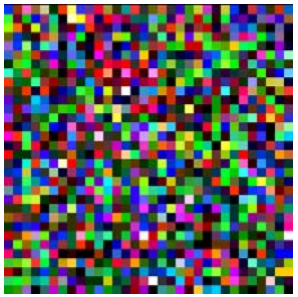
Mechanism of local convergence:

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

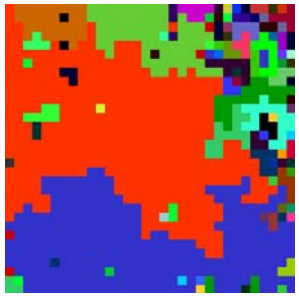
$$\begin{pmatrix} 5 & 5 \\ 0 & 9 \\ 7 & 7 \end{pmatrix}$$

Visualization of Axelrod´s Dynamics

$F = 3,\ q = 10$



$t = 0 \longrightarrow$



System freezes in an absorbing multicultural state

Interdisciplinarity and Cleavages

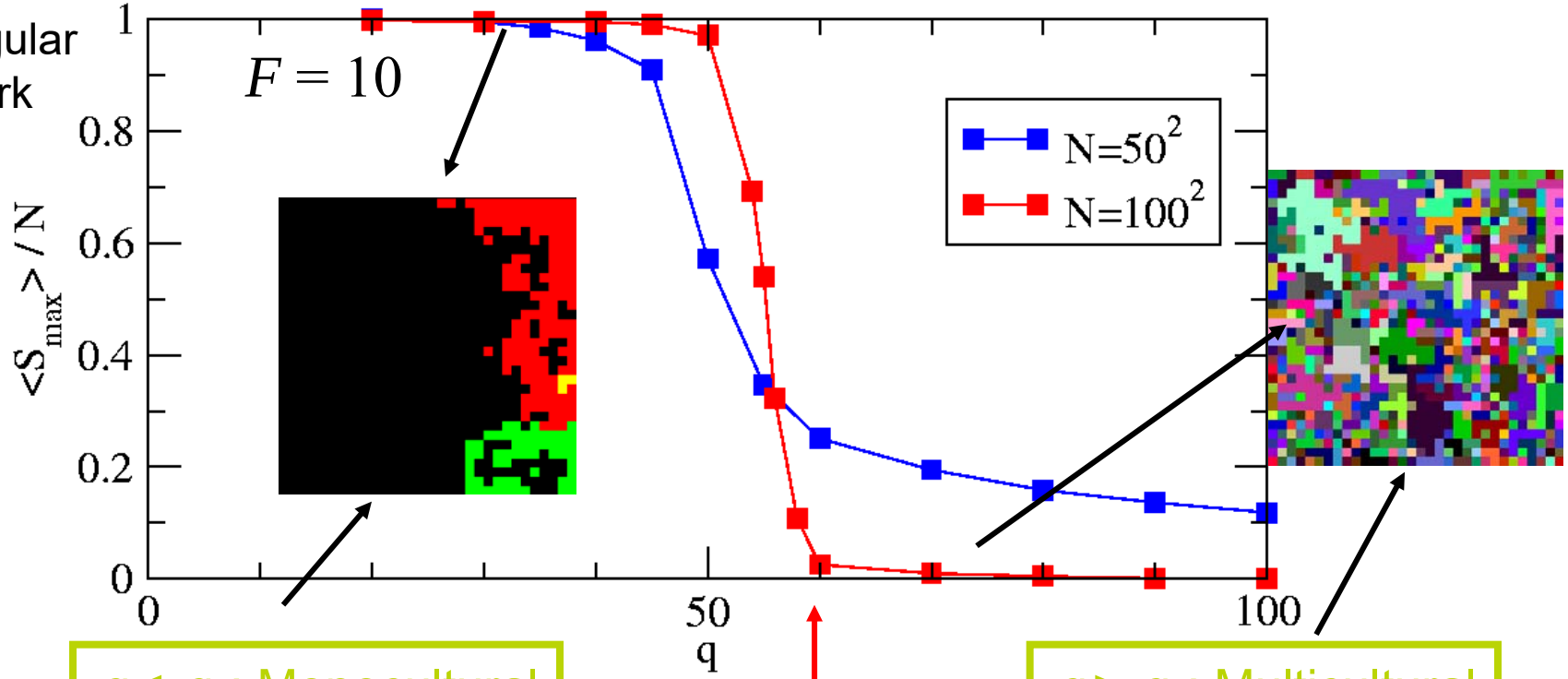
The model illustrates how local convergence can generate global polarization.

Polarization-Globalization Transition

Castellano, Marsili, Vespignani, Phys. Rev. Lett. ***85****, 3536 (2000)*
San Miguel et al., Computing in Science and Engineering ***7****, 67 (2005)*

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

2d regular network



$q < q_c$: Monocultural

Global culture

q_c

$q > q_c$: Multicultural

Cultural diversity

Global polarization

Beyond Axelrod's original model

1. Social structure: *" With random long distance interactions, the heterogeneity sustained by local interactions cannot be sustained."* R. Axelrod, J. Conflict Res. (1997)

Klemm et al., Phys. Rev. E **67**, 026120 (2003);
San Miguel et al., Computing in Science and Engineering **7**, 67 (2005)

2.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)

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 **51** 905(2007)

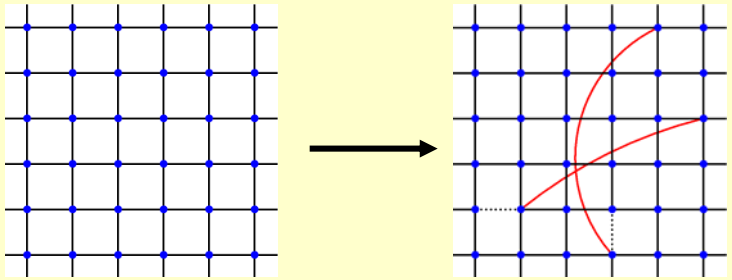
4.Multilayered Social Influence F. Battiston et al ArXiv 1606.05641 (2016)

5. The function of mass media:

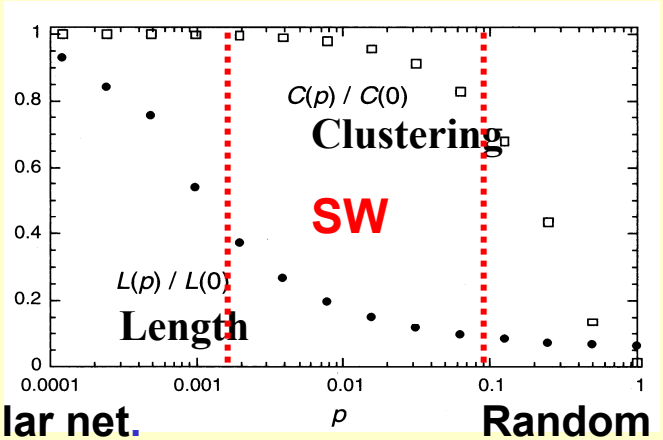
Information feedback through agents: Shibanai et al., J. Conflict Resolution. **45**, 80 (2001
J.C. González-Avella et al., Phys. Rev. E **73**,046119 (2006); JASSS **10**, 1-17 (2007) ;
New J. Phys. 12, 013010 (2010), PLoS One **7**, e51035 (2012)

Small-world networks

Watts, Strogatz, Nature 393, 440 (1998)

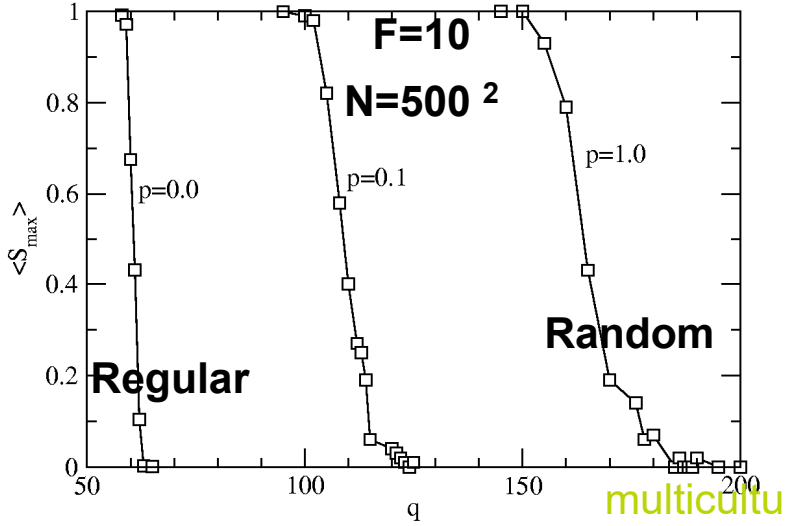


Rewire with prob. *p*

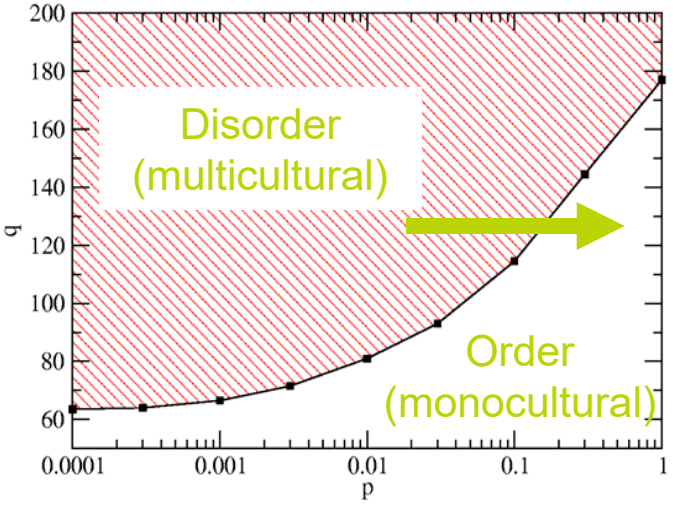


Regular net. **Random net.**

monocultural



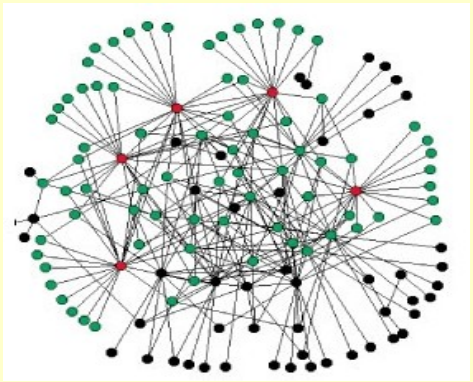
multicultural



Small world connectivity favors cultural globalization

Scale-free networks

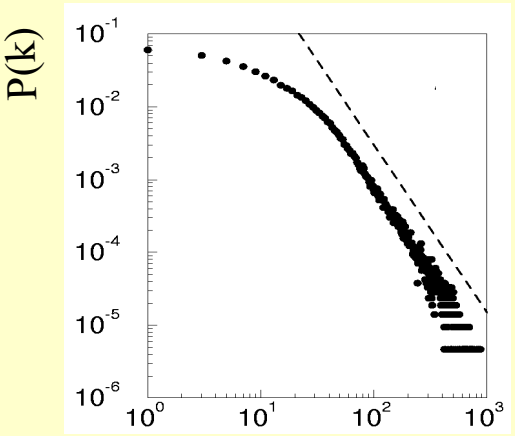
Albert & Barabasi, Rev. Mod. Phys.74, 47 (2002)



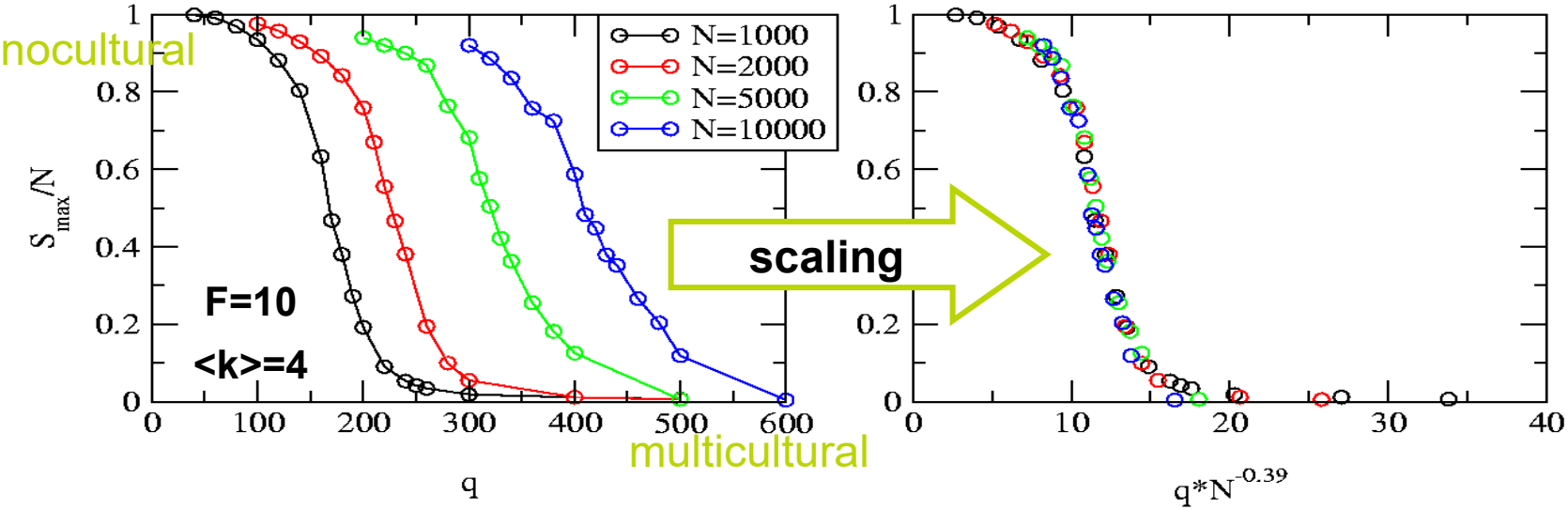
Power law for the degree distribution

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

Importance of hubs

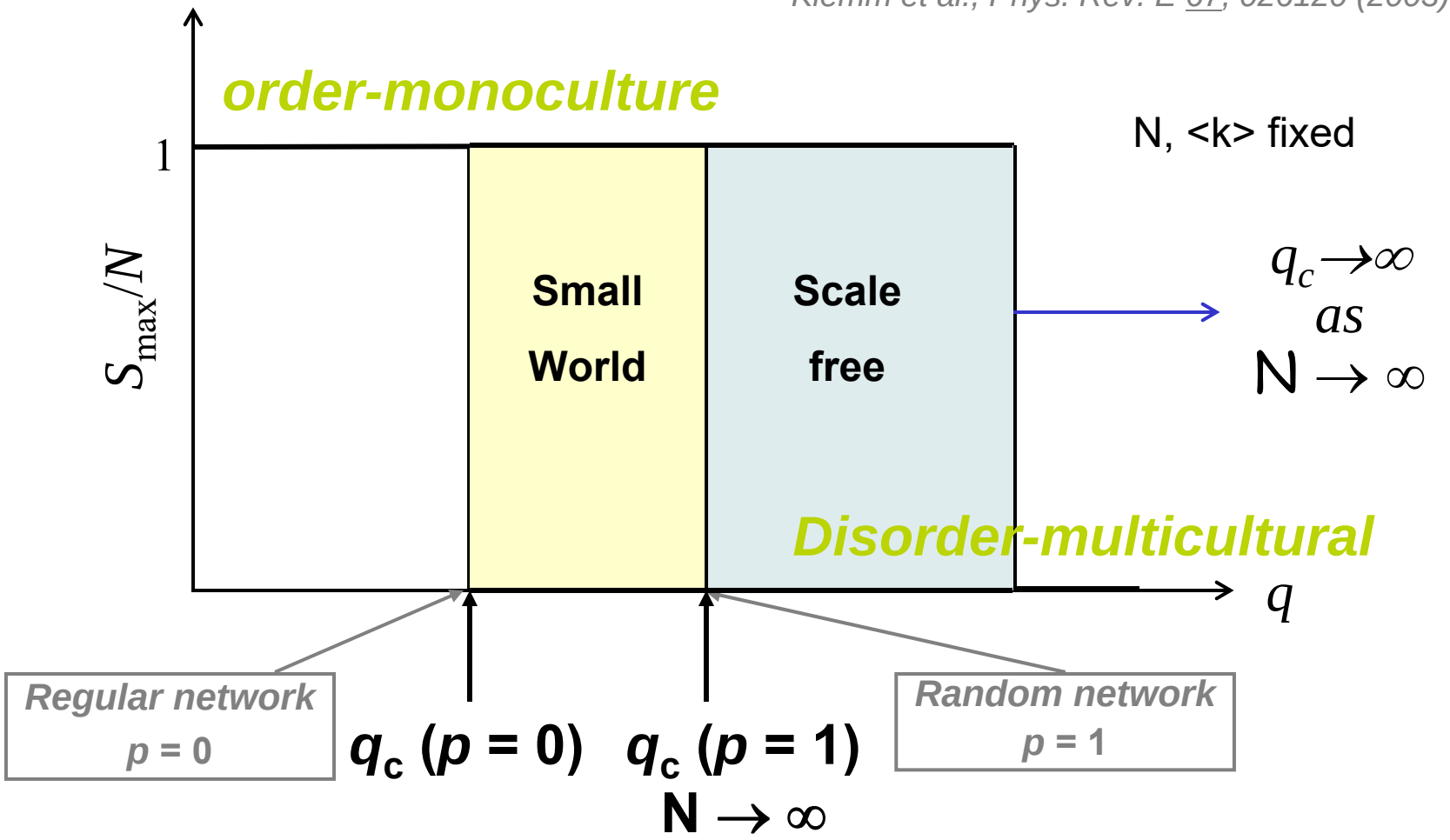


monocultural



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

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



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

Beyond Axelrod's original model

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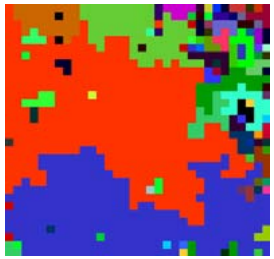
Robustness and Cultural Drift



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

Frozen states stable against perturbations?

Robustness of transition?

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)

Question: Time scales of evolution.

Role of noise?

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

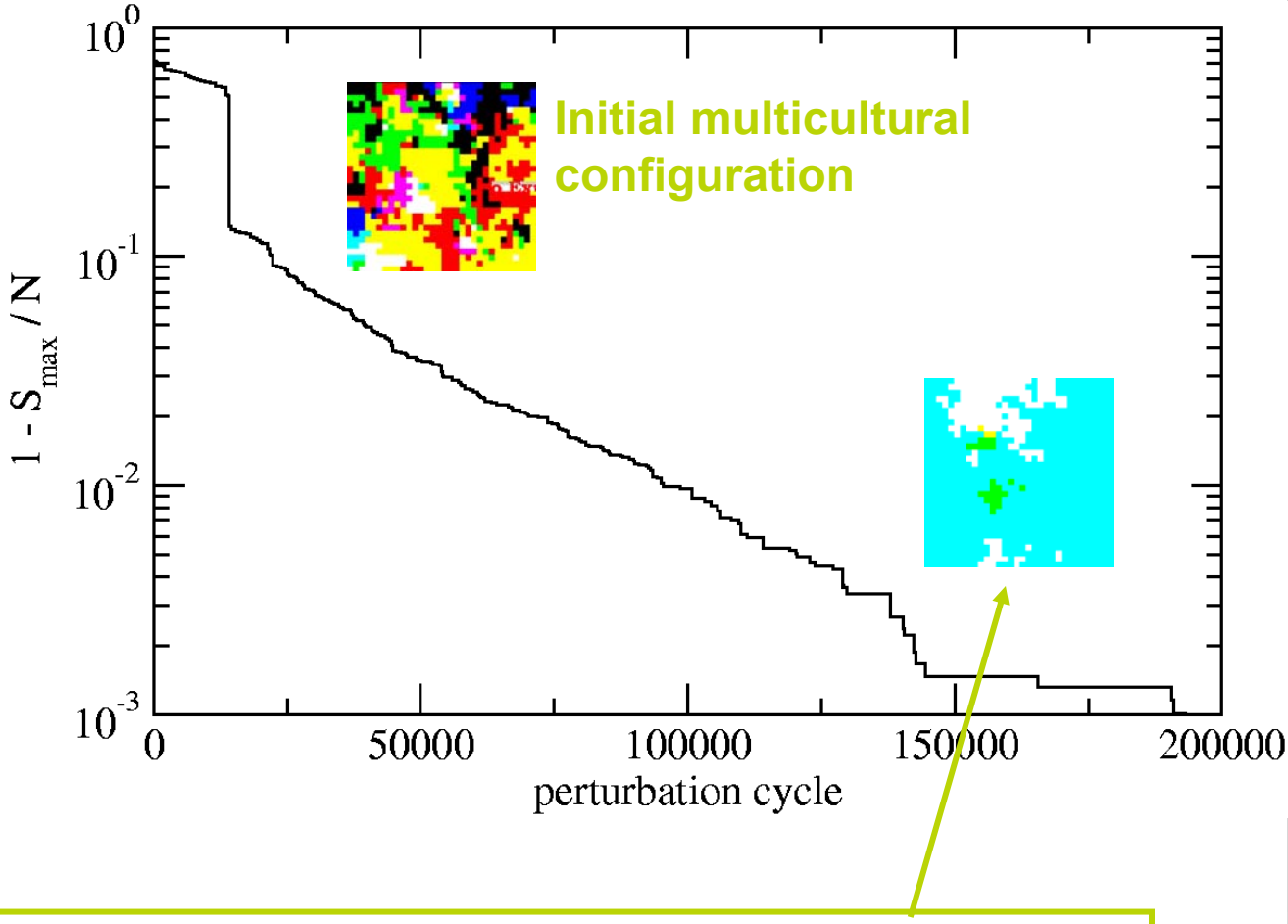
Metastable states?

Perturbation-relaxation cycles:

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

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

3. Return to 1.

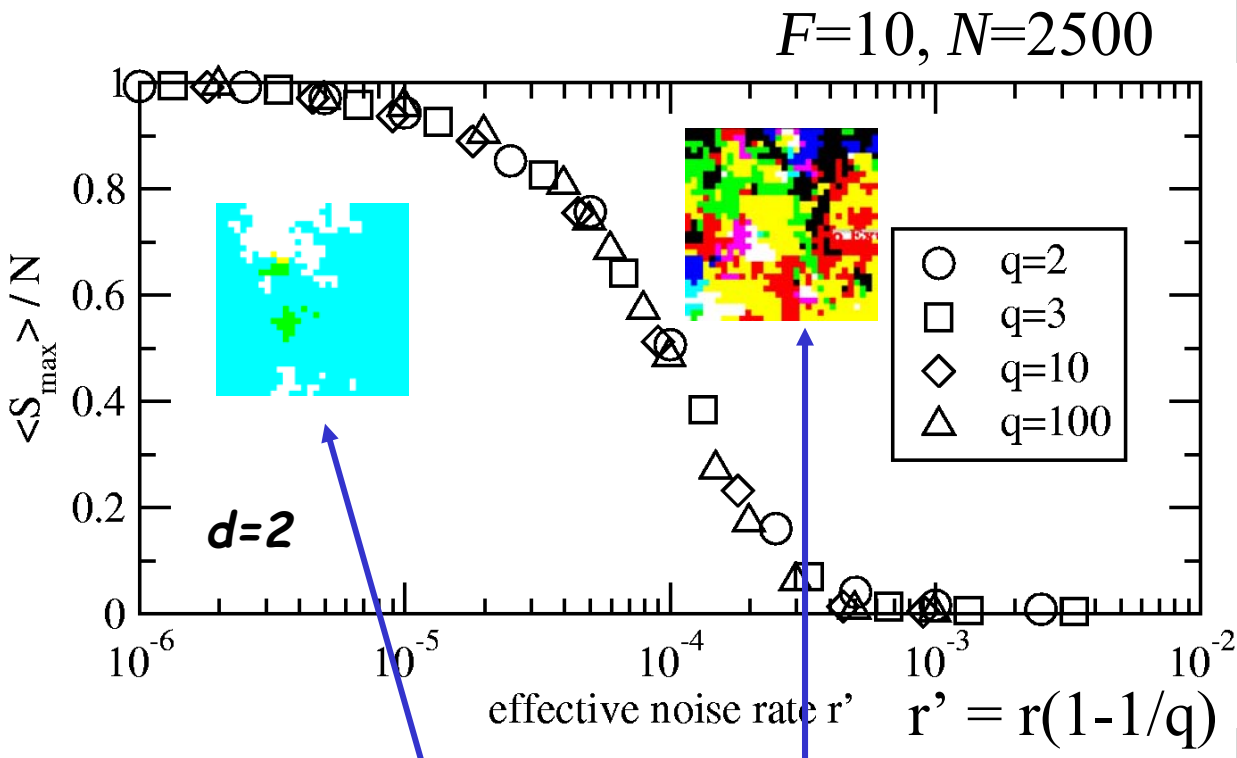


System driven by noise towards a state of global culture

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

IFISC

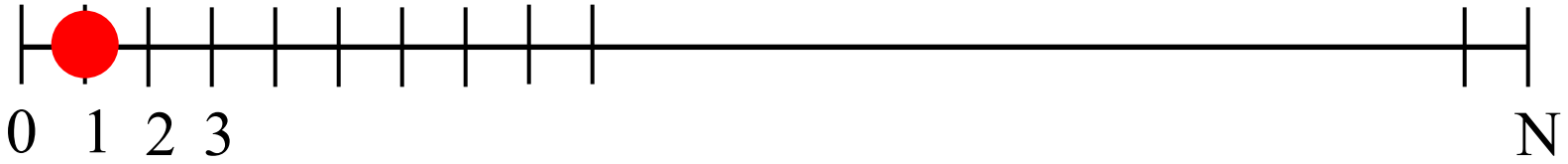
Competition between noise time scale (1/r) and relaxation time of perturbations T:

- 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?

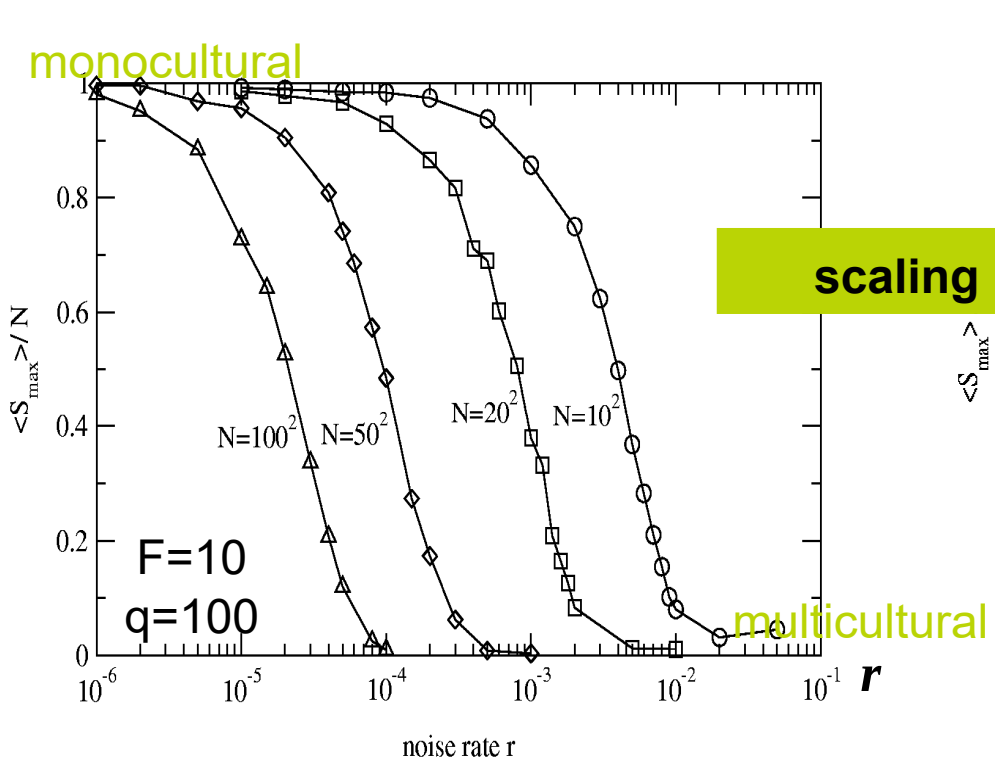
Exit time in *random* walks (mean field)



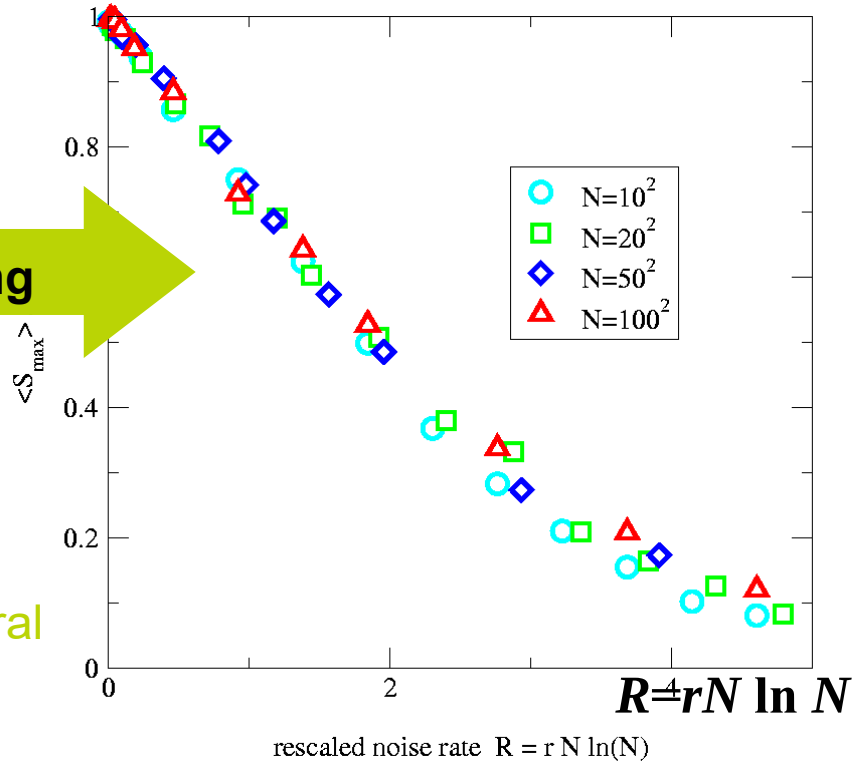
Damage x(0)=1 reaches $x=0$ or $x=N$ in a mean exit time

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

System size dependence



scaling



- 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.

Cultural Drift: Summary

•**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 ($r > T^{-1}(N) \to 0$) 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.

Beyond Axelrod's original model

1. Social structure: *" With random long distance interactions, the heterogeneity sustained by local interactions cannot be sustained."* R. Axelrod, J. Conflict Res. (1997)

Klemm et al., Phys. Rev. E **67**, 026120 (2003);
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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 **51** 905(2007)

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New J. Phys. 12, 013010 (2010), PLoS One **7**, e51035 (2012)

Axelrod's model of social influence

J. Conflict Resolution 41, 203 (1997)

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

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´s conclusion: 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: **COEVOLUTION Dynamics**

CO-EVOLUTION

M. Zimmerman, et al Lecture Notes in Economics and Mathematical Systems 503, (2001)

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, Am. J. Soc. 97, 808 (1991))

Final Goal: Understanding *dynamical* processes of group formation and social differentiation: Emergence of social dynamical networks with

-Social structure

-Weak links (Granovetter)

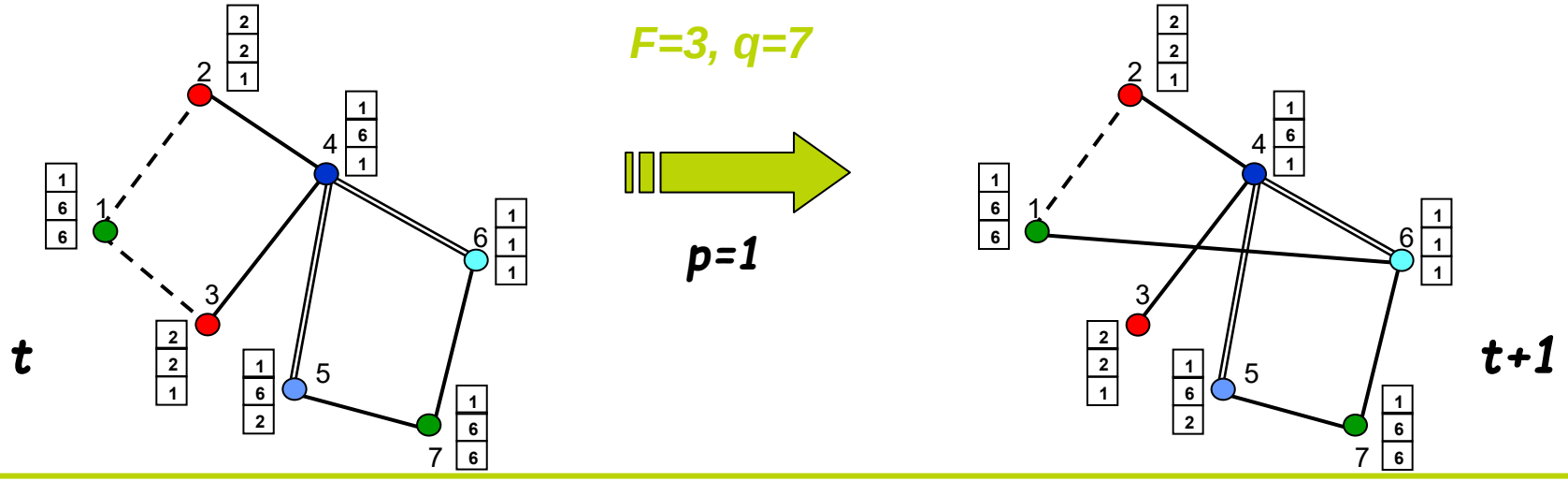
-Community structure

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)

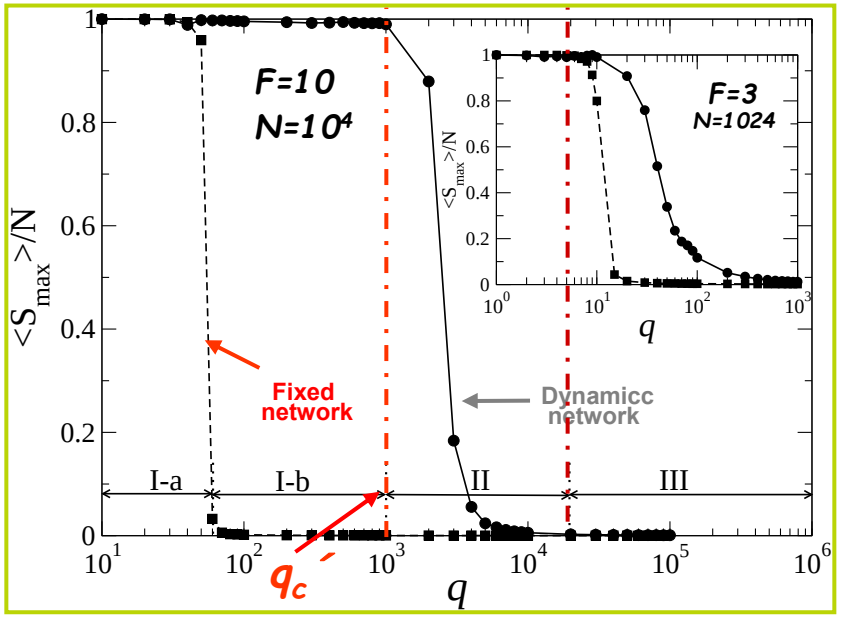
Step 2: Social influence dynamics: interaction results in one more common trait

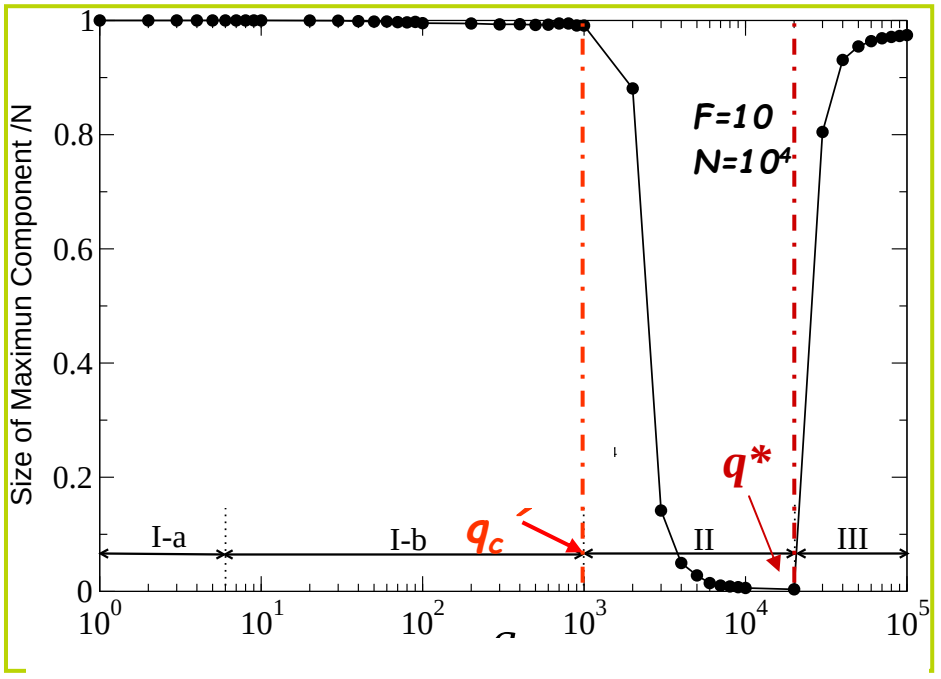
Step 3: *NETWORK DYNAMICS:* New homophily specification

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



Polariza[illegible]





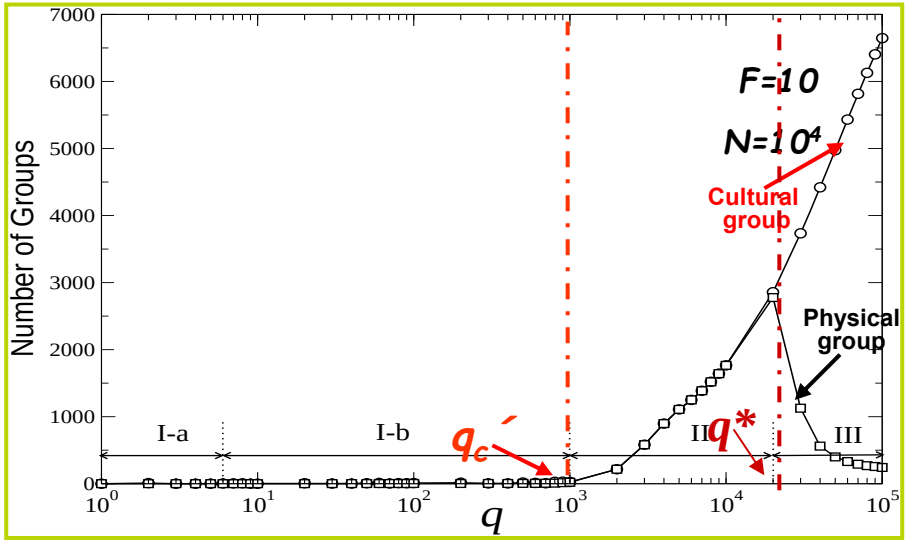
I) $q < q_c'$ (frozen)
Monocultural state in giant network component

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

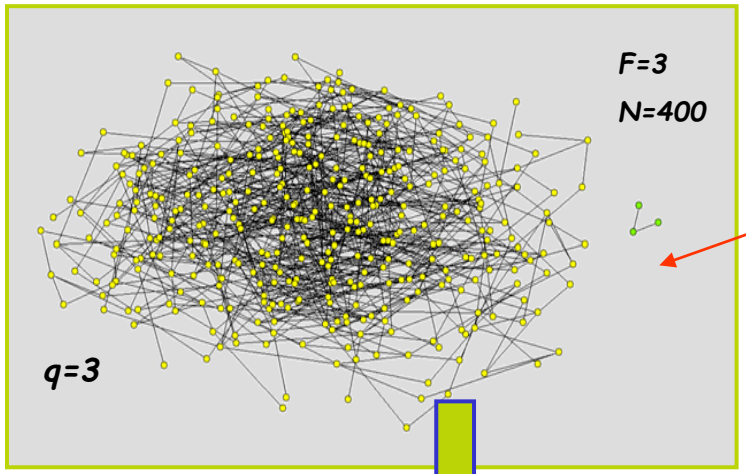
III) $q > q^*$ (dynamic configuration)
Continuous break of links and search of new partners
Giant network component
Cultural and physical groups do not coincide.



Network fragmentation and recombination

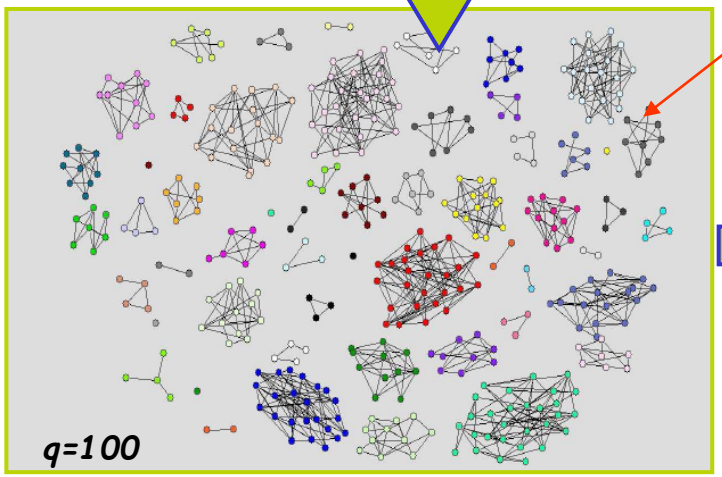
F. Vázquez et al. Phys. Rev. E **76**, 046120(2007)

Region I (frozen configuration)



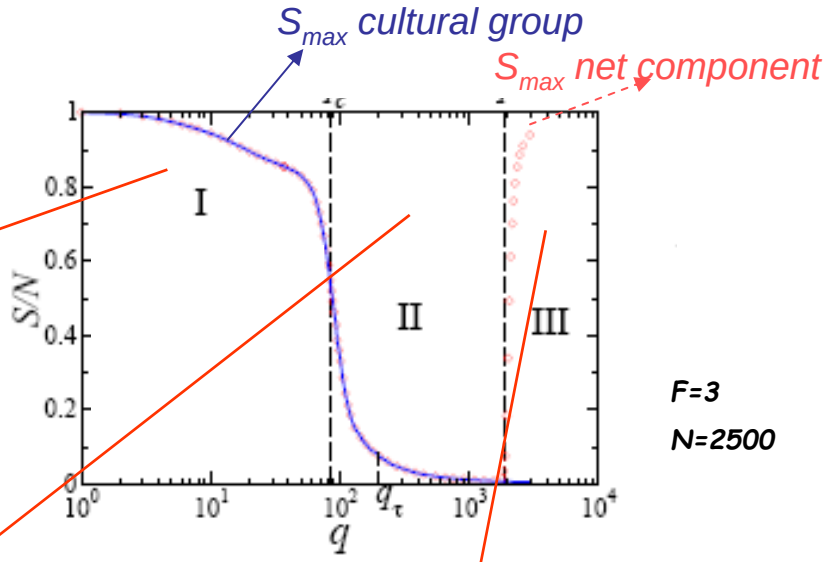
Fragmentation

Region II (frozen)

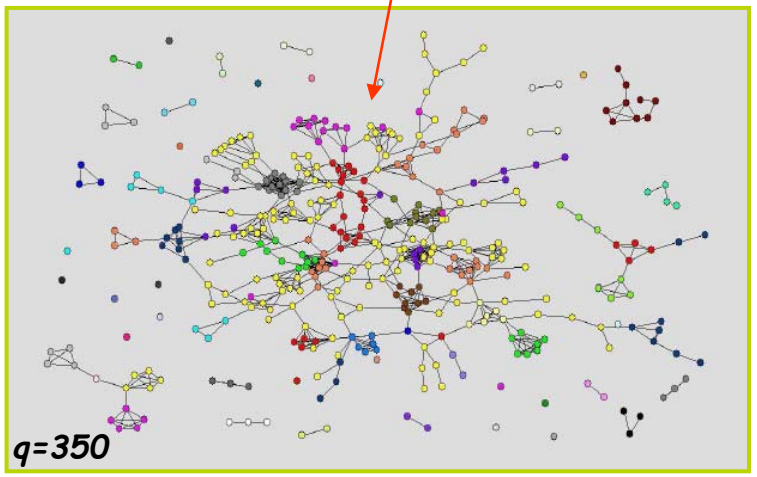


Recombination

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



Region III (dynamic frustrated configuration)



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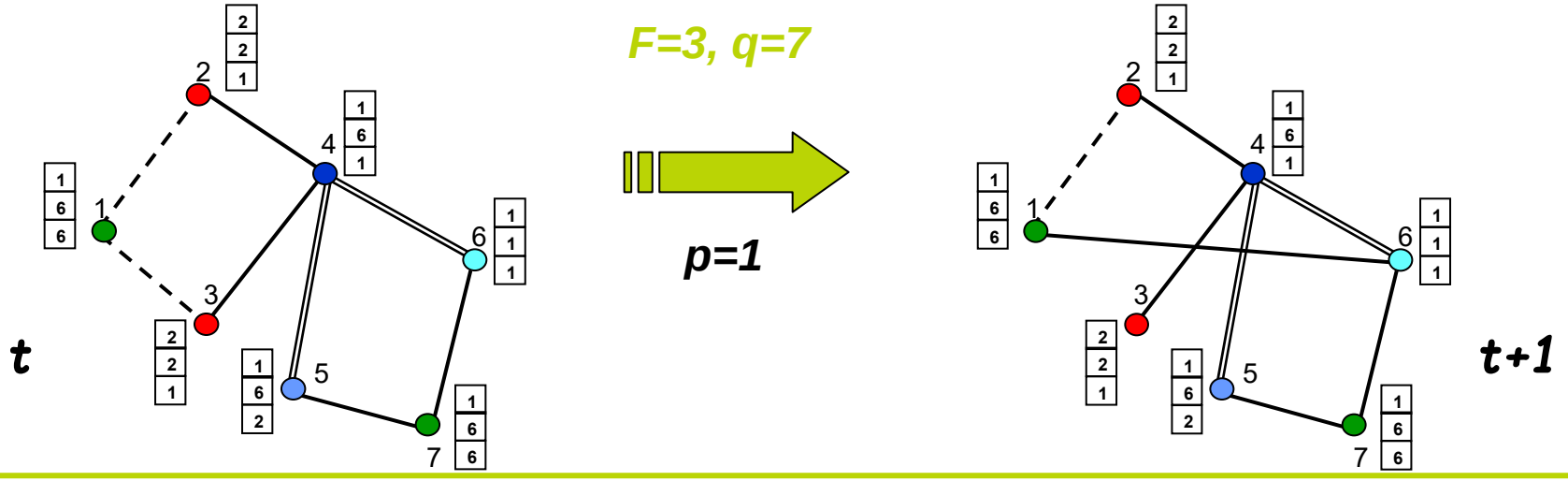
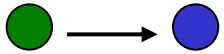


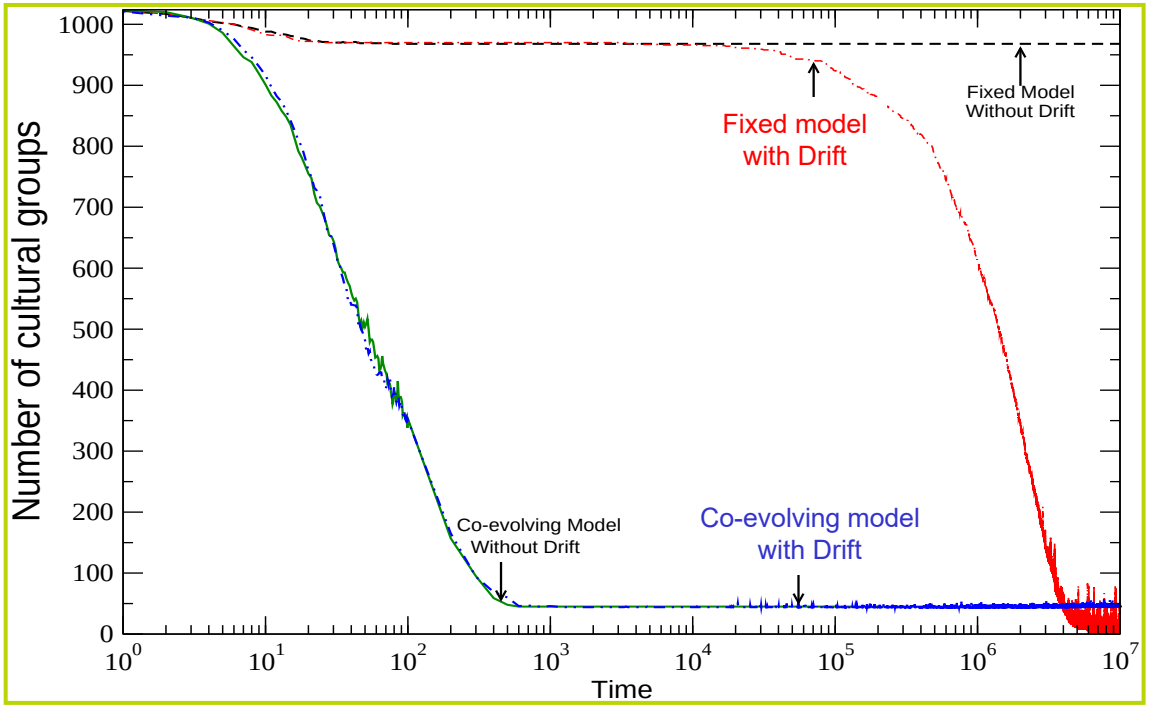
Step 4: Cultural drift:

Single feature perturbation with probability r



Cultural drift in a Co-evolving Network

*D. Centola et al. J. of Conflict Resolution **51**, 905 (2007)*



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)

Robustness of cultural polarization

Alternatives to coevolution: (modifying local interactions)

-Threshold of cultural overlap for interaction (~ bounded confidence)

Flache and Macy, ArXiv 0604201

-Nondyadic interactions (whole neighborhood matters)

*Flache and Macy, J. Conflict Resolution **55**, 970 (2011)*

-Social differentiation: tendency to increase cultural differences

*Flache and Macy, J. Math. Sociology, **35**, 146 (2011)*

Mas, Flache and Kitts in Perspectives on culture and agent based models, Dignum and Dignum, eds Springer (2014)

-Layered social influence *F. Battiston et al ArXiv 1606.05641 (2016)*

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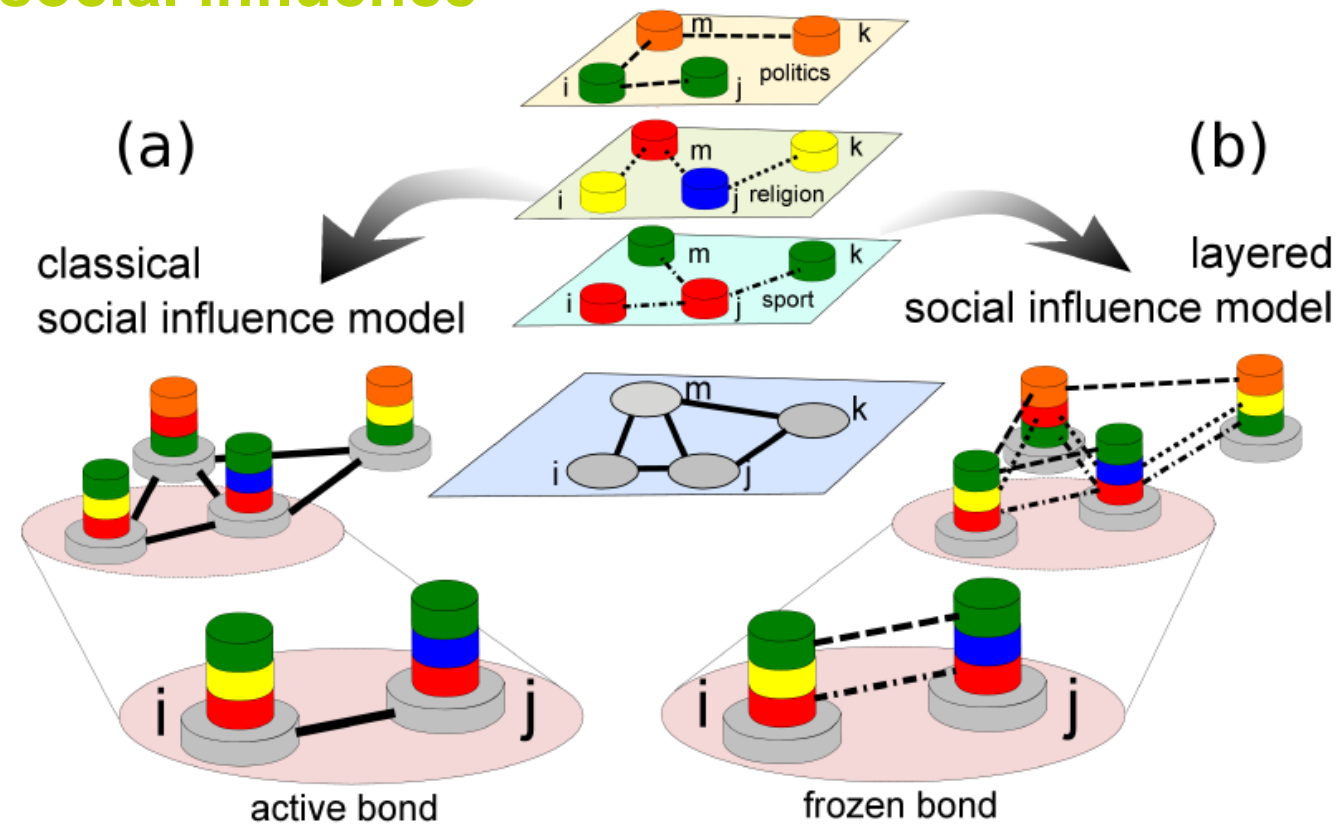
Axelrod´s multilayer model

F. Battiston et al ArXiv 1606.05641 (2016)

Layered social influence



New parameter: ***Structural edge overlap O***

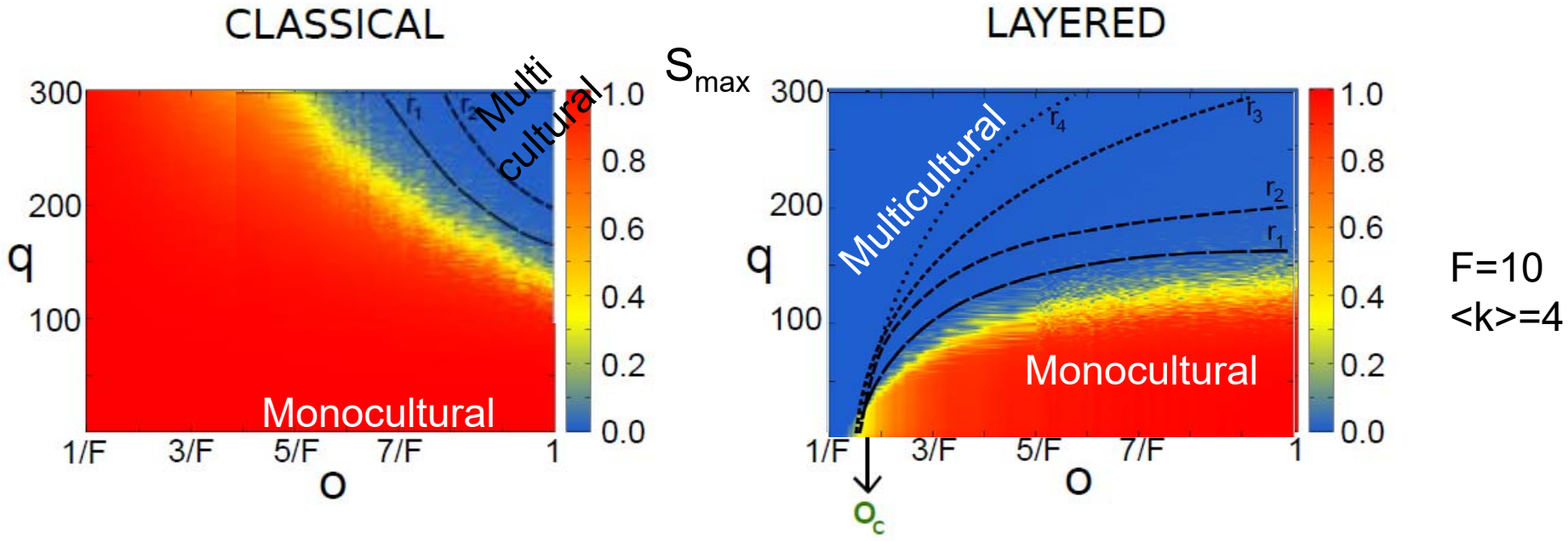
Classical model uses aggregated network with *O*-dependent connectivity

Classical and layered model coincide for maximum overlap *O=1*

Axelrod´s multilayer model

F. Battiston et al ArXiv 1606.05641 (2016)

Globalization-Polarization transition:



Implications of layered social influence:

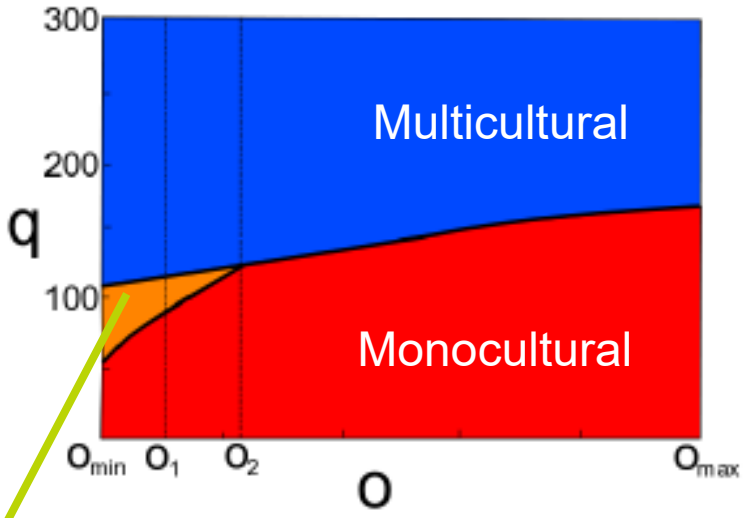
- For $O<O_c$ multiculturality exists for any q
- Multiculturality for O<Oc is robust against cultural drift

Axelrod´s multilayer model

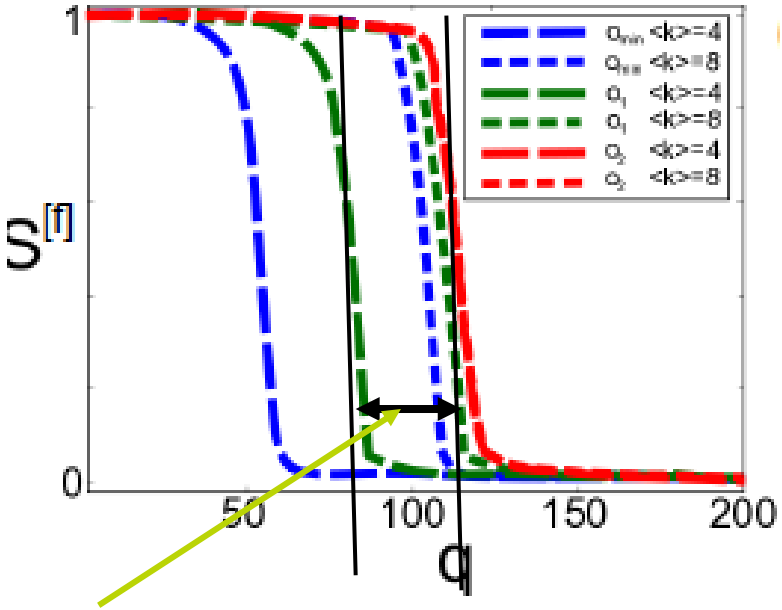
F. Battiston et al ArXiv 1606.05641 (2016)

New phase of Feature-level consensus

F=10, 5 layers with <k>=4, 5 layers with <k>=8



Consensus in five layers and polarization in other layers



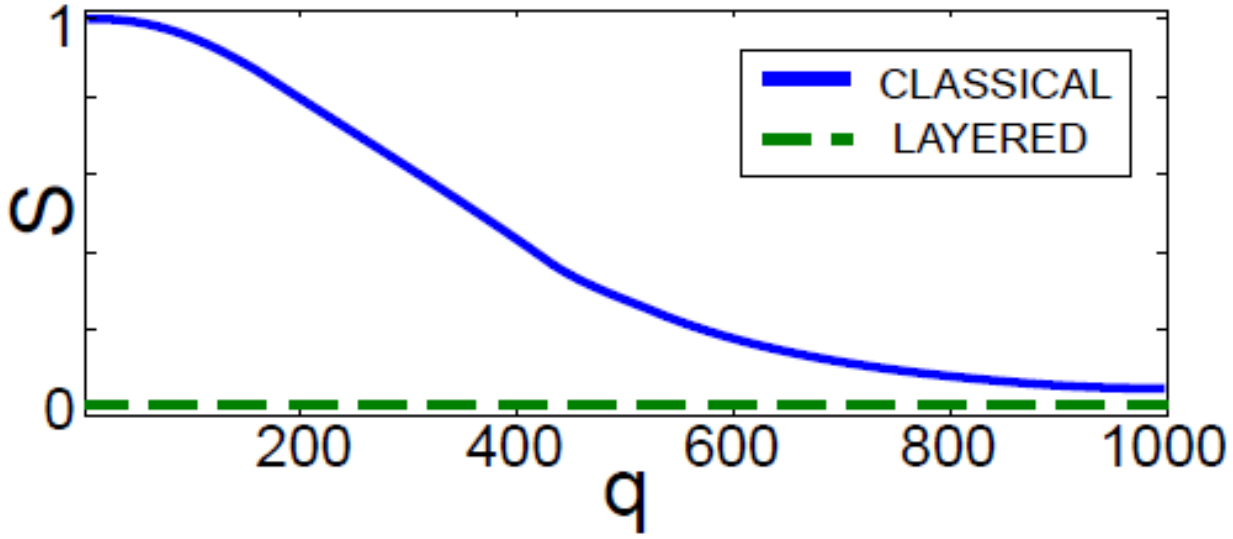
$O=O_1$, Multi for <k>=4 layers
Mono for <k>=8 layers

* **Global culture for some features coexist with polarization for other features**

Axelrod´s multilayer model

F. Battiston et al ArXiv 1606.05641 (2016)

Multiculturality in empirical multilayer networks



Pierre Augier collaboration network (F=16, O = 0.07, N=475)

Axelrod´s multilayer model

F. Battiston et al ArXiv 1606.05641 (2016)

Layered social influence:

- *Multicultural states for all values of q (for O<Oc)*
- *Multicultural states robust against cultural drift (noise)*
- *New phase: Globalization in some features and multiculturality in others*

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New J. Phys. 12, 013010 (2010), PLoS One **7**, e51035 (2012)

Question addressed:

Competition between
collective social self-organization
vs.
external mass-media or propaganda message

Local agent-agent interactions vs. global interactions

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 modify 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?

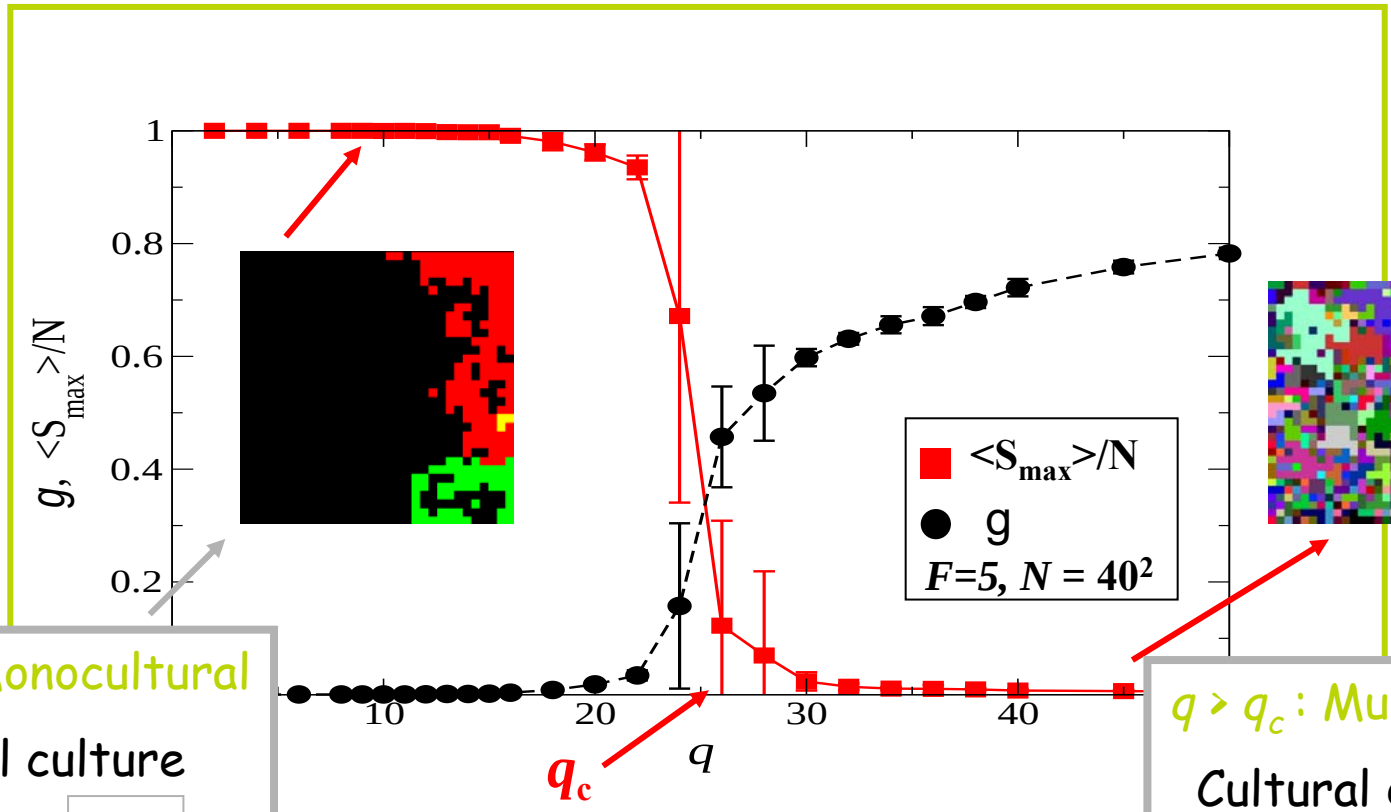
Q4. What is more efficient in producing cultural homogeneity, local mass media or global mass media ?

Q5. What social structure is needed to reach consensus opposed to a mass media message ?

Polarization-Globalization transition

Order parameters: a) S_{max} size of the largest homogeneous domain

b) $g = \langle N_g \rangle / N$, N_g = # cultural groups



$q < q_c$: Monocultural

Global culture

$\frac{\langle S_{max} \rangle}{N} \to 1$ g→0

$q > q_c$: Multicultural

Cultural diversity

Global polarization

$\frac{\langle S_{max} \rangle}{N} \to 0$ g→1

Castellano, Marsili, Vespignani, Phys. Rev. Lett. ***85****, 3536 (2000).*

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

Modelling Mass Media

Mass Media message or field: $M = (\mu_1, \mu_2, ..., \mu_f, ..., \mu_F)$ $\mu_f \in \{0, ..., q-1\}$

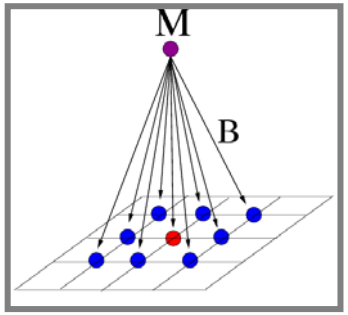
External media:

(Big brother)

μ_f *given*

- Uniform for all agents i

- Fixed for all times



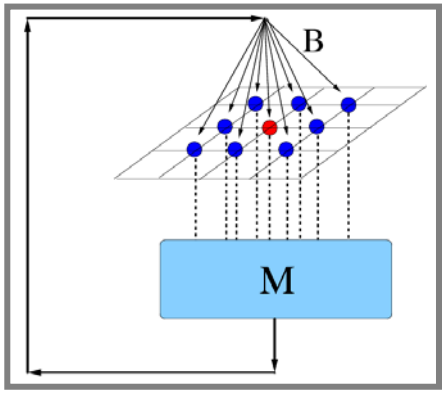
Propaganda or advertising

Endogenous media:

(4th democratic power)

Global media

Broadcast: Feedback of dominant global cultural trend



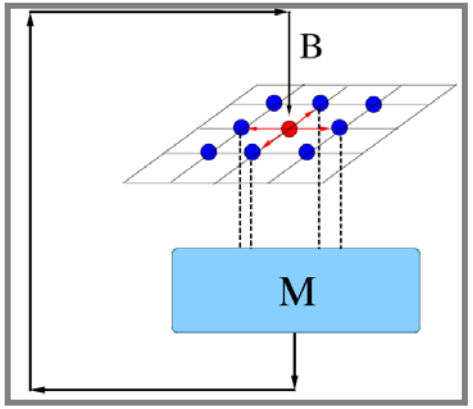
$\mu_f = \sigma_{jf}$ most abundant in system

- Uniform

-Time dependent

Local media

Narrowcast: Feedback of dominant local cultural trend



$\mu_f = \sigma_{jf}$ most abundant in neighborhood

- Non-uniform

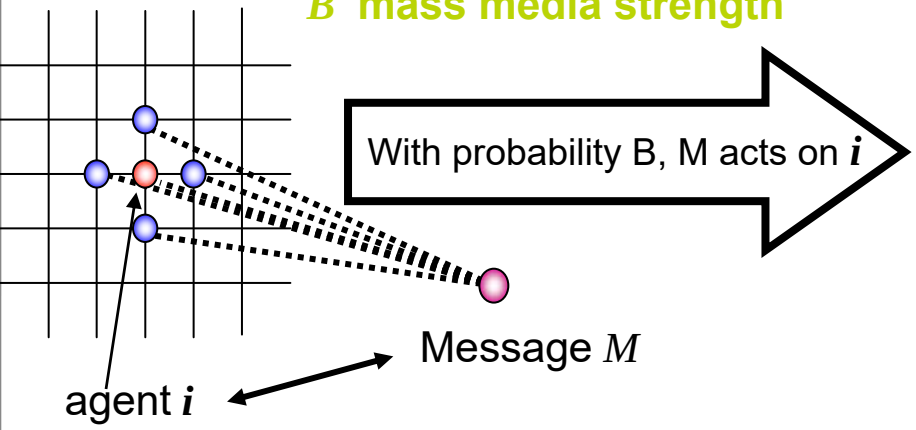
- Time dependent

Dynamics of interaction with mass media field

Agent i: $C_i = (\sigma_{i1}, \sigma_{i2}, ..., \sigma_{if}, ..., \sigma_{iF})$ $\longleftrightarrow$ Mass media: $M = (\mu_1, \mu_2, ..., \mu_f, ..., \mu_F)$

Parameter $B \in [0, 1]$: probability that *M* acts on element *i* in one time step: "*strength*" of mass media

$1 - B$: probability to interact with *j* selected at random among nearest neigbors of *i*. $\Rightarrow$ *M* acts as a 5th effective neighbor of *i*.



1) If M acts on agent i, the probability of interaction p_{iM} is proportional to the cultural overlap between i and M

2) Agent-Mass Media interaction results in agent i adopting a cultural feature of M

Mass media effects: monocultural state $(q < q_c)$

Globalization-polarization transition induced by mass media:

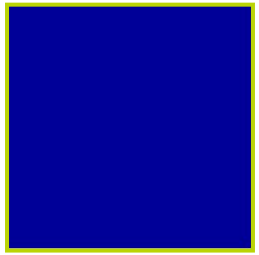
Mass media message produces polarization

Asymptotic states for **external** mass media

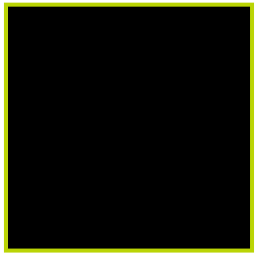
F=5, q=10

$M \rightarrow$ 

B=0

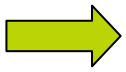


B=0.0084



B=0.5

B=0.9



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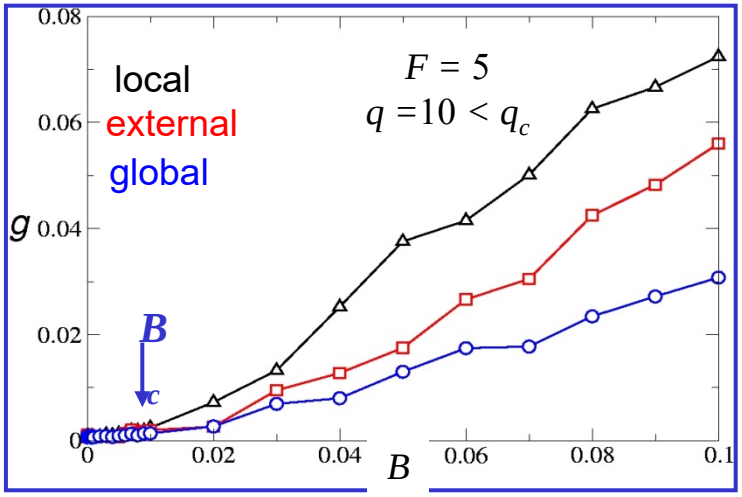
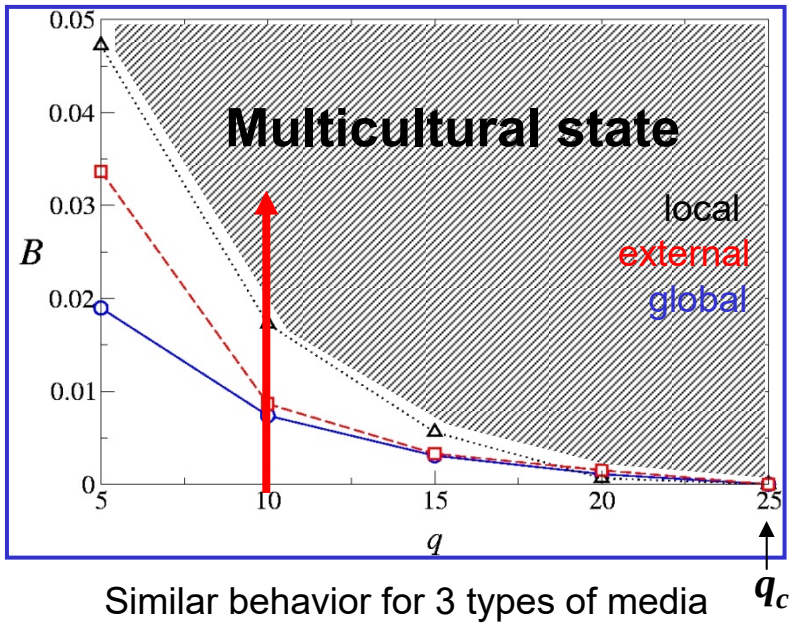


$B > B_c$: any Mass Media leads to cultural diversity

Phase Diagram



Similar behavior for 3 types of media

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

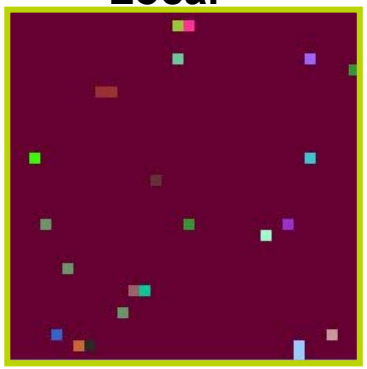
Cultural homogenization for weak mass media:

B=0.0042, F=5, q=28

B=0

t = 727

Local

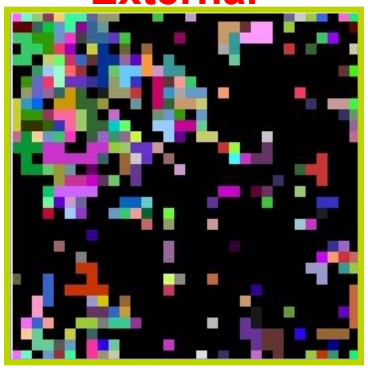


t = 6058

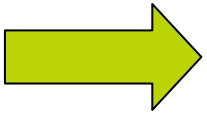
Global

t = 4827

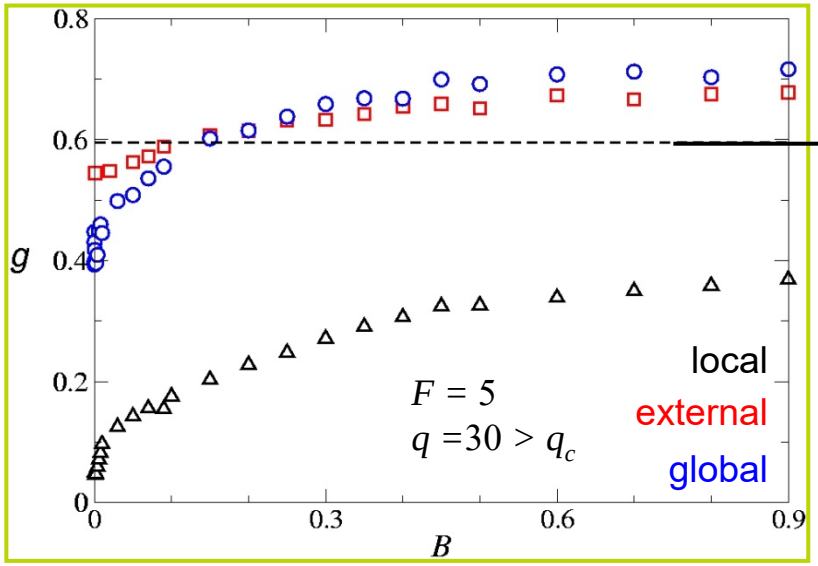
External



t = 5748



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



- For B small, $g < g(B=0)\ \forall\ M$:

  Cultural homogenization by weak media.

- Discontinuity for $B \to 0$

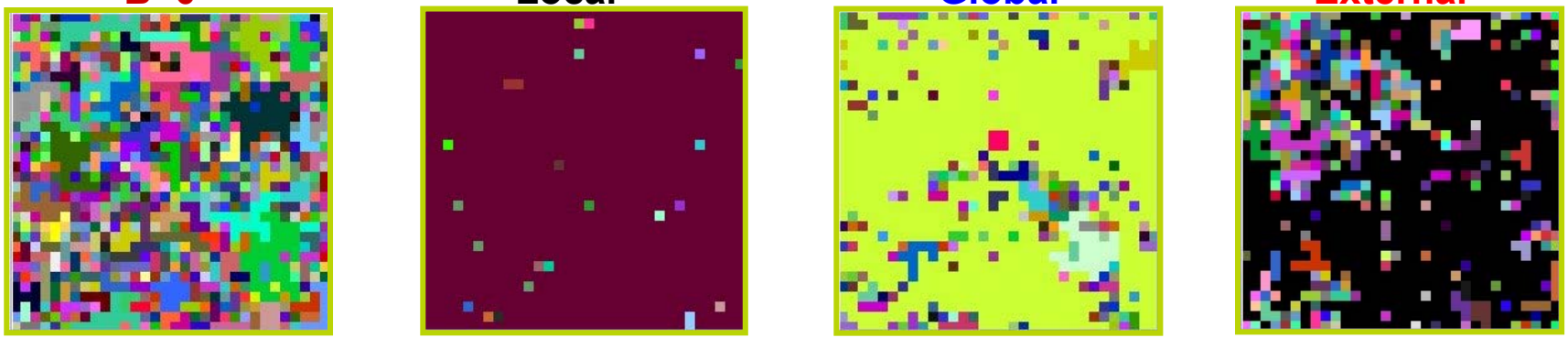
  Cultural homogenization produced by same mechanism than cultural drift.

- $\forall\ M$, increasing B enhances diversity.

- *Local M more efficient in cultural homogenization.*

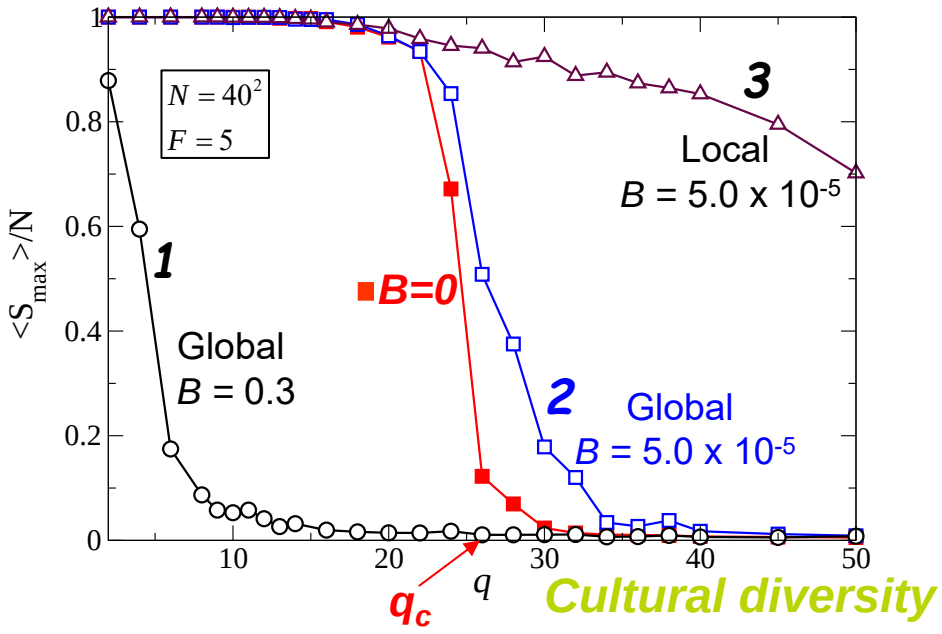
Dynamics of cultural homogenization for weak (B=0.0042) mass media:

F=5, q=28



Mass Media effects: Summary

J. C. González-Avella et al.,
J. of Artificial Societies and Social Simulation 10, 1-17 (2007)



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)

Answers to questions

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***

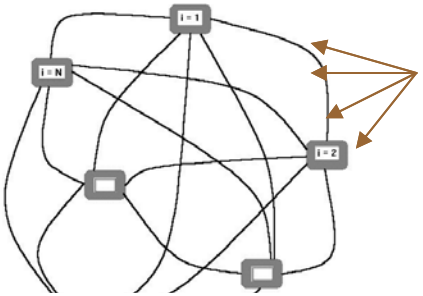
Q4. What is more efficient in producing cultural homogeneity, local mass media or global mass media ?

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

Q5. Social structure needed to reach consensus opposed to a mass media message ?

Globally coupled society

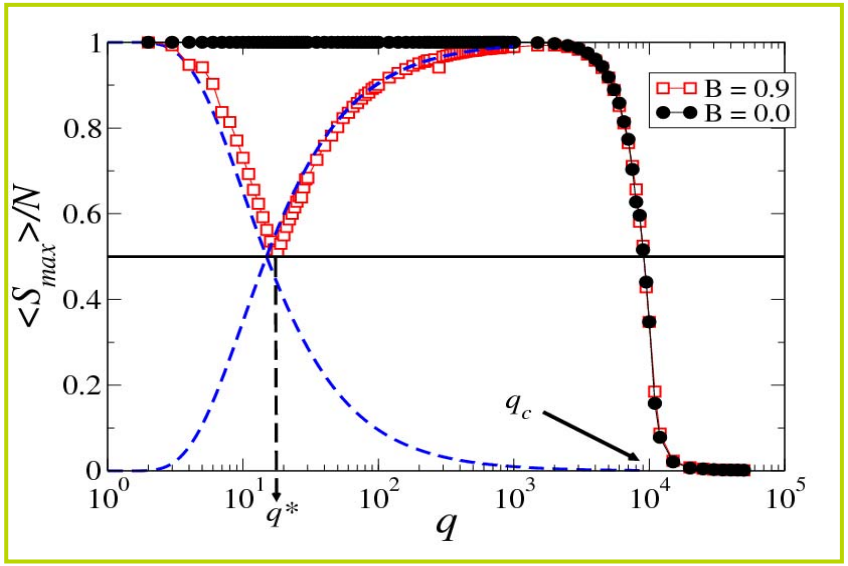
Global coupling: all-to-all

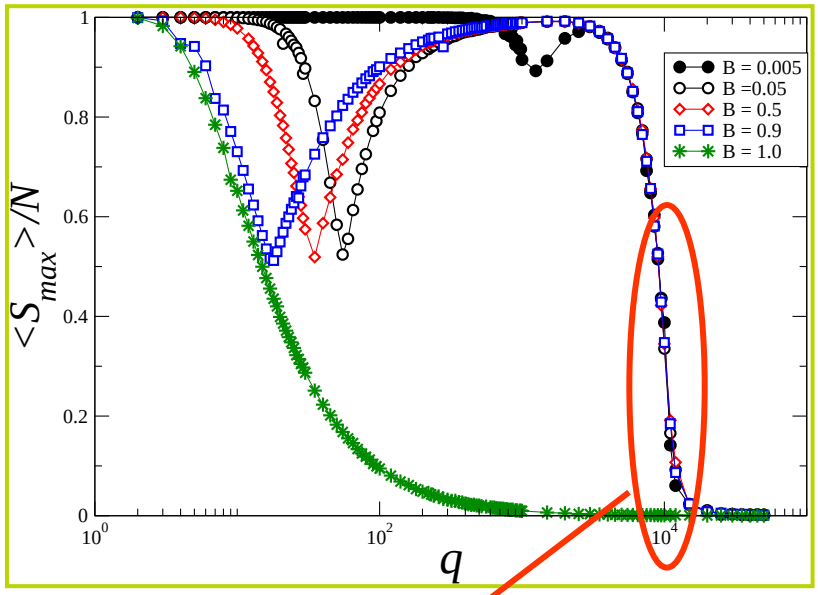


M: external media

$F = 10$

$N = 2500$





$q_{c(G)}$ is independent of B.

- $q_{c(G)} >> q_{c(reg.)} \approx 56$
- Competition between the order induced by an external mass media and spontaneous order.
- For $B \to 1$: where:

$$\frac{\langle S_{\max} \rangle}{N} = \begin{cases} 1-\left(1-\frac{1}{q}\right)^F, & if \quad q \le q^* \\ \left(1-\frac{1}{q}\right)^F, & if \quad q > q^* \end{cases}$$

$$q^* = \left[1-\left(\frac{1}{2}\right)^{1/F}\right]^{-1}$$

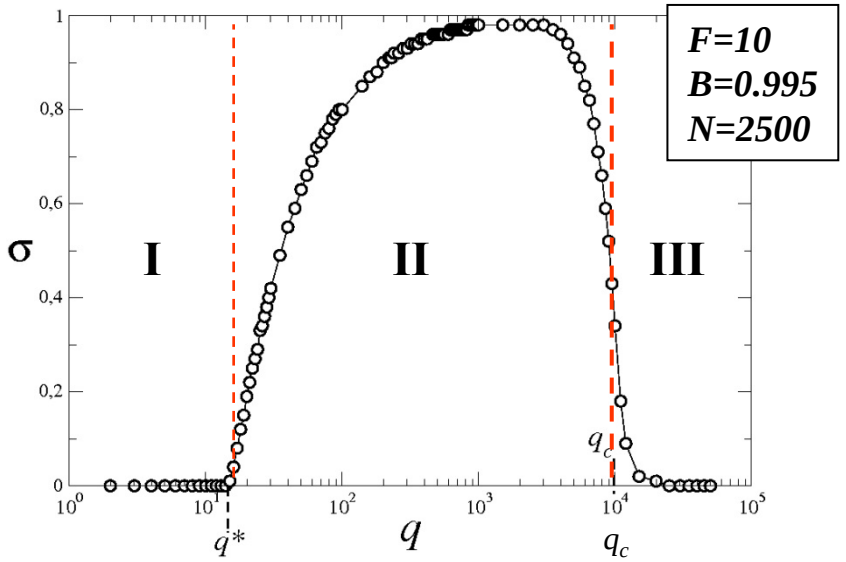
Transitions in globally coupled society

External Media

$$\sigma = \frac{\langle S_{\max} - S_M \rangle}{N}$$

$S_{\max}$: size of largest domain

S_M : size of domain having state equal to M



Phases:

I: homogeneous, ordered = external field

$S_{\max} = S_M \neq 0$ for $q < q^*(B)$

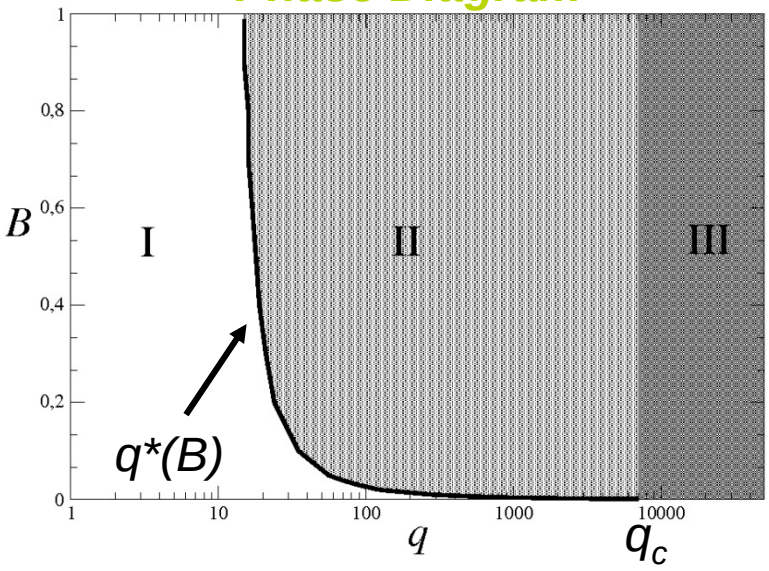
II: alternative ordering state ≠ external field

$S_{\max} > S_M$ for $q^*(B) < q < q_c$

III: disordered

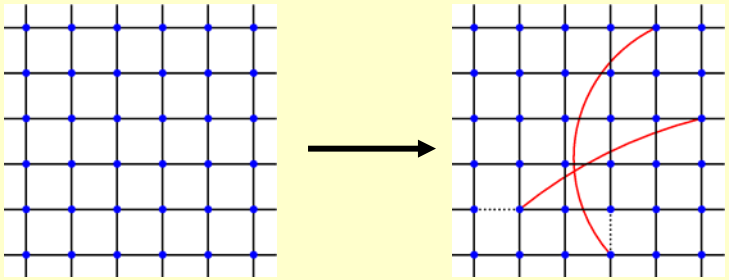
$S_{\max} \to 0,\ S_M \to 0$ for $q > q_c$

Phase Diagram

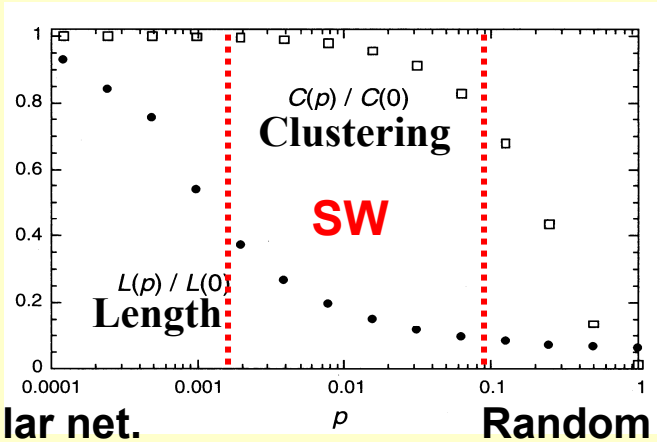


The role of long range social links

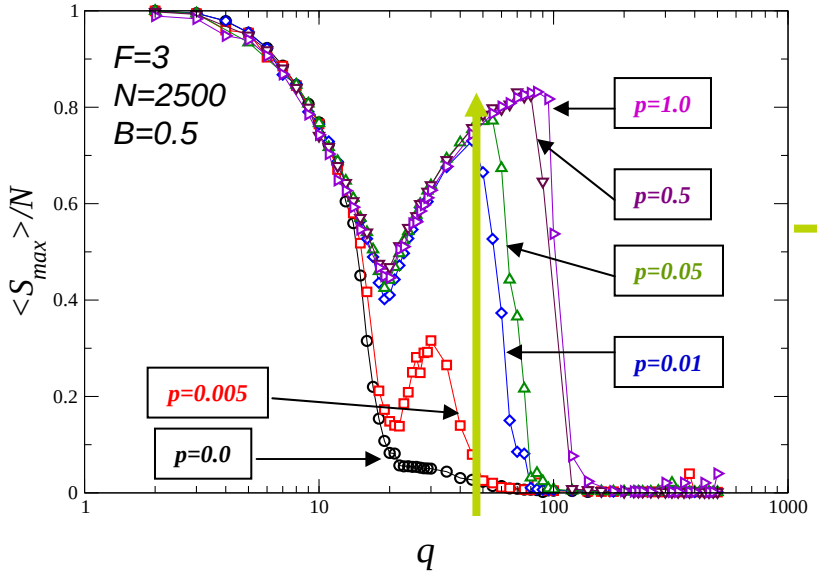
Small World Networks

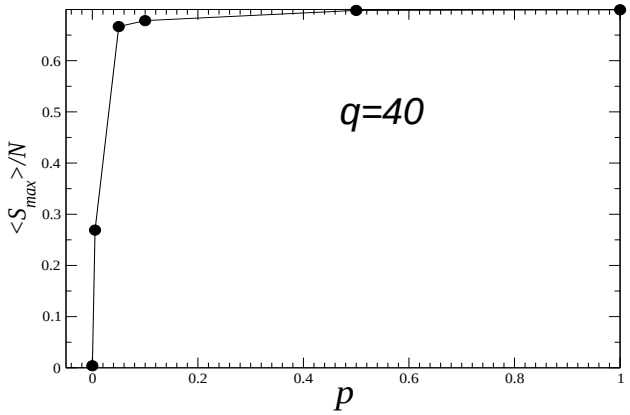


Rewire with prob. *p*



Regular net. **Random net.**





The emergence of a self-organized group opposed to the external message is possible because of the existence of long range social links.

- **Question addressed:** Competition between collective social self-organization vs. external mass-media or propaganda message

- **Take home results:**

1) Strong messages do not homogenize, but rather produce polarization

2) Social interactions can lead to a social consensus different from the external message

provided there are long range links in the social network of interactions

J.C. González-Avella et al., Phys. Rev. E 73,046119 (2006)
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https://ic2s2.org/2017/, Cologne July 2017