

Reconciling long-term cultural diversity and short-term collective social behavior

Reference:

Valori et al., *PNAS* vol. 109, no. 4, pp. 1068-1073 (2012)



Diego Garlaschelli

Assistant Professor

Lorentz Institute for Theoretical Physics

Leiden Institute of Physics

garlaschelli@lorentz.leidenuniv.nl

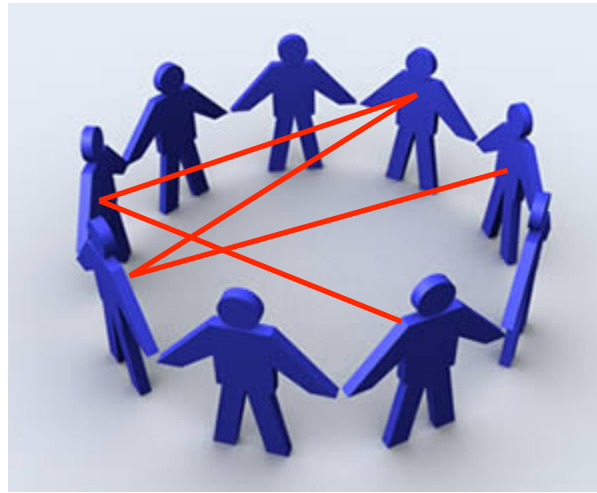


“As one in the short run, diverse in the long run”: **a paradox?**

Short-term collective social behavior

(fashion, financial bubbles, spontaneous order...)

increases in an interconnected, online world.



Long-term cultural diversity

(barriers among social groups, identities, beliefs...)

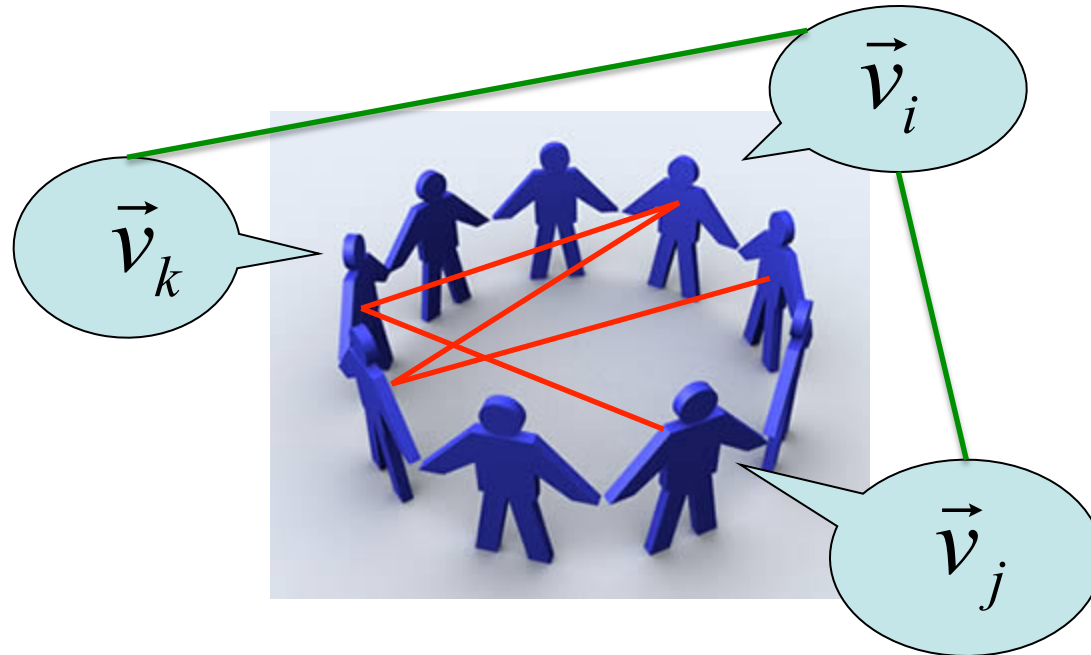
persists irrespective of interconnectedness.

Models cannot explain both phenomena with same parameter choice:

different mechanisms at different timescales?

Preconditions for information diffusion

In models, an individual i is a vector \vec{v} of F “features”, each with Q “traits”



Bounded confidence (ω): information is expected to diffuse on the overlap a_{ij} between the **social network** s_{ij} and the **cultural network** c_{ij}

$$a_{ij}(\omega) = s_{ij} \cdot c_{ij}(\omega)$$

$$c_{ij}(\omega) = \begin{cases} 1 & d_{ij} \leq \omega \\ 0 & d_{ij} > \omega \end{cases}$$

Realistic choices for s_{ij} have been studied. For c_{ij} only random vectors.

What about real cultural data?

The EuroBarometer Project

- large-scale survey of the European Commission;
- face-to-face interviews with multiple-choice questions;
- “beliefs, opinions and attitudes” about scientific (hot) topics.

“One day science will be able to give a complete picture of how nature and the universe work”

“There should be no limit to what science is allowed to investigate on”

“Food made from genetically modified organisms is dangerous”

“The authorities should formally oblige scientists to respect ethical standards”

“Scientists put too little effort into informing the public about their work”

Used to track scientific attitudes, and to aid policy making

Here: data for year 1992, N=13000 individuals, 12 countries, 161 questions

<http://www.ec.europa.eu/research/press/>

Mapping questionnaire data to vector opinions

N individuals being asked $F=161$ multiple-choice questions (Q answers).

Mapping to N F -dimensional “**cultural vectors**” (answers = features):

$$\vec{v}_i = (v_i^{(1)}, v_i^{(2)}, \dots, v_i^{(161)})$$

Cultural distance between individuals:

$$d_{ij} = \frac{1}{F} \sum_{k=1}^F d_{ij}^{(k)}$$

- Metric answers: $d_{ij}^{(k)} = |v_i^{(k)} - v_j^{(k)}|$ $\left(v_i^{(k)} = 0, \frac{1}{Q^{(k)} - 1}, \frac{2}{Q^{(k)} - 1}, \dots, 1 \right)$
- Non-metric answers: $d_{ij}^{(k)} = \begin{cases} 0 & v_i^{(k)} = v_j^{(k)} \\ 1 & v_i^{(k)} \neq v_j^{(k)} \end{cases}$

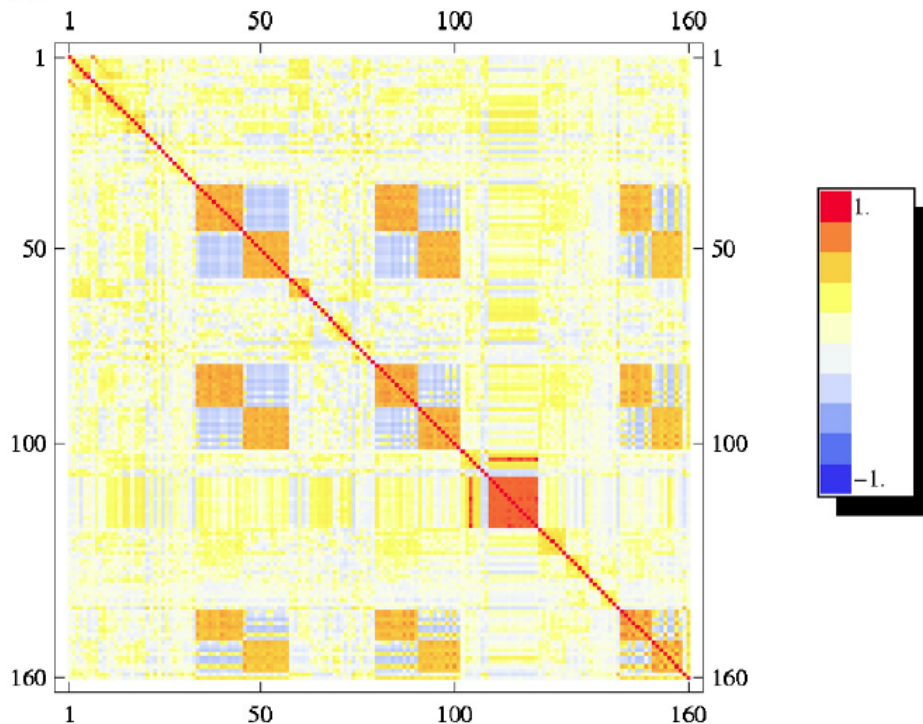
2 null models: shuffled and random answers

Correlations among opinions

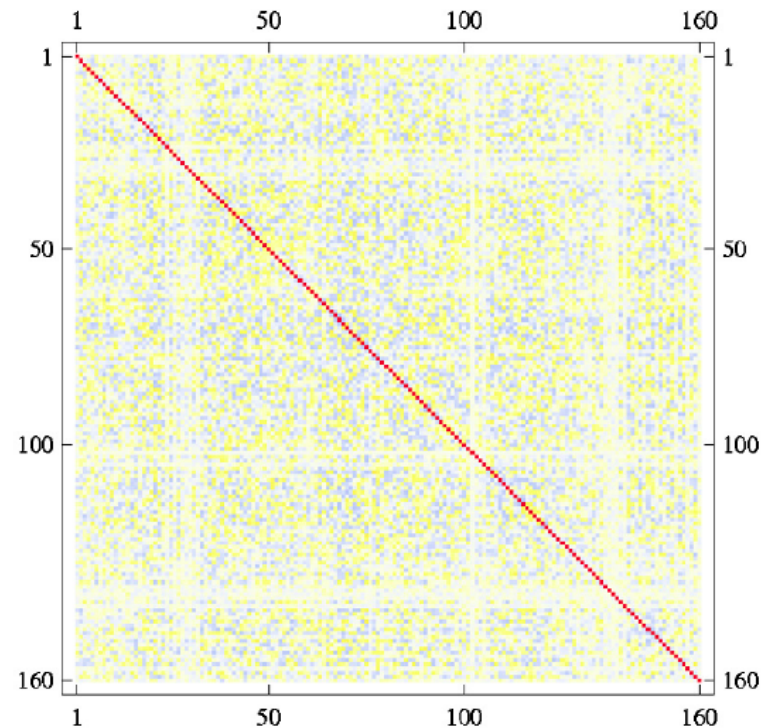
Real and randomized data differ, due to strongly correlated answers:

$$\sigma_{kl} = \left\langle \frac{d_{ij}^{(k)}}{F} \frac{d_{ij}^{(l)}}{F} \right\rangle_{ij} - \left\langle \frac{d_{ij}^{(k)}}{F} \right\rangle_{ij} \left\langle \frac{d_{ij}^{(l)}}{F} \right\rangle_{ij} = \frac{\left\langle d_{ij}^{(k)} d_{ij}^{(l)} \right\rangle_{ij} - \left\langle d_{ij}^{(k)} \right\rangle_{ij} \left\langle d_{ij}^{(l)} \right\rangle_{ij}}{F^2}$$

A Inter-opinion correlation matrix (Germany, real)



B Inter-opinion correlation matrix (Germany, shuffled)

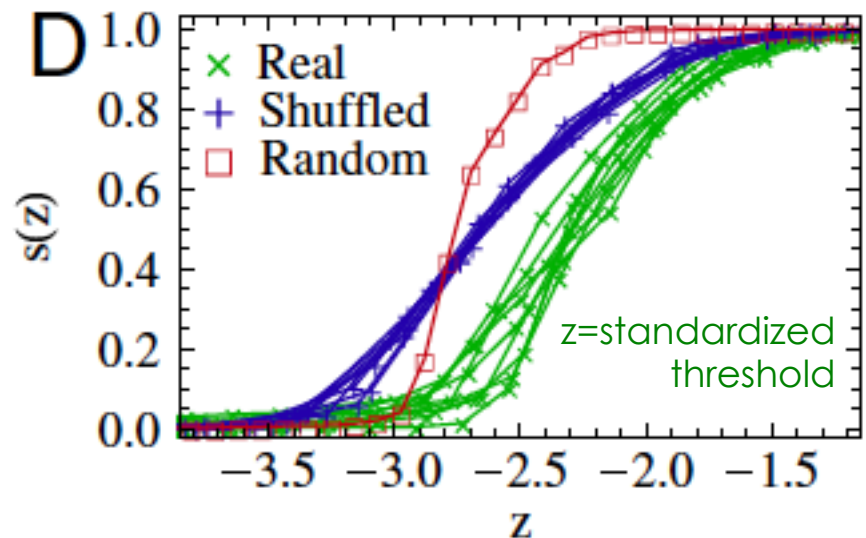
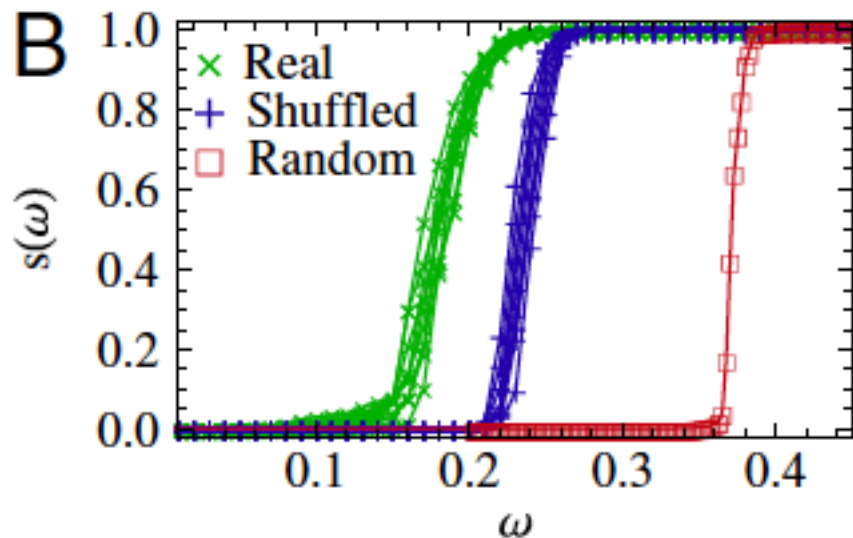
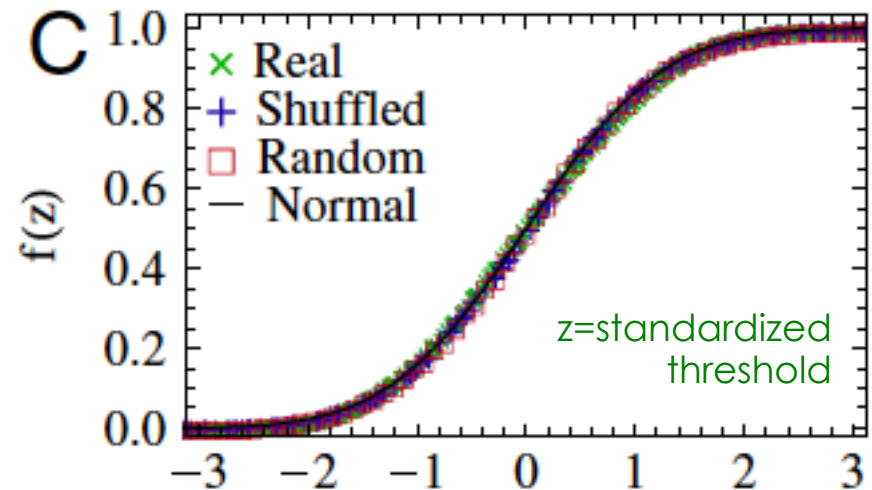
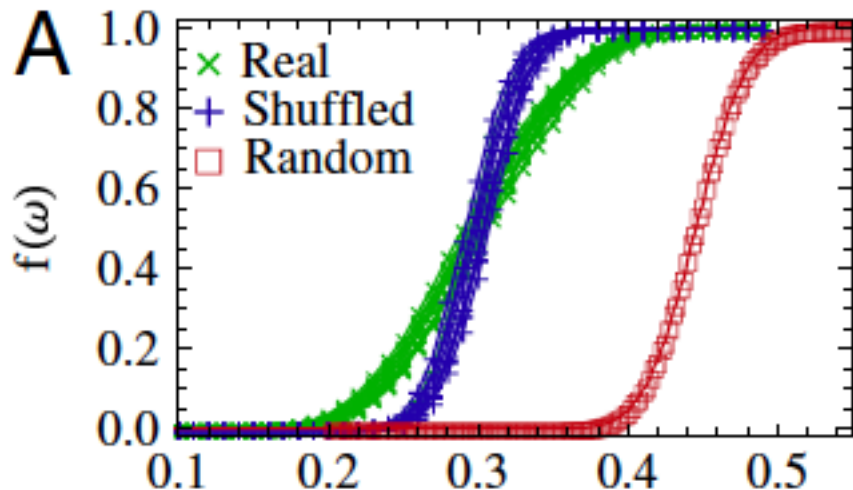


$$d_{ij} = \frac{1}{F} \sum_{k=1}^F d_{ij}^{(k)} \Rightarrow \sigma_d^2 = \sum_{k=1}^F \sum_{l=1}^F \sigma_{kl} = \sum_{k=1}^F \sum_{l \neq k} \sigma_{kl} + \sum_{k=1}^F \sigma_k^2 = 2 \sum_{l < k} \sigma_{kl} + \sum_{k=1}^F \sigma_k^2$$

Bias toward positive correlations: consistent with homophily (likes attract)

Local and global measures of influence

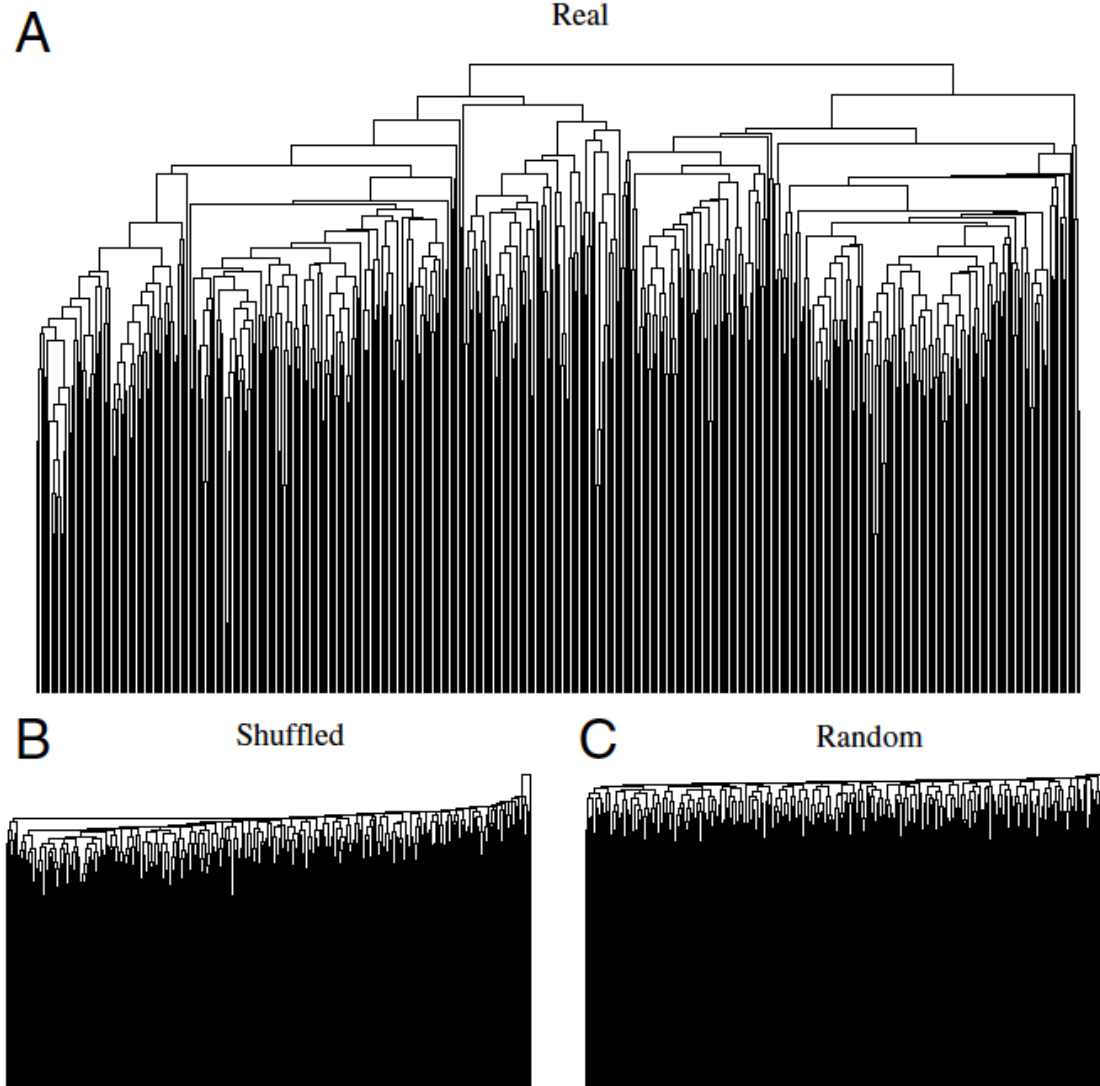
Local influence: connection probability (f) of the cultural graph



Global influence: size fraction (s) of the LCC in the cultural graph

Ultrametric distribution of individuals in cultural space

Germany data: real, shuffled and random



Ultrametricity has **strong effects** on short-term and long-term dynamics

Short-term collective social behavior

Human dynamics depends on culture/opinions (elections, fashion, etc.)

Let $\phi_i = \pm 1$ represent the (binary) choice of the individual i ($\langle \phi_i \rangle = 0$)

Assume information diffusion **subject to bounded confidence**:

$$\begin{cases} \phi_i = \phi_j & d_{ij} \leq \omega \\ \langle \phi_i \phi_j \rangle = \langle \phi_i \rangle \langle \phi_j \rangle & d_{ij} > \omega \end{cases}$$

Average choice (total outcome):

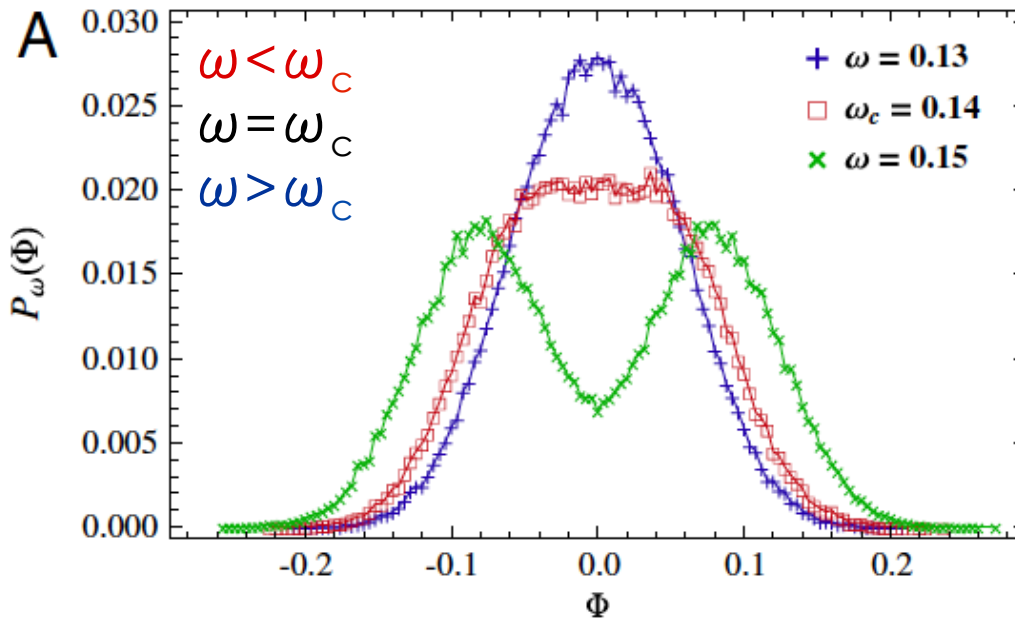
$$\Phi = \frac{1}{N} \sum_{i=1}^N \phi_i = \frac{1}{N} \sum_{c=1}^{n_c} s_c \phi_c$$

ϕ_c : common choice of all individuals within cluster c

s_c : size of c - n_c : number of clusters

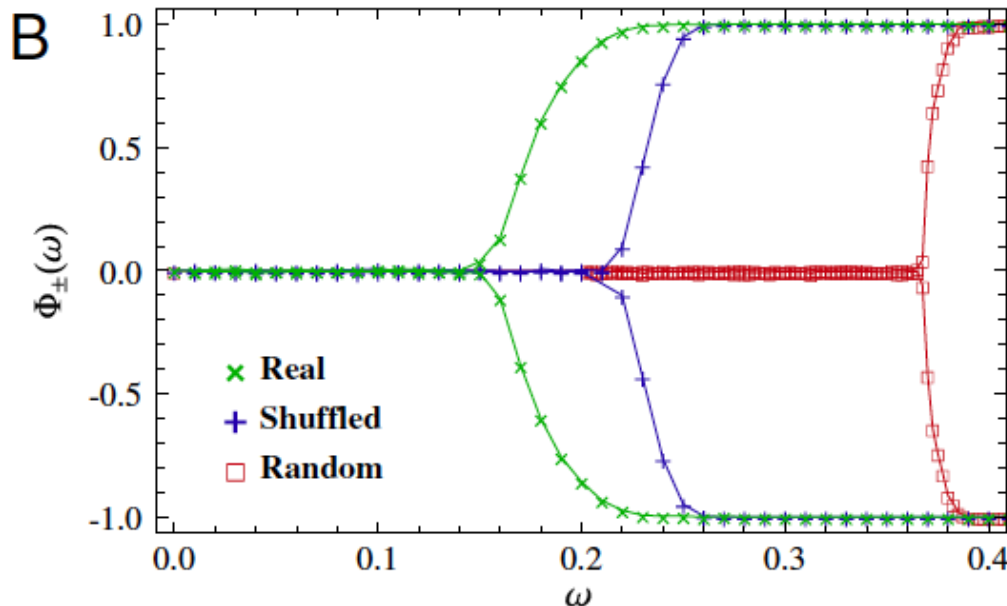
Isolated individuals ($\omega=0$): $\Phi = \frac{1}{N} \sum_{i=1}^N \phi_i \approx \text{Normal with zero mean}$

Spontaneous symmetry breaking



“Social coordination”:
breadth of distribution

$$C(\omega) \equiv \sigma_\omega(\Phi) = \sqrt{\sum_A \left(\frac{S_A}{N} \right)_\omega^2}$$

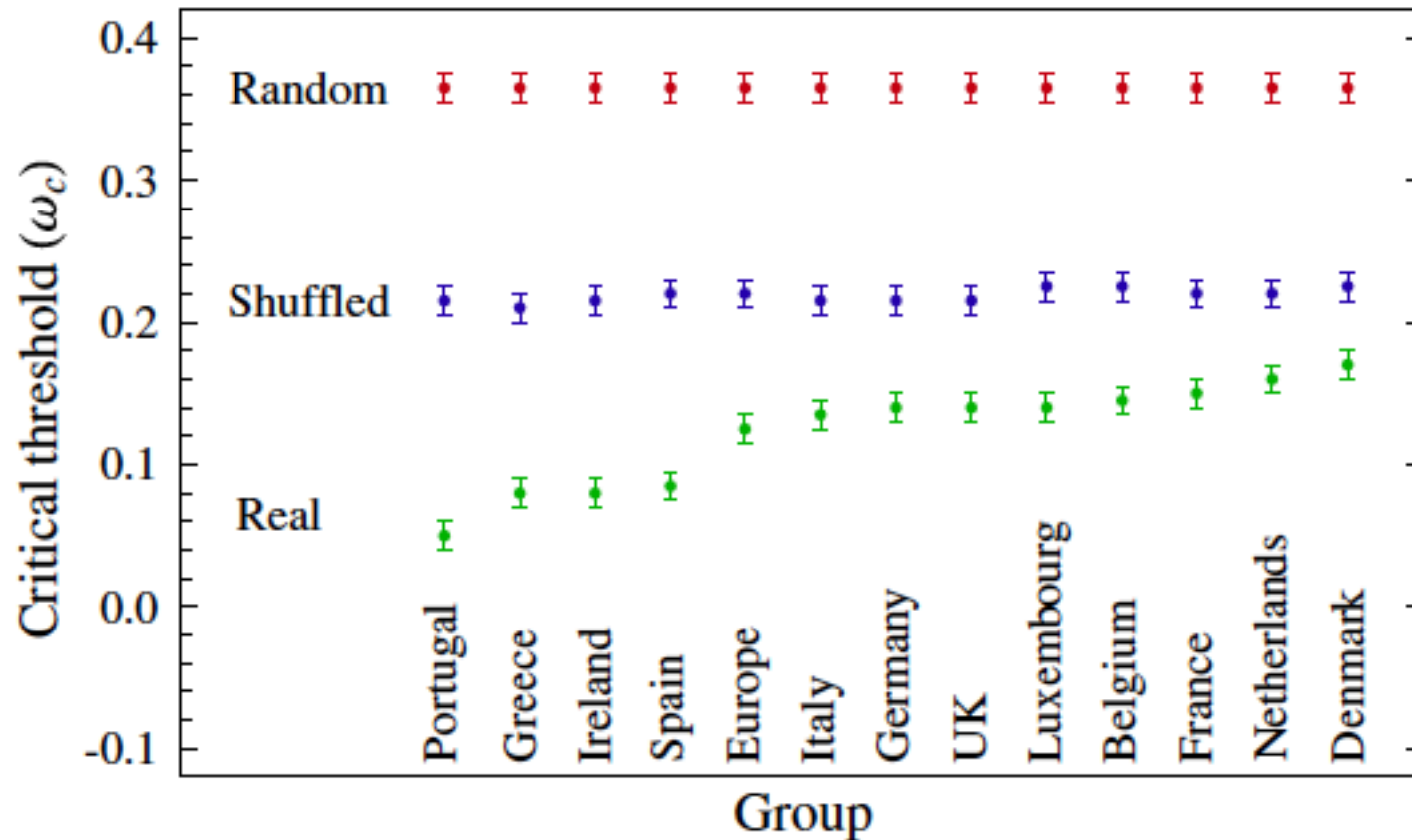


Order parameter:
most probable value of Φ

$$\Phi^* = \begin{cases} 0 & \omega < \omega_c \\ \Phi^\pm(d) & \omega \geq \omega_c \end{cases}$$

Critical thresholds across Europe

A measure of 'resistance' to collective behaviour

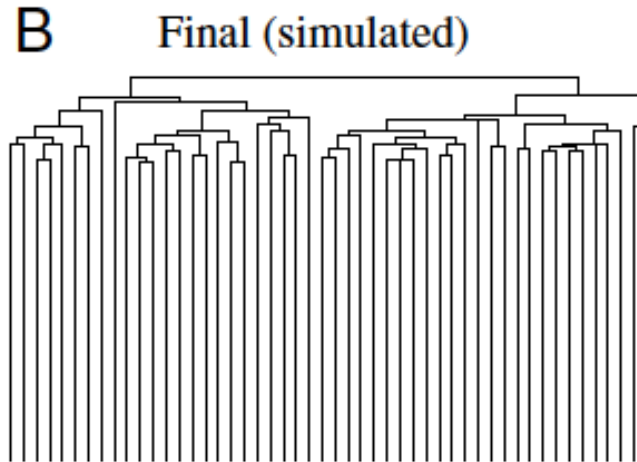
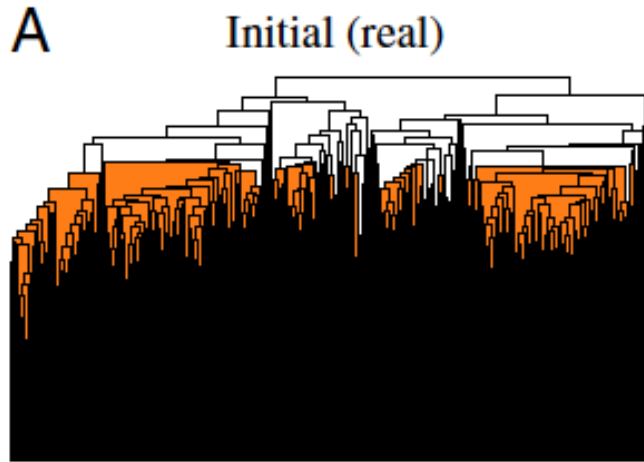


REAL < SHUFFLED

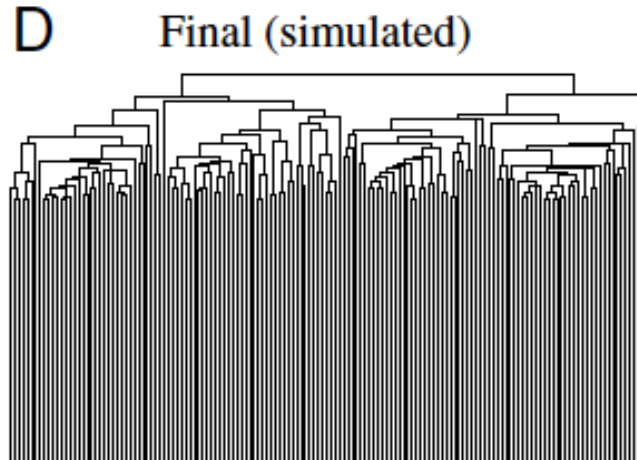
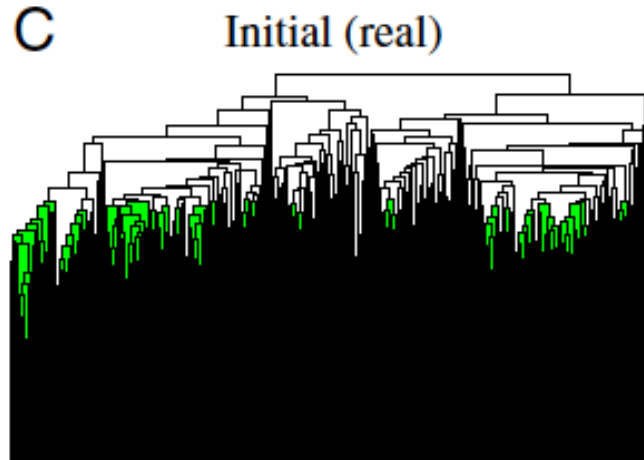
Ultrametricity systematically **facilitates** collective behaviour

Long-term cultural diversity

Axelrod model with threshold (as in Flahe and Macy, physics/0701333):



“**Cultural diversity**”:
number of final
cultural domains

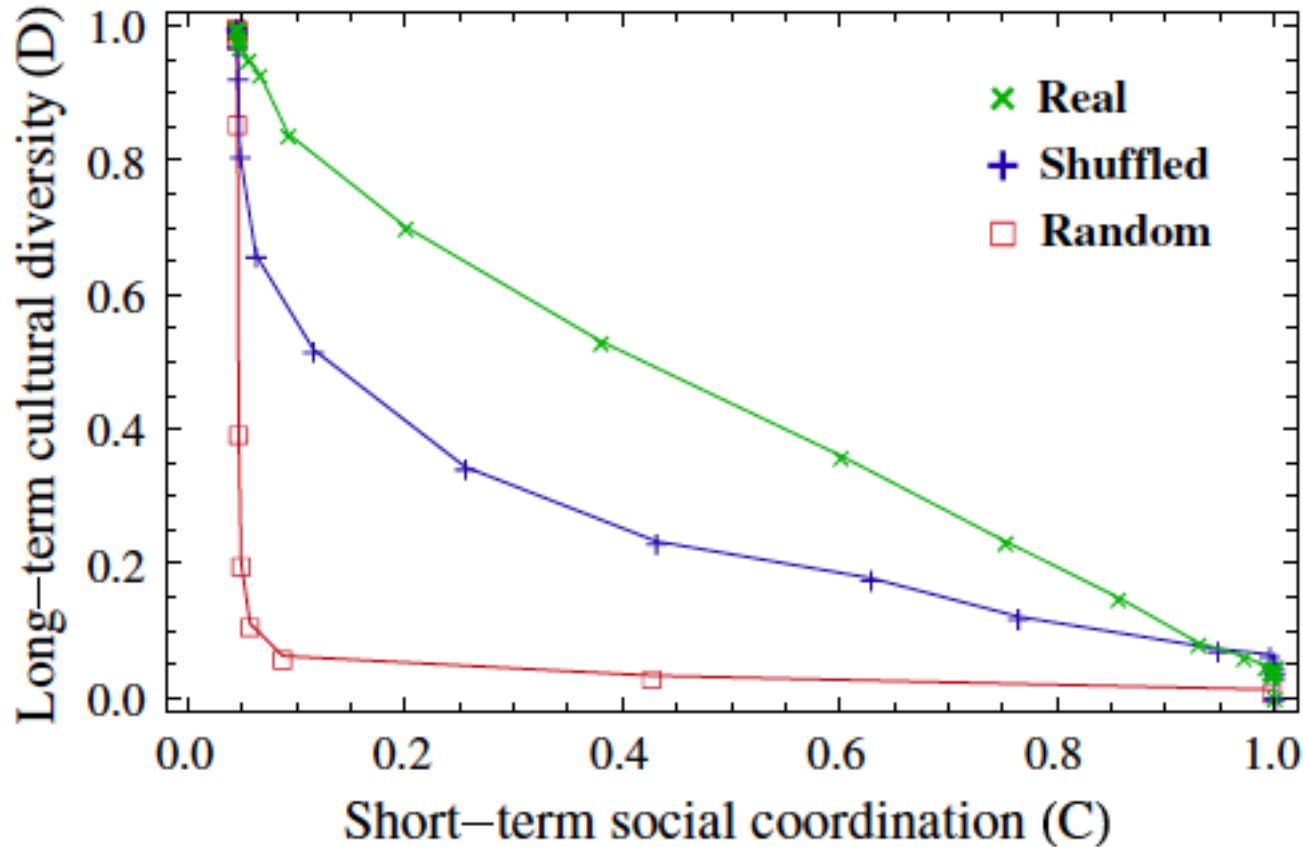


$$D(\omega) \equiv \frac{\langle N_D \rangle_\omega}{N}$$

Ultrametricity **confines** cultural evolution within sub-branches

Short-term coordination versus long-term diversity

Phase diagram combining the two processes:



Random data: either coordination or diversity (paradox)

Real data: coordination and diversity **reconciled!**

Conclusions

- First large-scale analysis of cultural vectors
- Individuals are hierarchically distributed in cultural space
- Ultrametricity **facilitates** short-term collective social behavior (smaller threshold to coordination)
- Ultrametricity **constrains** long-term cultural diversity (frozen branches of the dendrogram)
- With random data, coordination and diversity **cannot** coexist
- With real data, they **can** coexist: *ultrametricity explains the paradox*

Reference:

Valori et al., *PNAS* vol. 109, no. 4, pp. 1068-1073 (2012)