

Cooperation, Norms and Conflict: Towards Simulating the Foundations of Society

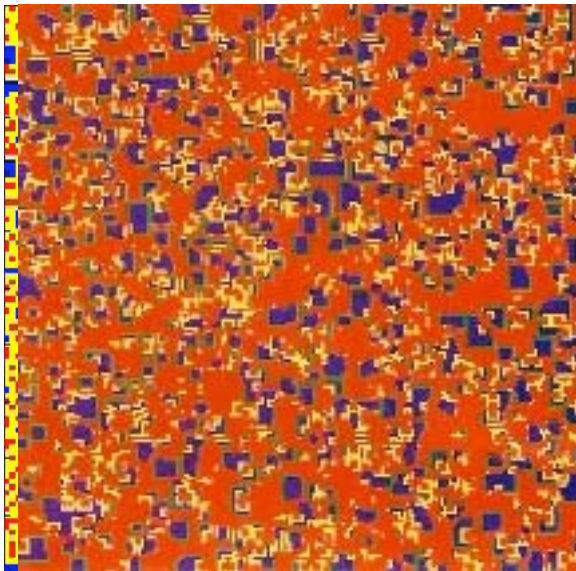
Dirk Helbing,

with Wenjian Yu, Anders Johansson, Carlos Roca, Thomas Chadeaux
and other collaborators in Zurich, Dresden, and all over the world



Start with the Spatial Prisoner's Dilemma...

Nowak and May (1992) have extended the prisoner's dilemma to simultaneous **spatial interactions** in an $L \times L$ grid involving L^2 players, assuming that each player would have binary **interactions with $m=8$ nearest neighbors**, and would afterwards **imitate the strategy C or D of the most successful neighbor**, if he or she performed better. Computer simulations for $R=1$ and $P=S=0$ show **“chaotic” pattern formation phenomena** in a certain parameter range of T .



For $R=1$ and $P=S=0$ Nowak and May have found that big clusters of defection shrink for $T < 1.8$, while for $T > 2$, cooperative clusters do not grow, and in between, both **cooperative and defective clusters would expand, collide, and fragment**.

Source: M. A. Nowak and R. M. May, Nature 359, 826 (1992).

blue = cooperator, red = defector, yellow = turned to defection, green = turned to cooperation

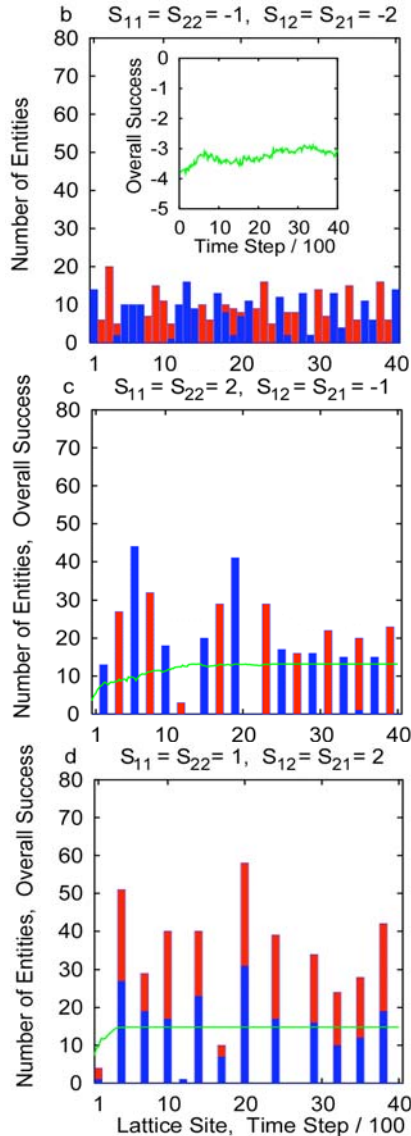
Marrying Models of Motion with Game Theory

- What will happen when **integrating** game-theoretical models and **models of mobility**?
- Will the resulting individual-based models produce **new kinds of self-organization**?
- Why are **group, class, and niche formation, agglomeration, segregation** etc. so widespread in social, economic, and biological systems, although one often tries to counteract these phenomena?
- What is the **role of mobility for social cooperation**?
- Is migration a “bad thing”?
- Does leaving the birth place necessarily reduce cooperation by cutting social ties, as one may think?

... and Extend It, Considering Success-Driven Migration

- We will now combine strategic interaction, as described by game theory, with a special, **success-driven** kind of **motion**. Individuals are assumed to have a preference for a favorable neighborhood. A higher expected payoff, i.e. a higher level of cooperation, makes a neighborhood more attractive.
- We generalize the spatial prisoner's dilemma by adding a success-driven motion step before the interaction and imitation steps. We assume that $N < L^2$ grid locations are occupied, and **individuals can move to empty sites**.
- To keep things simple, for each empty site within a certain **mobility radius M** , each individual is assumed perform a “**test interaction**” to determine the fictitious total payoff that would result when moving to this location (“**neighborhood exploration**”). The individual would then move to the location with the highest payoff, and in case of several equivalent locations, to the closest of them. We assume a random sequential update and periodic boundary conditions.
- Restricting migration to empty sites **resembles relocations** (e.g. between apartments) and reflects that individuals tend to occupy a certain **territory**.

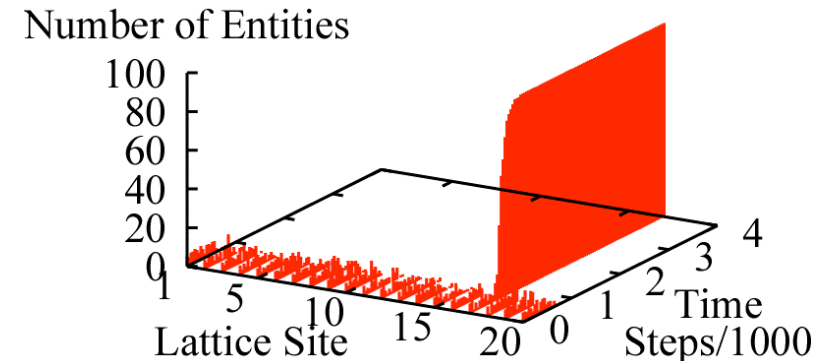
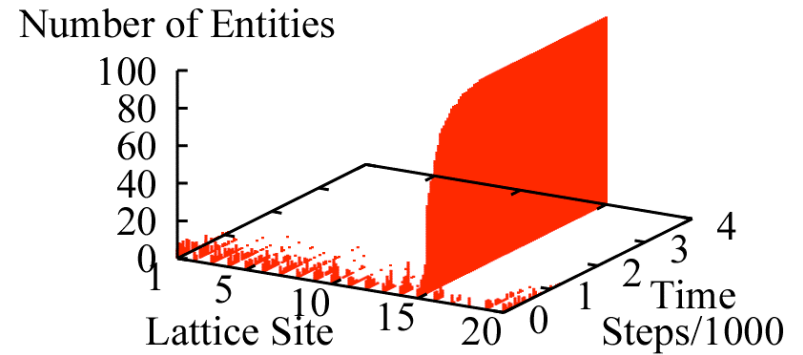
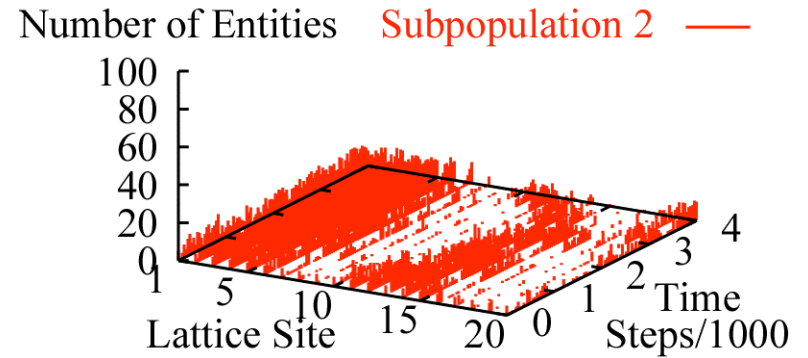
Spatio-Temporal Pattern Formation Due to Success-Driven Migration



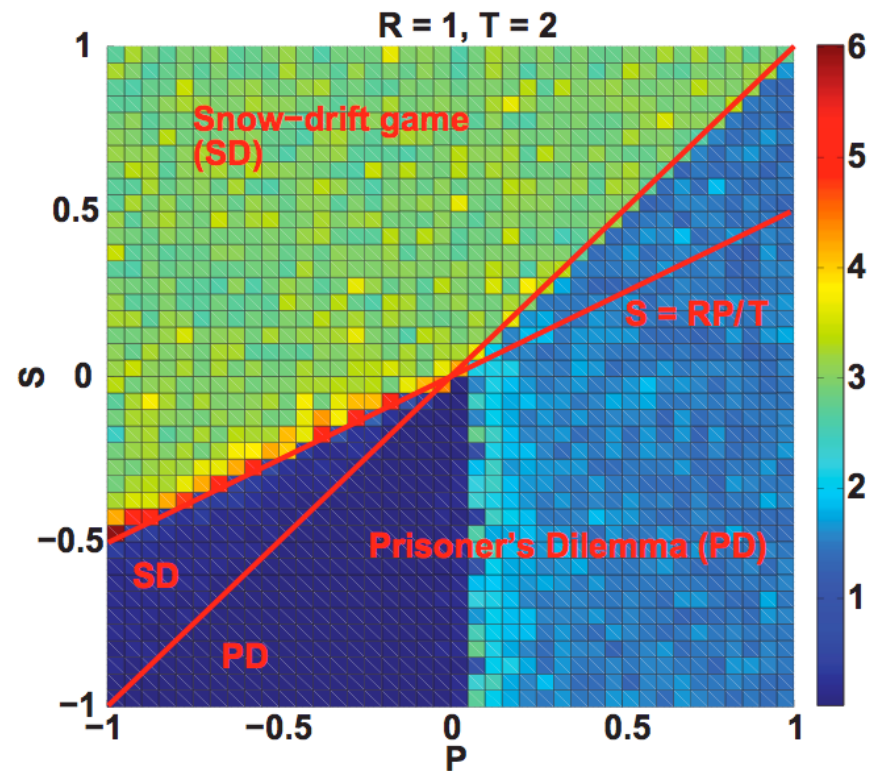
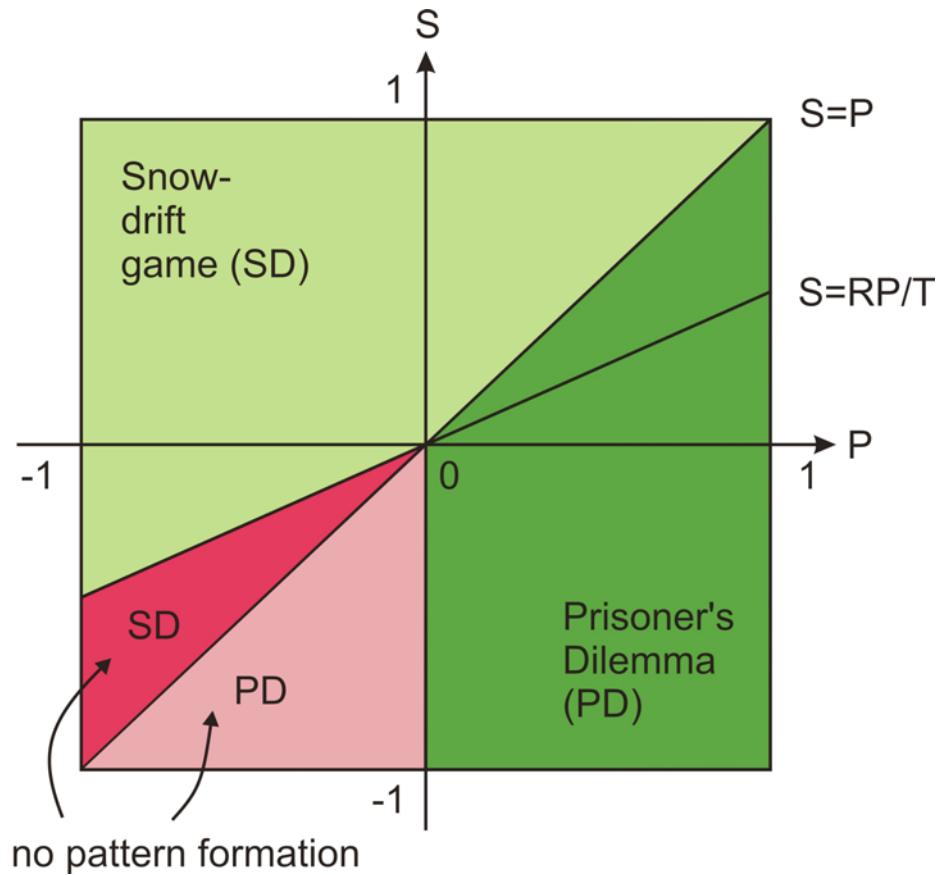
Segregation
("Lane Formation")

Repulsive Agglomeration
("Ghetto Formation")

Attractive Agglomeration
("Clustering")

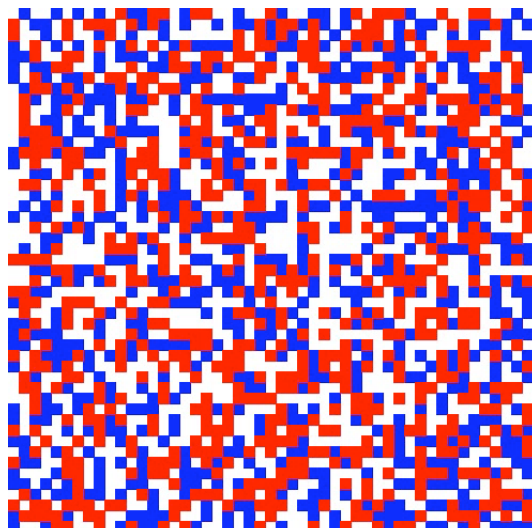


Agglomeration in the Prisoner's Dilemma and Snow Drift Game

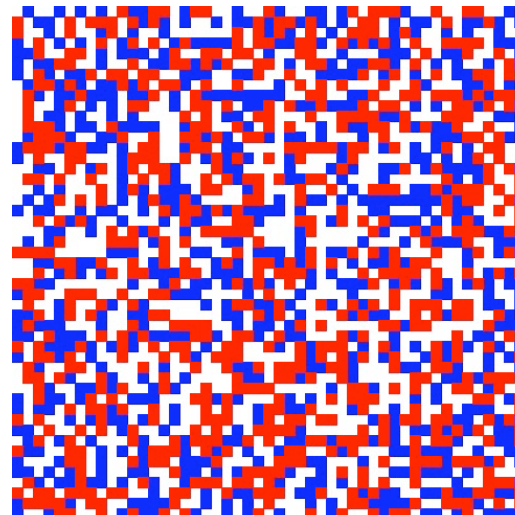


Imitation and Success-Driven Motion, Separately and Together

$P = 0$
 $R = 1$
 $S = 0$
 $T = 1.4$



imitation only

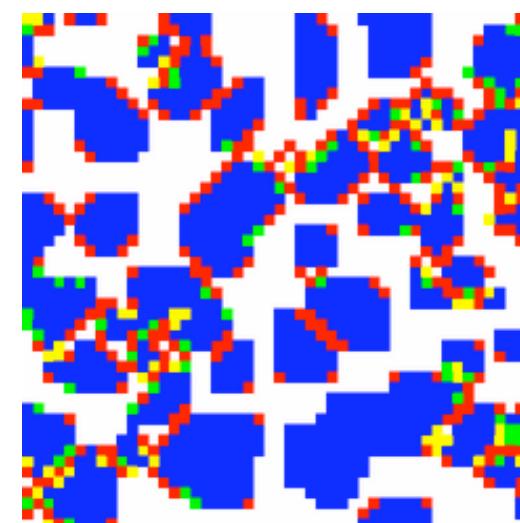
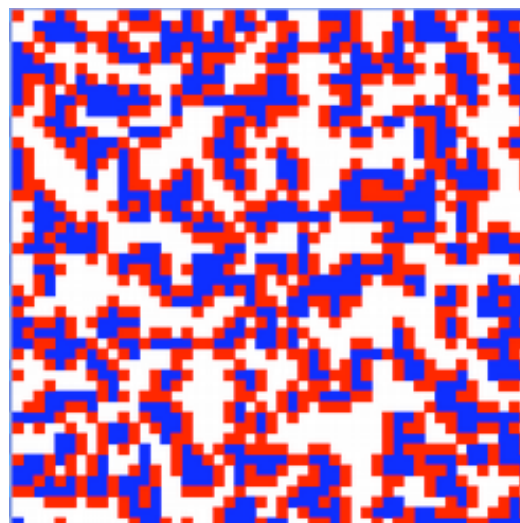
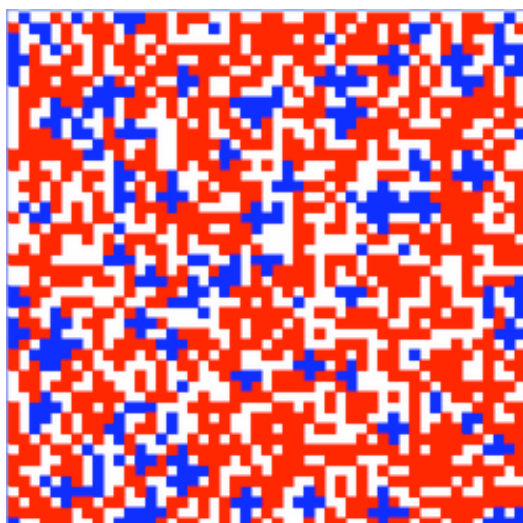


migration only



imitation & migration

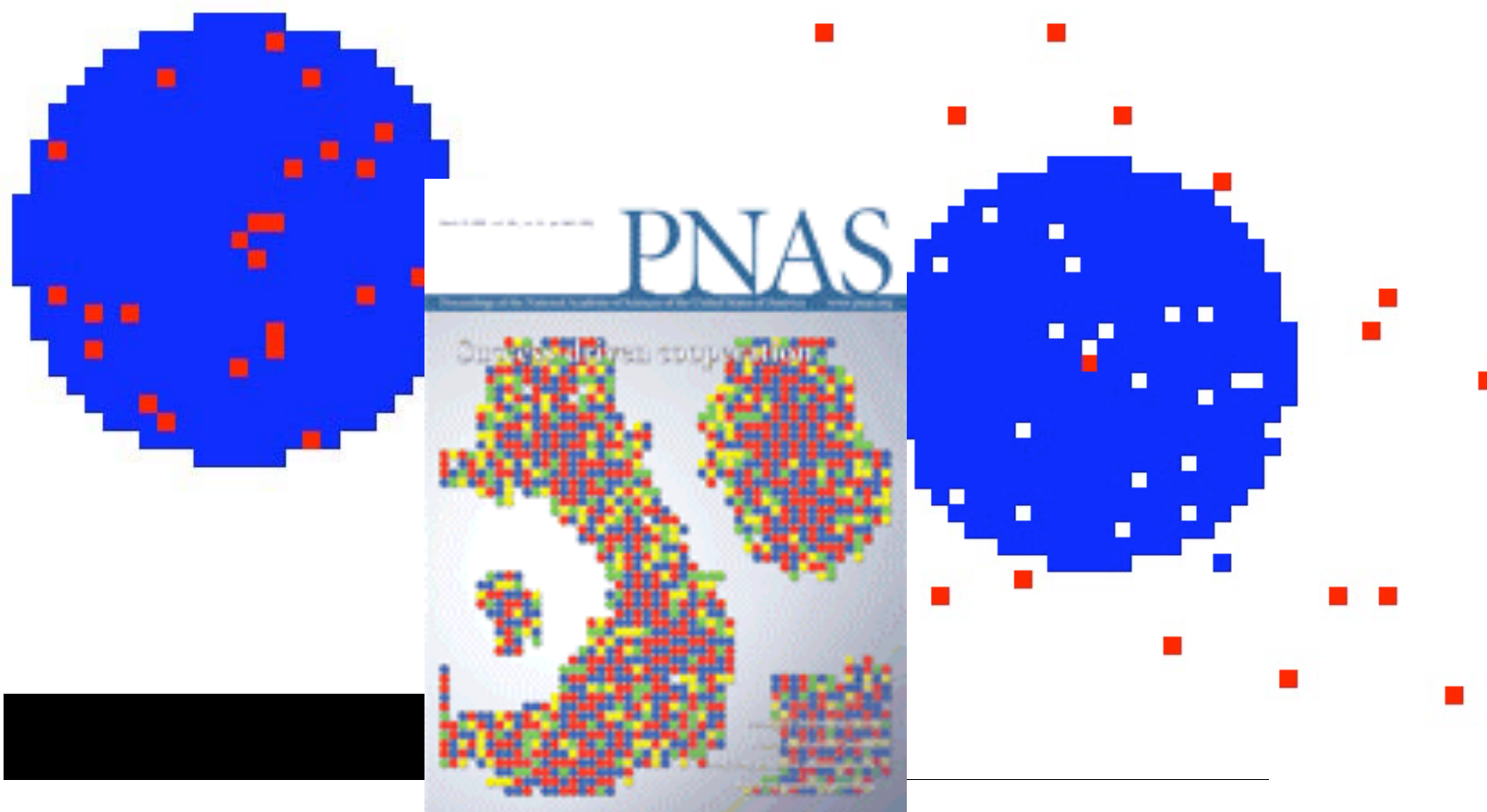
blue = C
red = D



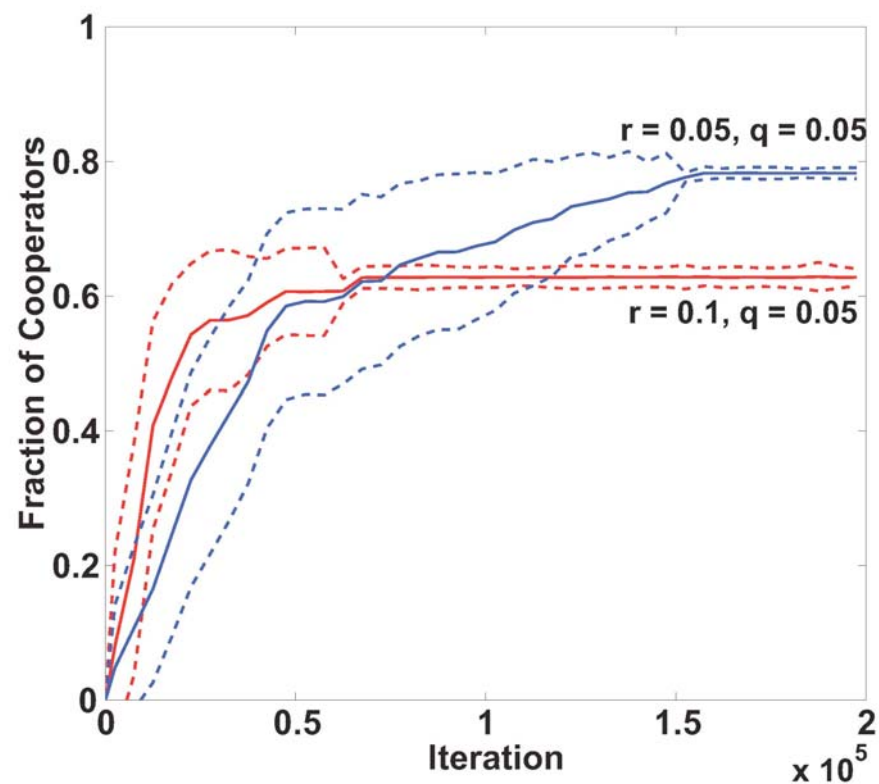
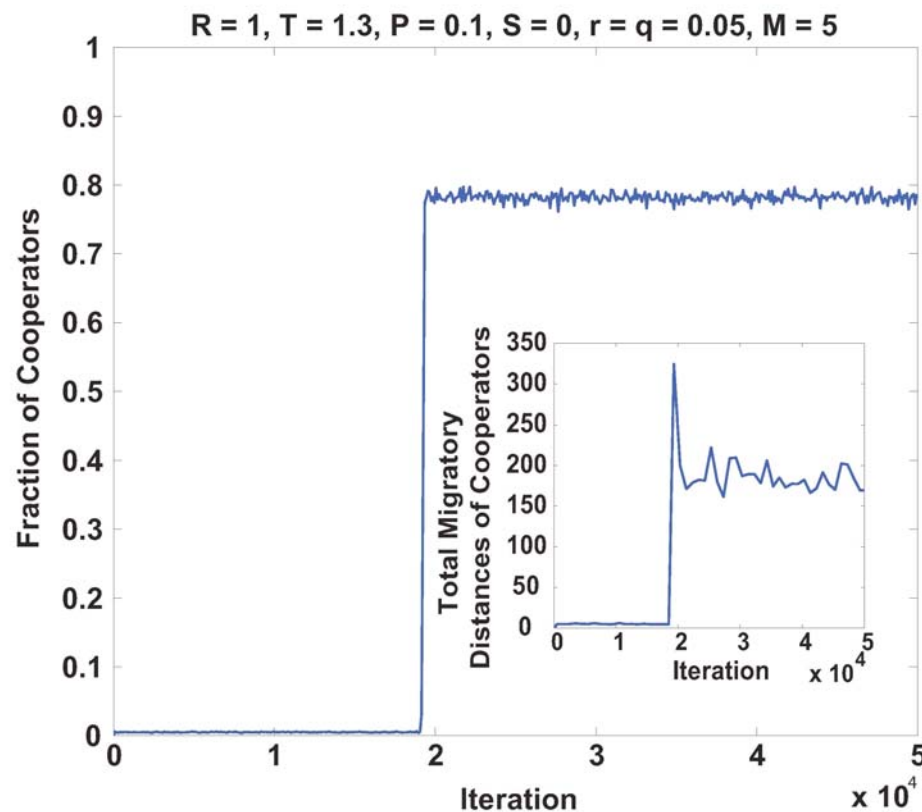
The Breakdown and Outbreak of Cooperation

Red, yellow: defectors (cheaters)

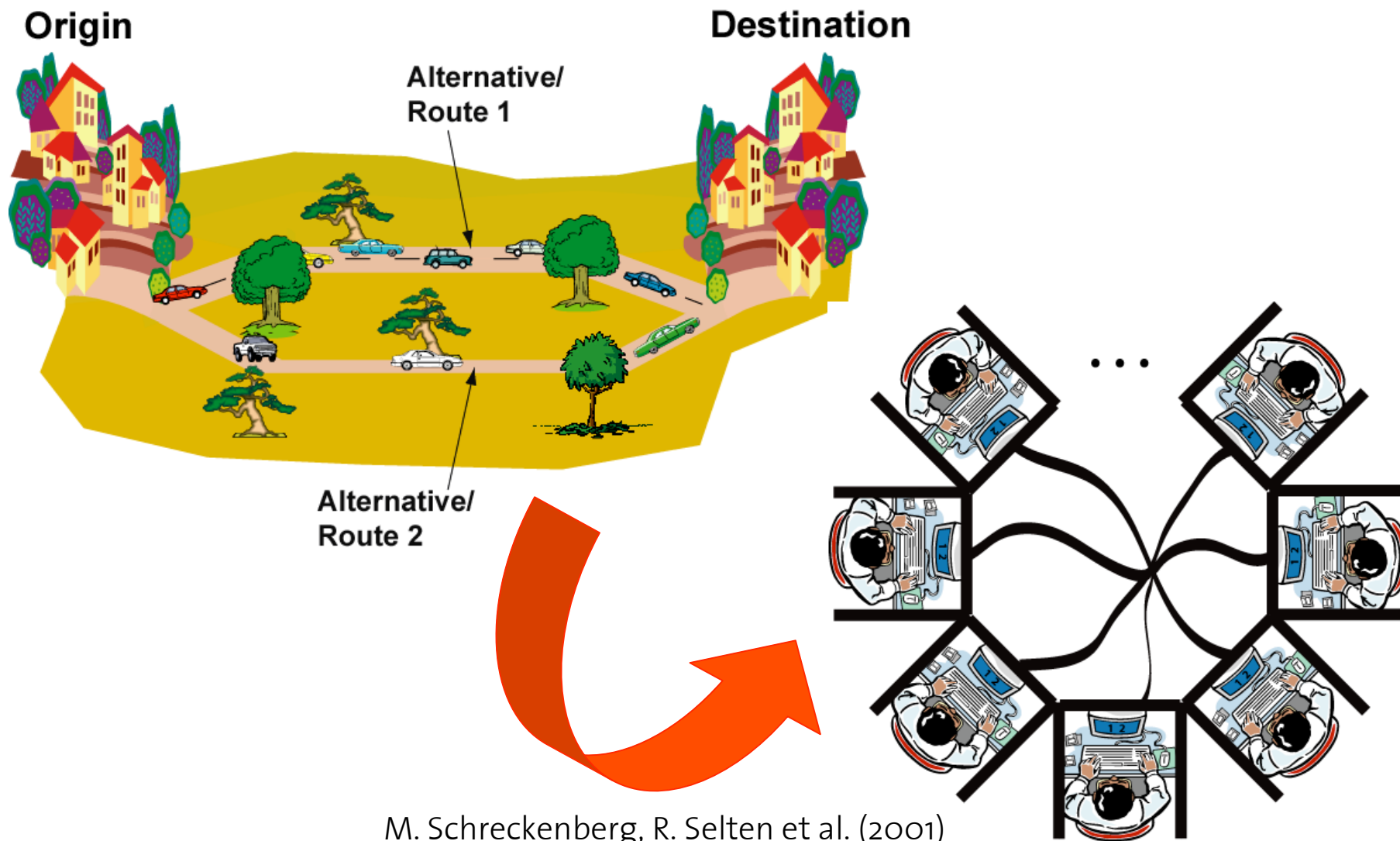
Blue, green: cooperators



Time-Dependence of Transition of Predominant Cooperation



The Route Choice Dilemma - Setup of an Experimental Game



M. Schreckenberg, R. Selten et al. (2001)

The 2-Person Route Choice Dilemma

a

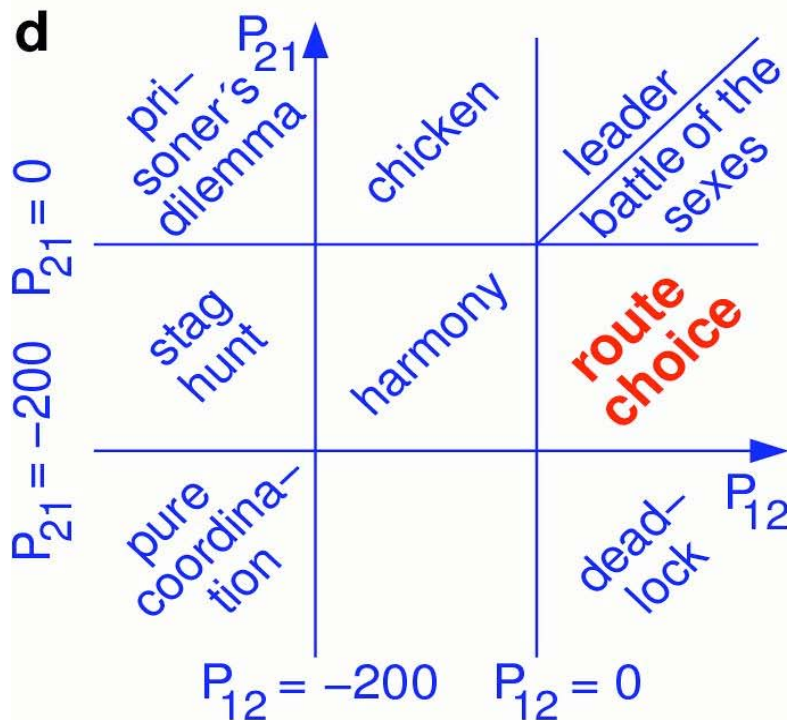
	coop.	def.
cooperation	0	-300
defection	100	-200

b

	1	2
strategy 1	0	P_{12}
strategy 2	P_{21}	-200

c

	1	2
route 1	0	300
route 2	-100	-200

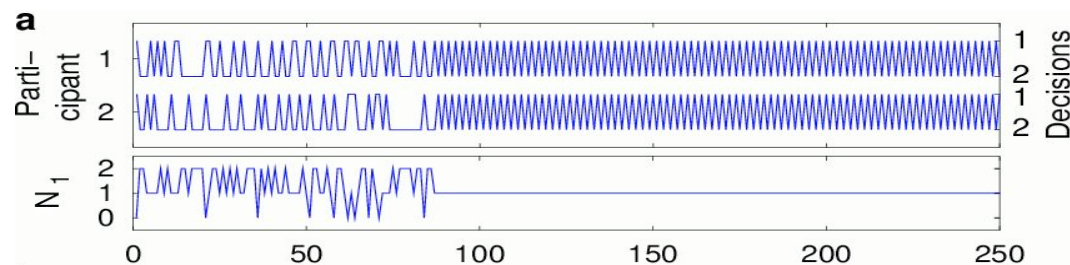


e

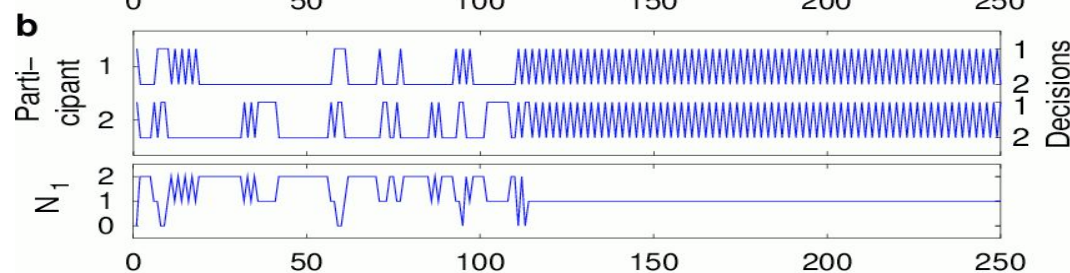
	11	12	21	22
11	0	300	300	600
12	-100	-200	200	100
21	-100	200	-200	100
22	-200	-300	-300	-400

Outbreak of Turn-Taking: Experiments and Simulations

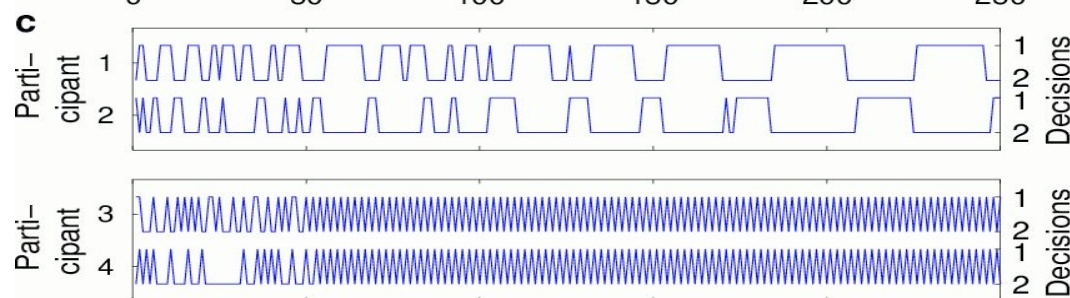
2 Persons:
Experiment



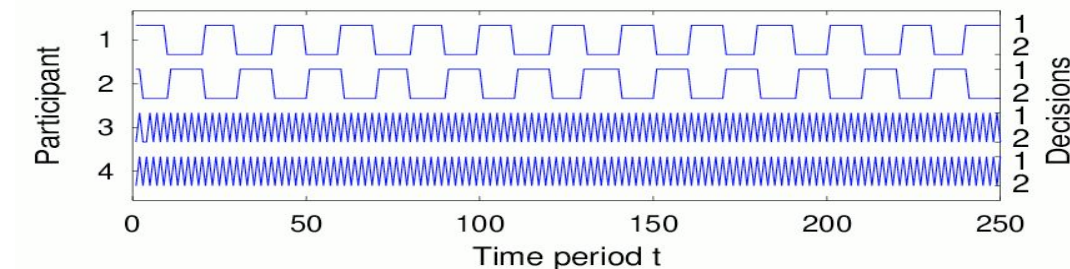
2 Persons:
Simulation



Subsequent
4-Person
Experiment



*Multi-Period
Decisions*



Intermediate Summary

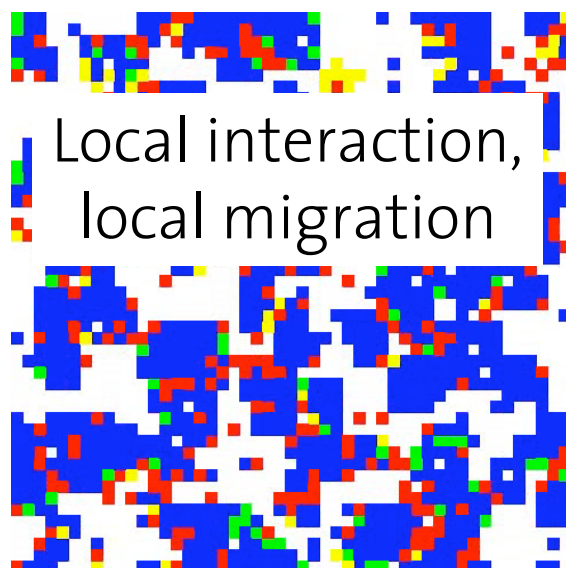
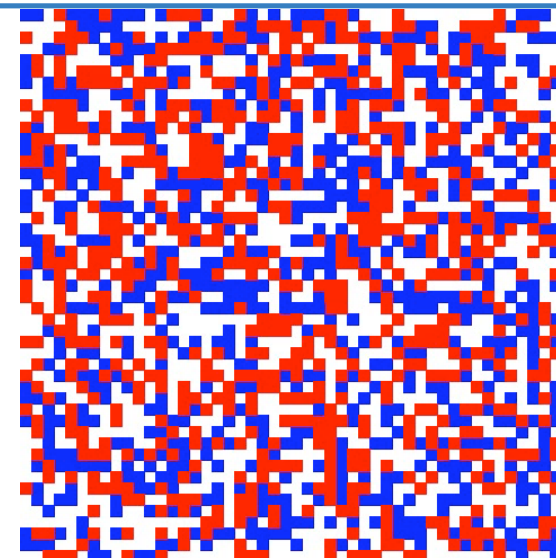
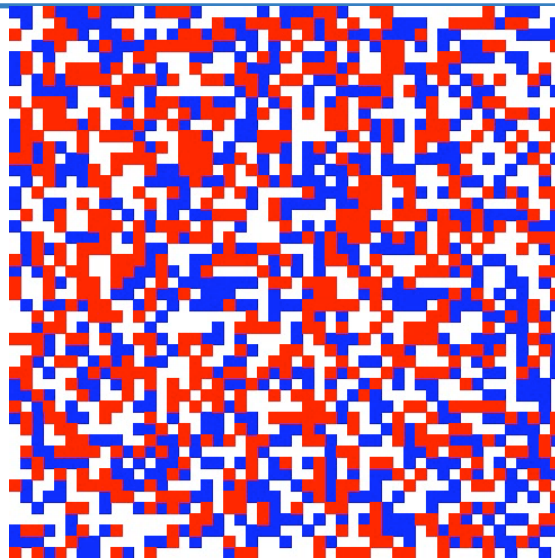
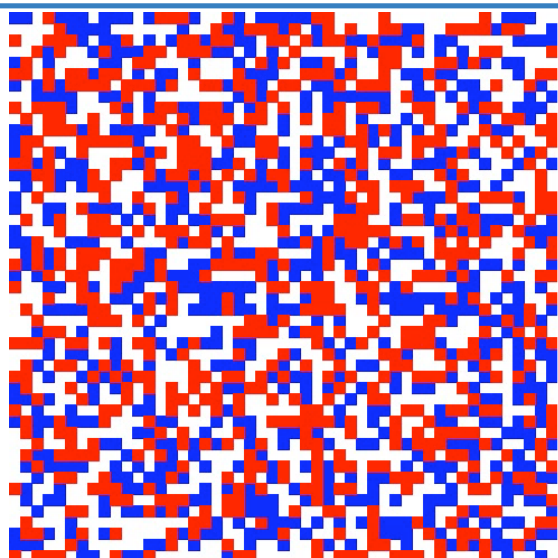
A simple model considering strategy and location changes and noise can reproduce various **stylized facts** of social systems:

1. Individuals like to **agglomerate** (form cities, groups, etc.)
2. Individuals with different behavioral strategies tend to **segregate** (--> see also Schelling)
3. **Levels of cooperation** in the prisoner's dilemma and in public goods games are **higher than expected**; they tend to break down, but may grow, if people can leave bad environments and choose more favorable ones
4. Individual **behaviors are partially determined by the social environment** they are contributing to (--> norms)
5. Social environments **persist** much longer than an average individual contributes to it (--> **social institutions**)
6. Social systems perform well by **continuous adaptation**

Intermediate Summary

- Extending spatial games by success-driven migration allows to describe
 - **survival and spreading of cooperation** in large parameter area of the PD by spatio-temporal **pattern formation**
 - **noise-resistance**
 - **outbreak** of predominant cooperation
- Success-driven migration can **destabilize** a homogeneous strategy distribution, but produces **adaptive**, self-stabilizing patterns (rather than frozen ones), allowing cooperators to **evade invasion attempts** of defectors
- This “inverts” the result of the replicator equation predicting 100% defectors
- The mechanism is **local**, and it **does not change the payoffs** (in contrast to taxes or punishment, for example)
- **Mobility is an important factor supporting human sociality**

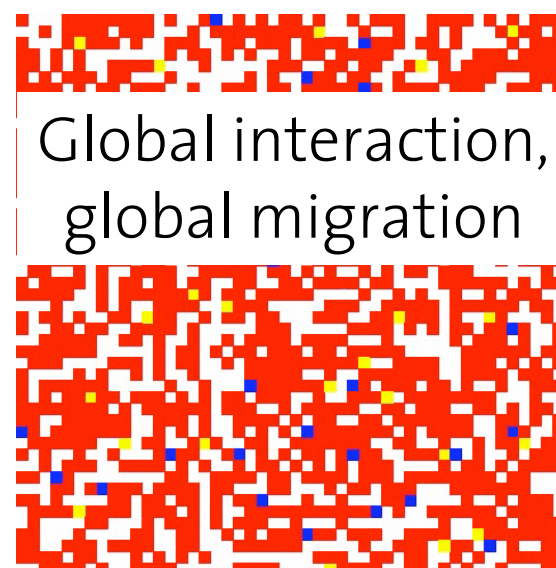
Does Globalization Endanger Social Cooperation?



Local interaction,
local migration

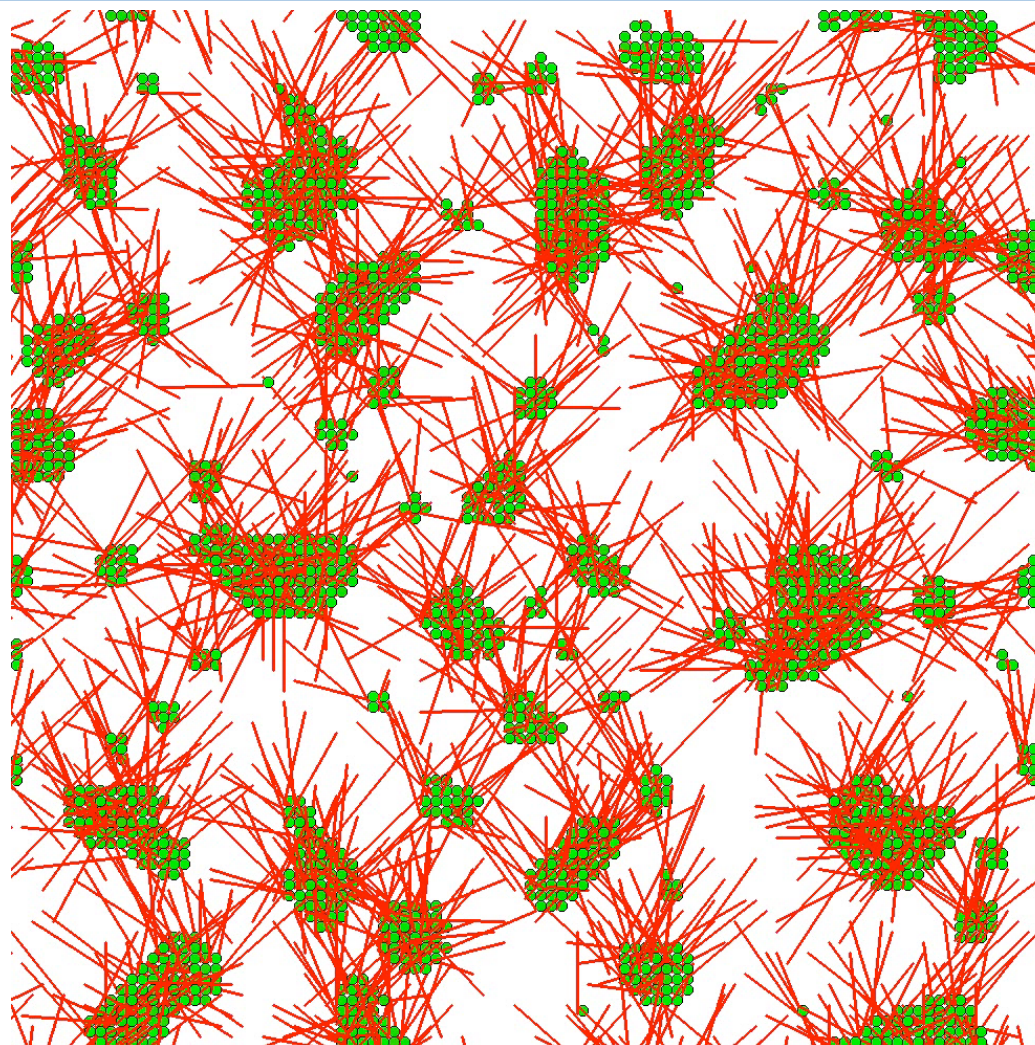


Global interaction,
local migration



Global interaction,
global migration

Can Social Networks Avoid a Collapse of Cooperation?

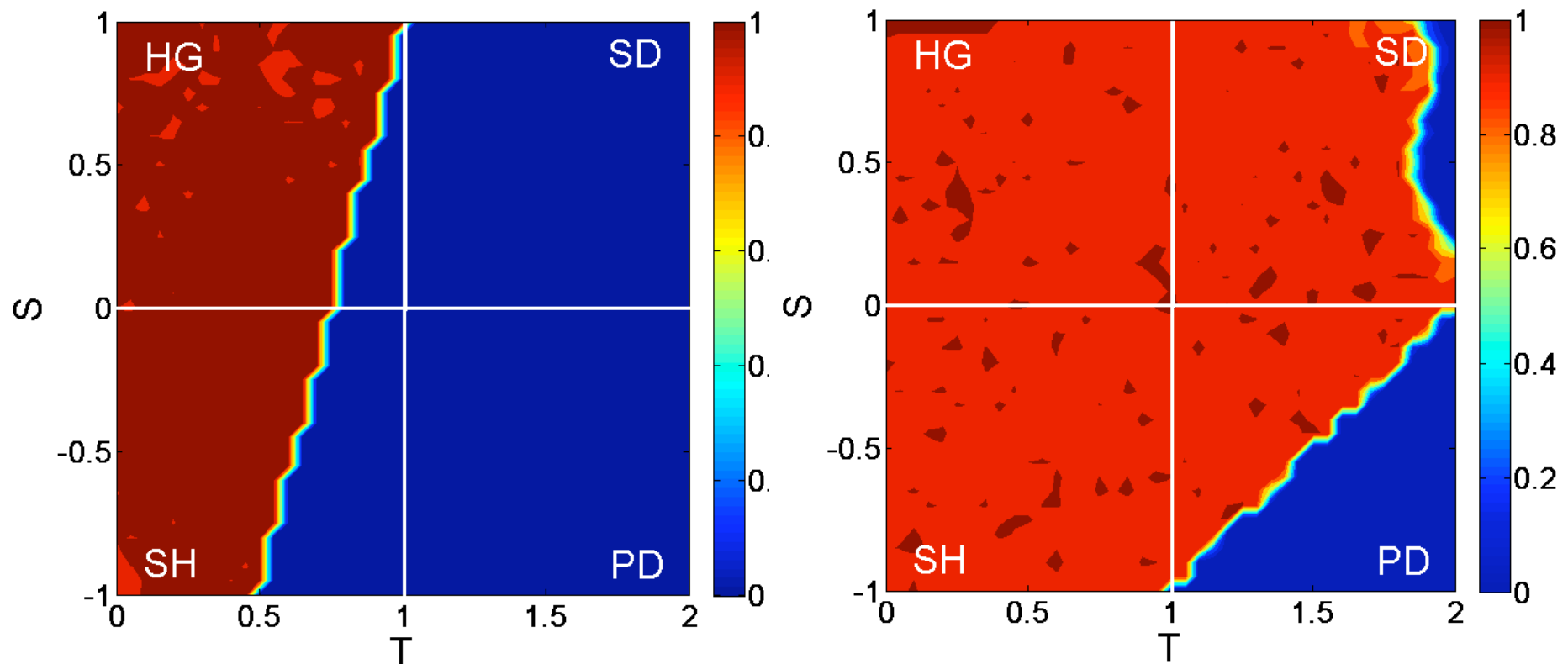


We assume that people move, but stay connected with their friends

Can Social Inequality Promote Cooperation?

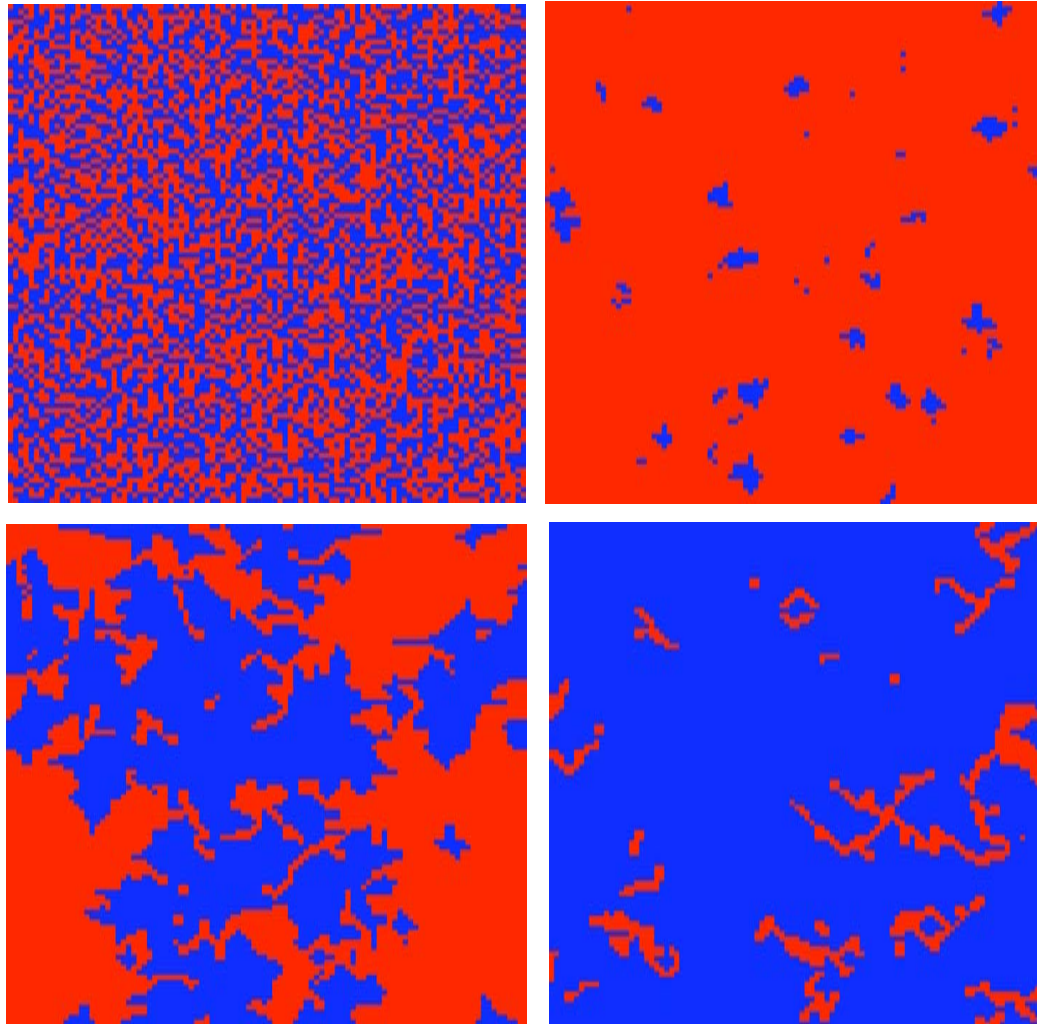
HG = Harmony Game, SD = Snowdrift Game/Chicken Game

SH = Stag Hunt Game/Assurance Game, PD = Prisoner's Dilemma



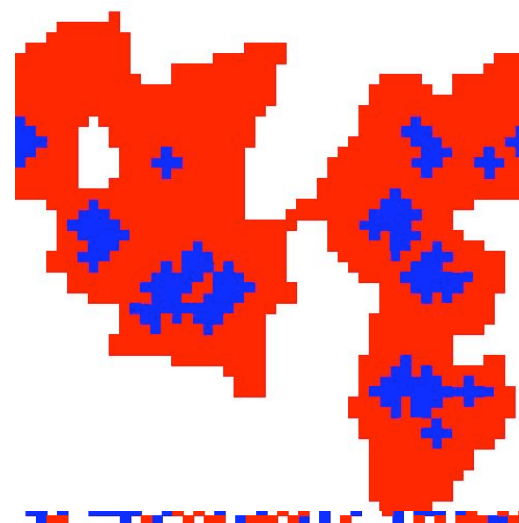
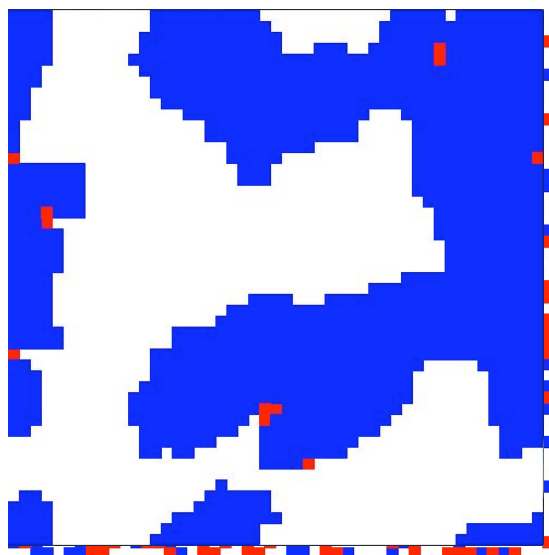
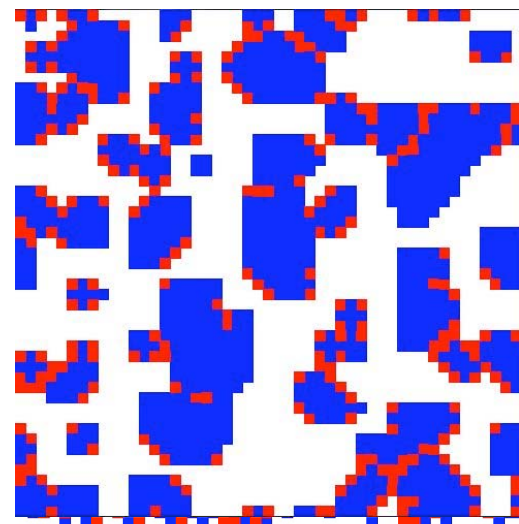
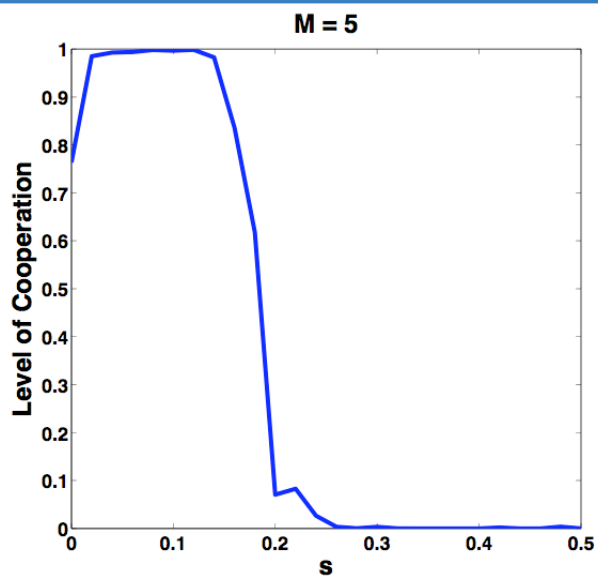
Is it the reason, why capitalism seems to have outperformed communism?

How the Rich-Gets-Richer-Effect Can Support Cooperation

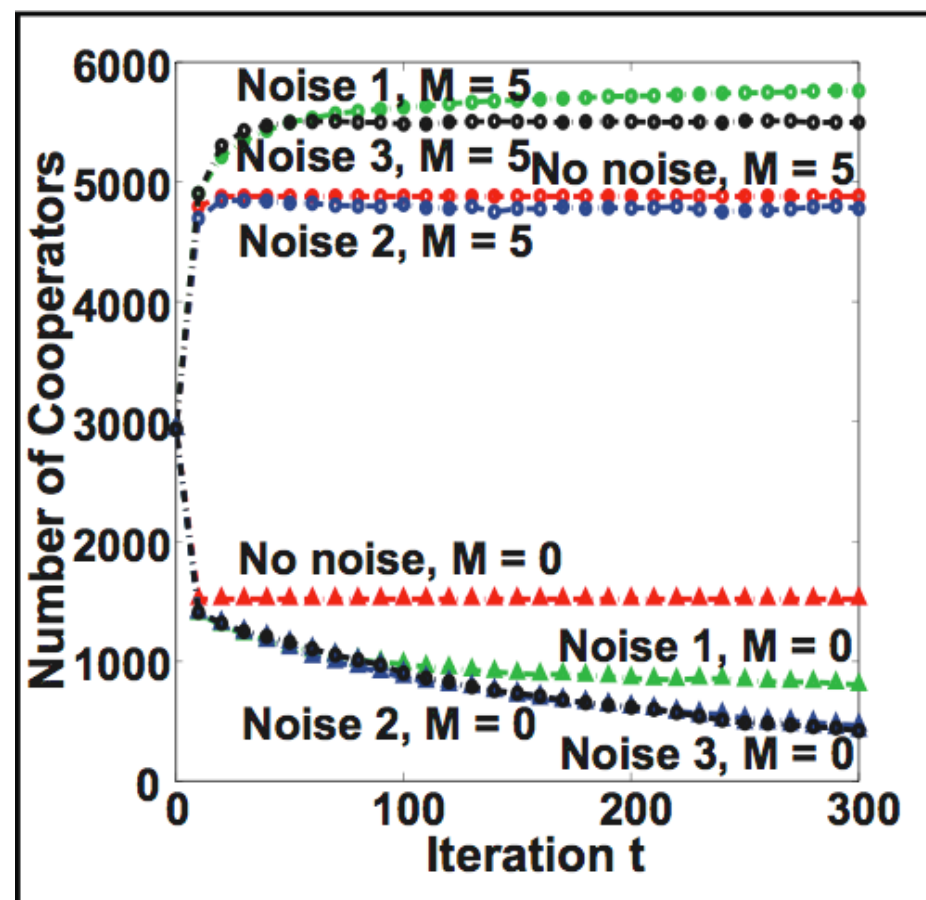
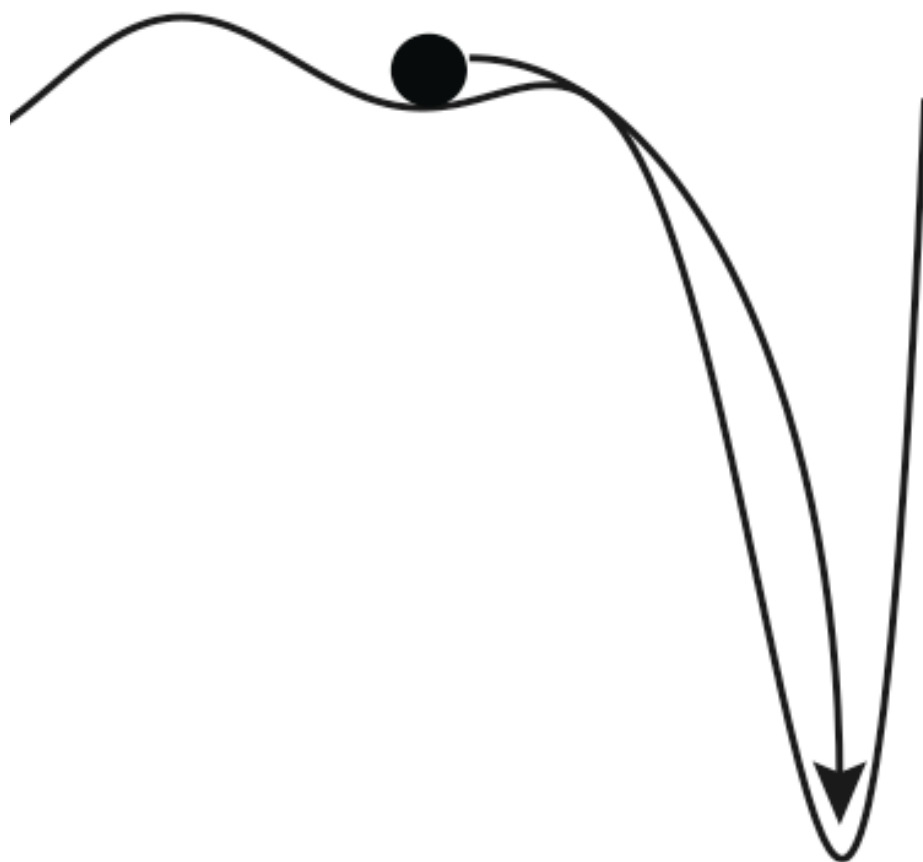


How much inequality is needed for the cooperation-enhancing effect?

Social Order: How Important is the Protection of Private Property?



The Positive Effects of Moderate Noise



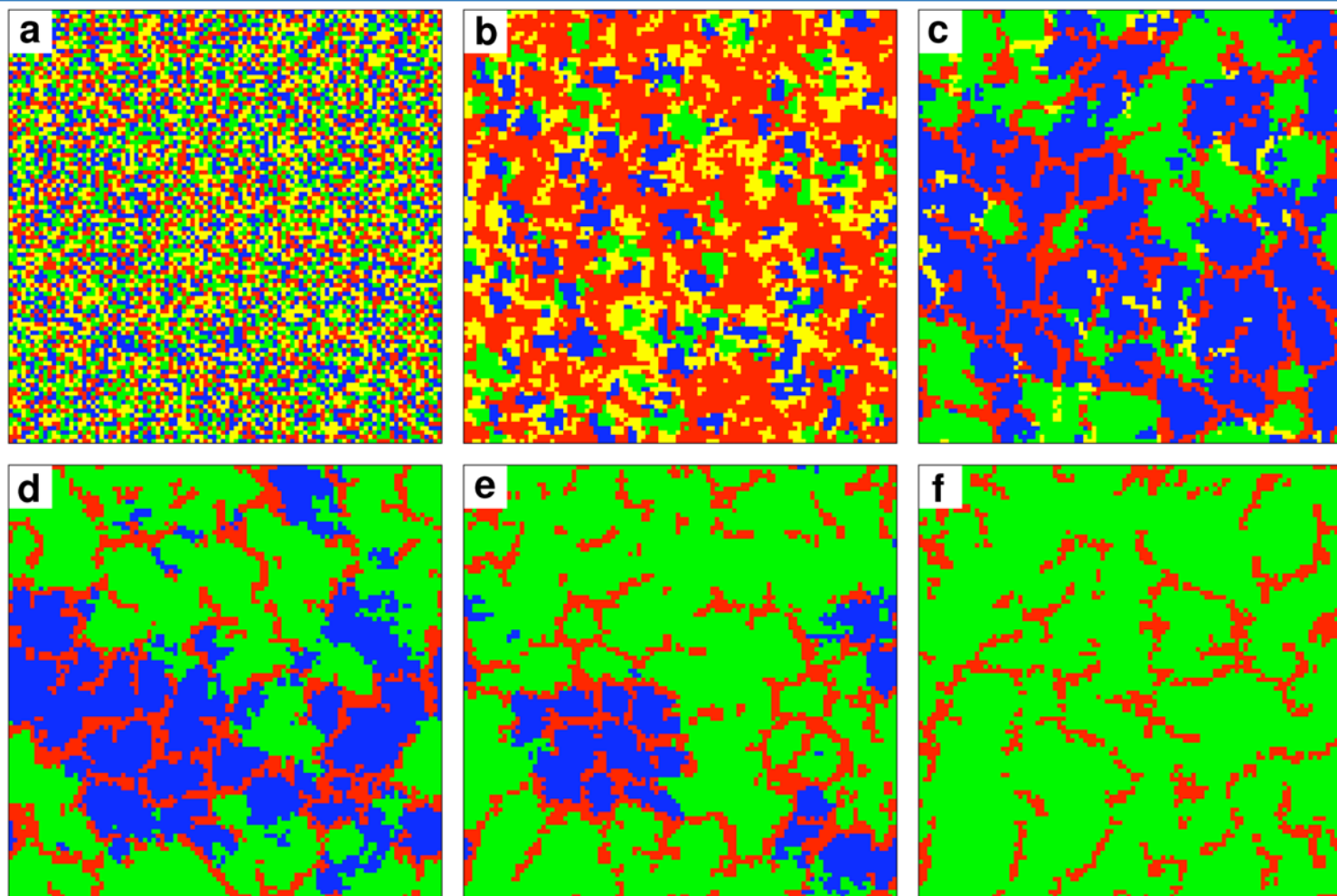
(A) 2% noise

Noise can overcome metastable, but suboptimal configurations

Global Warming and the Spreading of Costly Punishment

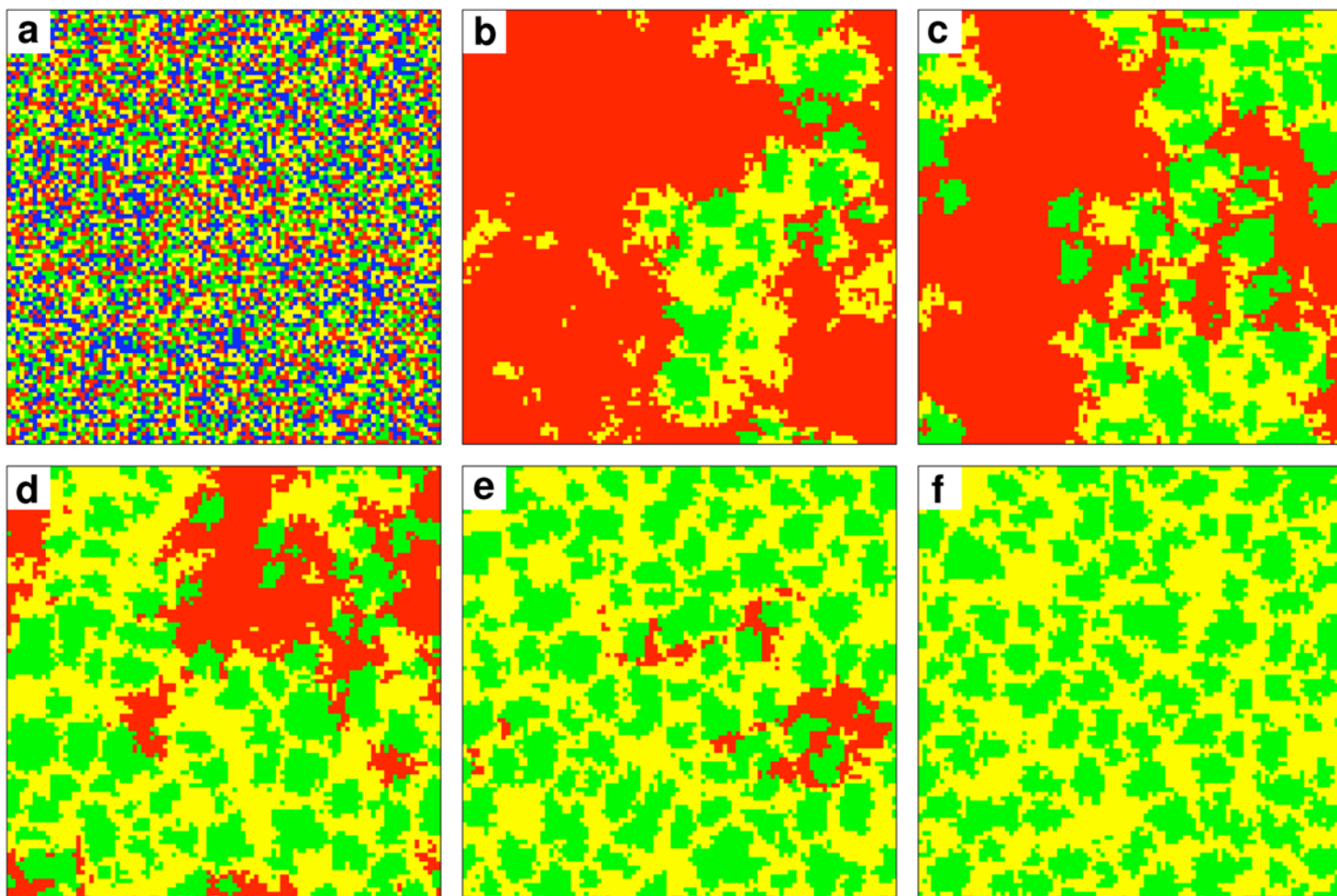
- Imagine that **cooperators (C)** correspond to countries trying to meet the CO₂ emission standards of the Kyoto protocol, and **“moralists” (M)** to cooperative countries that additionally enforce the standards by international pressure (e.g. embargoes). **Defectors (D)** would correspond to those countries ignoring the Kyoto protocol, and **“immoralists” (I)** to countries failing to meet the Kyoto standards, but nevertheless imposing pressure on other countries to fulfil them.
- For well-mixed interactions, **defectors will be the winners** of the evolutionary competition among the strategies, i.e. all countries would finally fail to meet the emission standards (**“tragedy of the commons”**). The reason is that **cooperators** (“second-order free-riders”) spread at the cost of moralists, while requiring them for their own survival. (See the work of Milinski et al.!)

How Second-Order Free-Riders Are Eliminated+Punishment Spreads



D = Defectors (Free-Riders), M = Moralists, I=Immoralists
C = Non-punishing Cooperators (Second-Order Free-Riders)

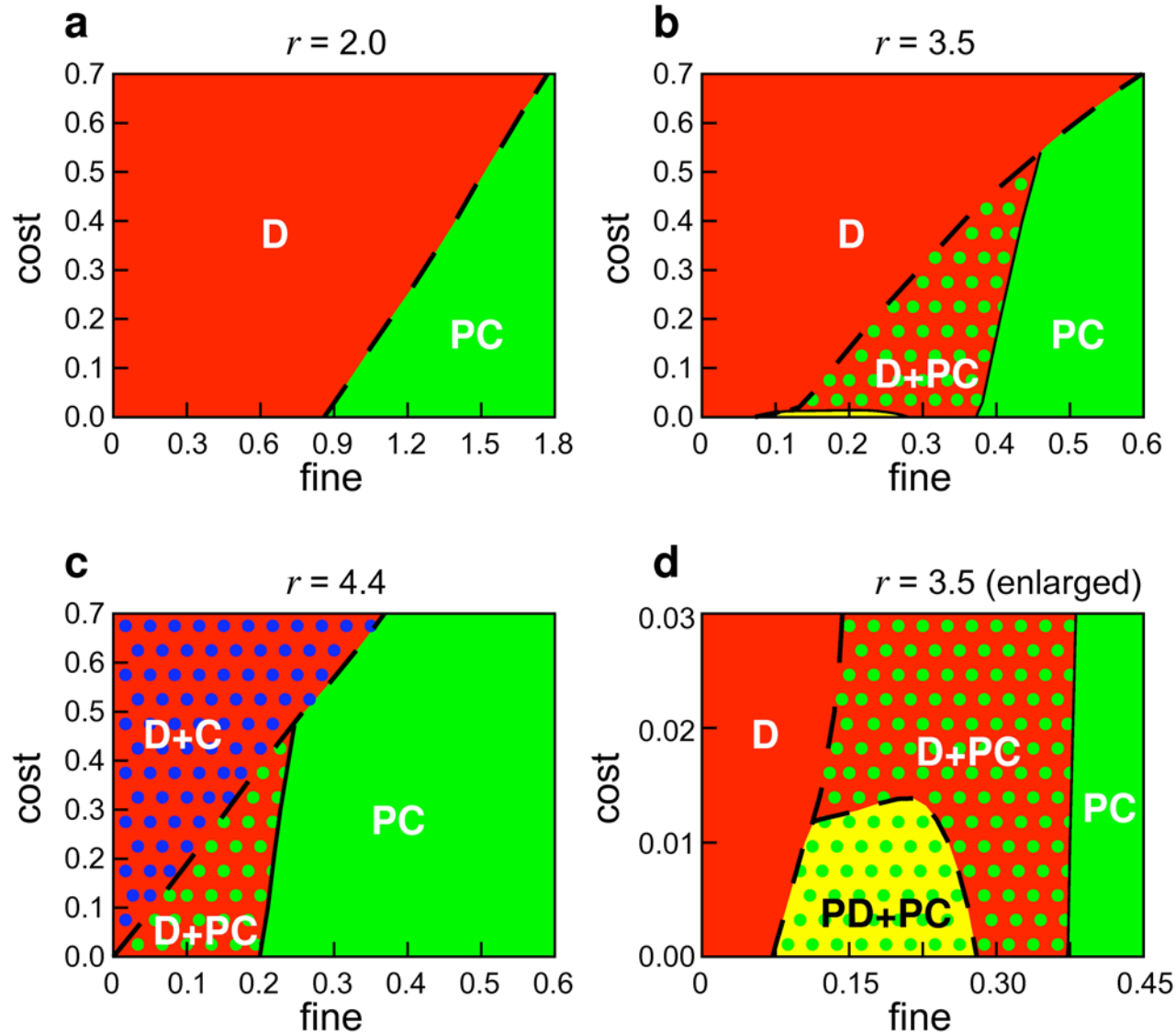
The “Unholy” Symbiosis of Moralists and Immoralists



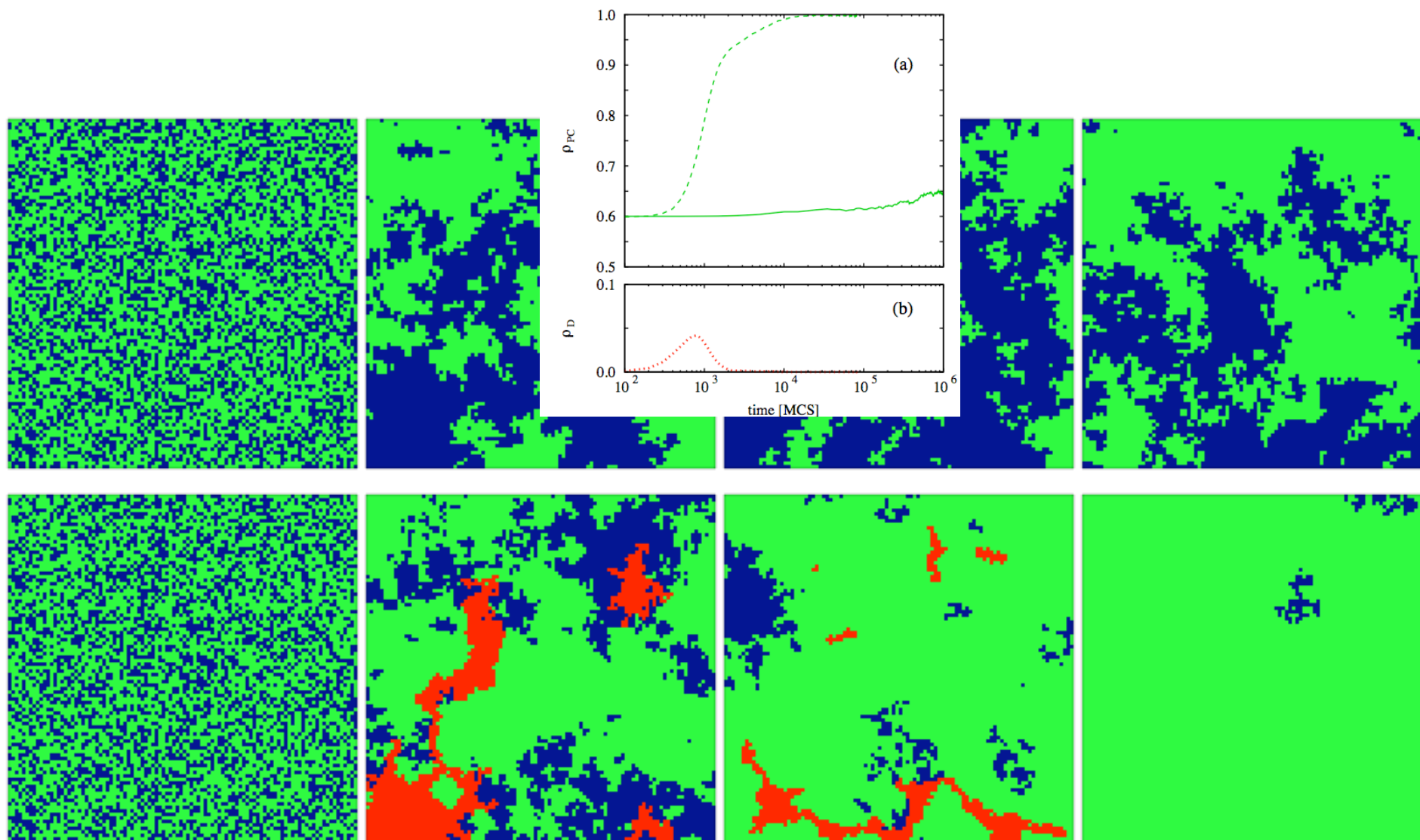
D = Defectors (Free-Riders), M = Moralists, I = Immoralists

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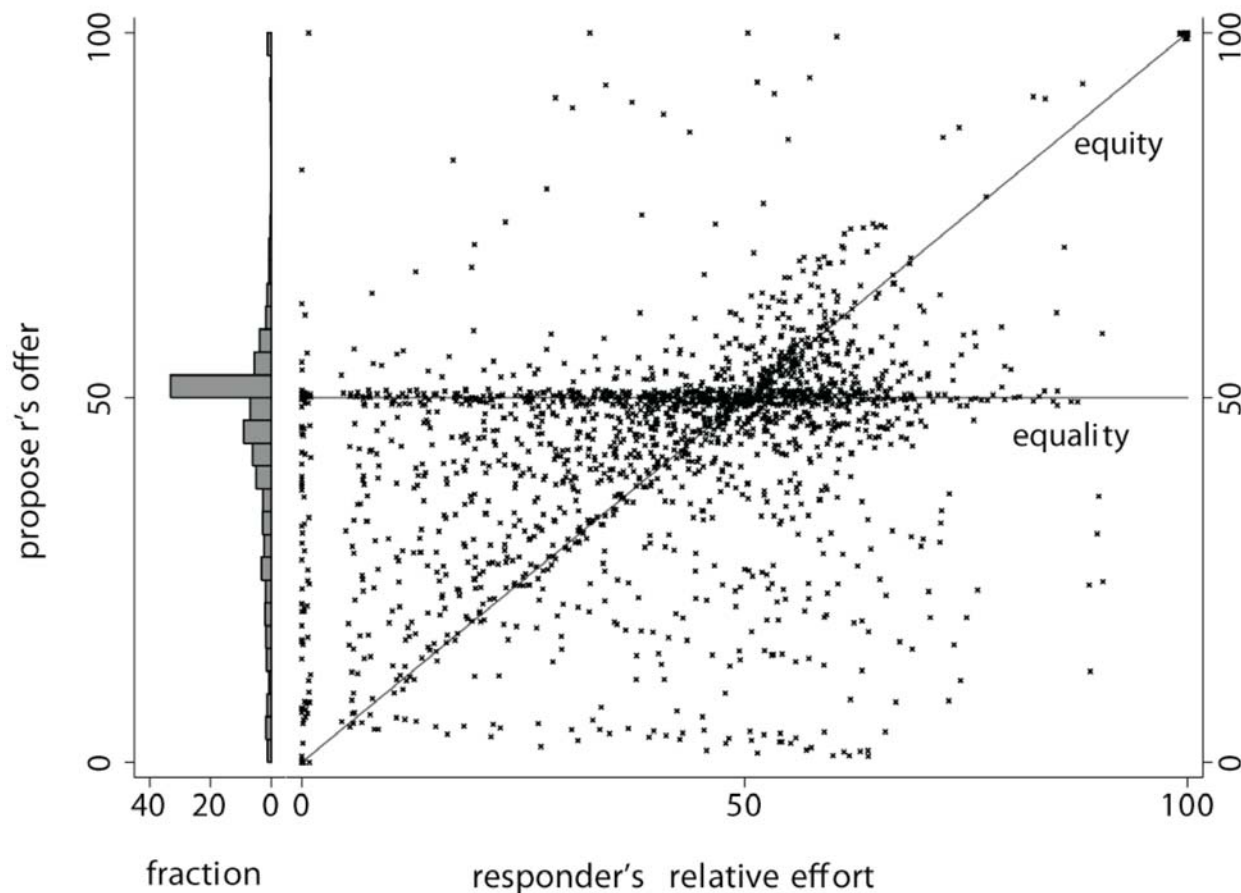
Overcoming the Tragedy of the Commons by Spatial Interactions



“Lucifer’s Positive Side Effects”



Conflict between Individuals With Equity and Equality Preferences



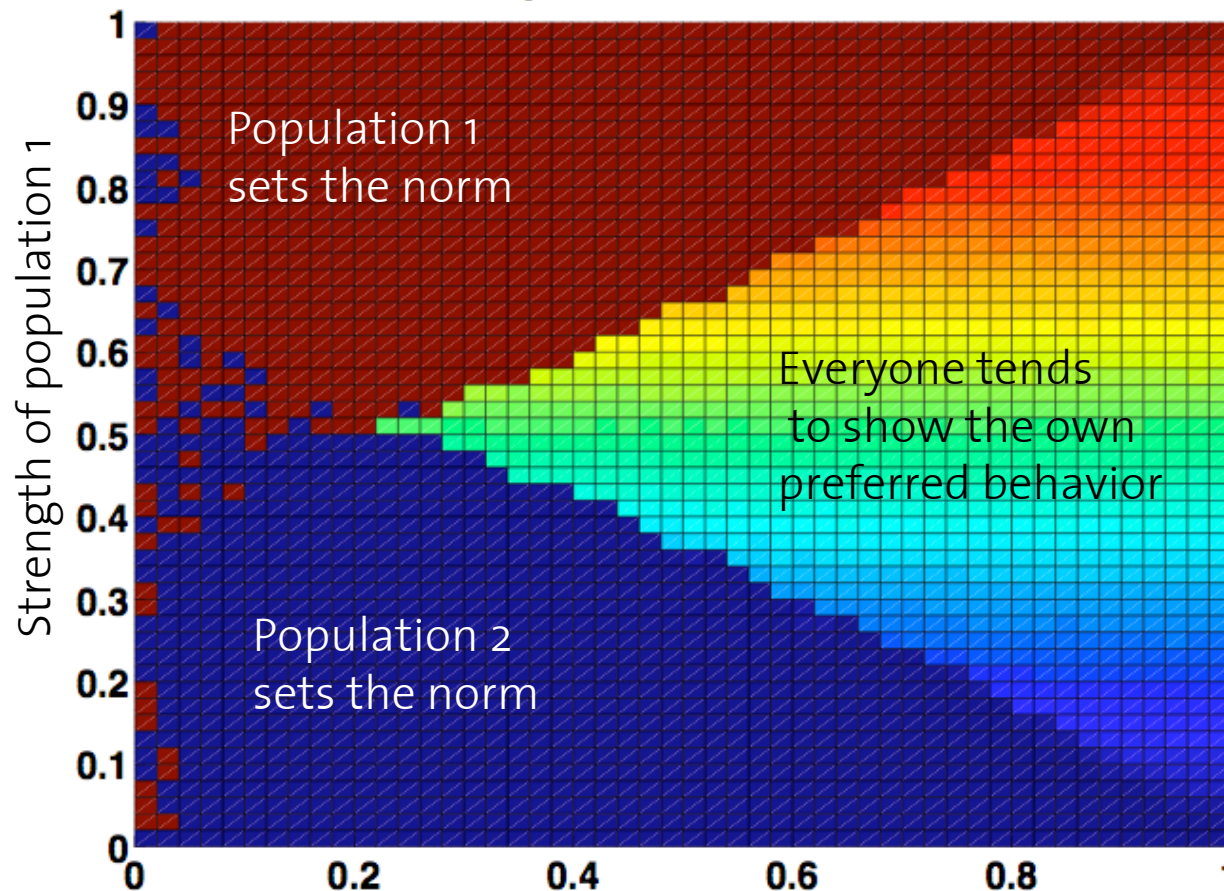
Results of an Ultimatum Game Experiment

Work with Fabian Winter and **Heiko Rauhut**

Possible Outcomes in the Two-Population Norms Game

$\varepsilon = 0.01$, Interaction Partner = 1, $p_0 = p_1 = 0.5$

Proportional Imitation



Reward of showing preferred behavior / Reward of conforming



Computer simulations:

Red = individuals preferring behavior 1

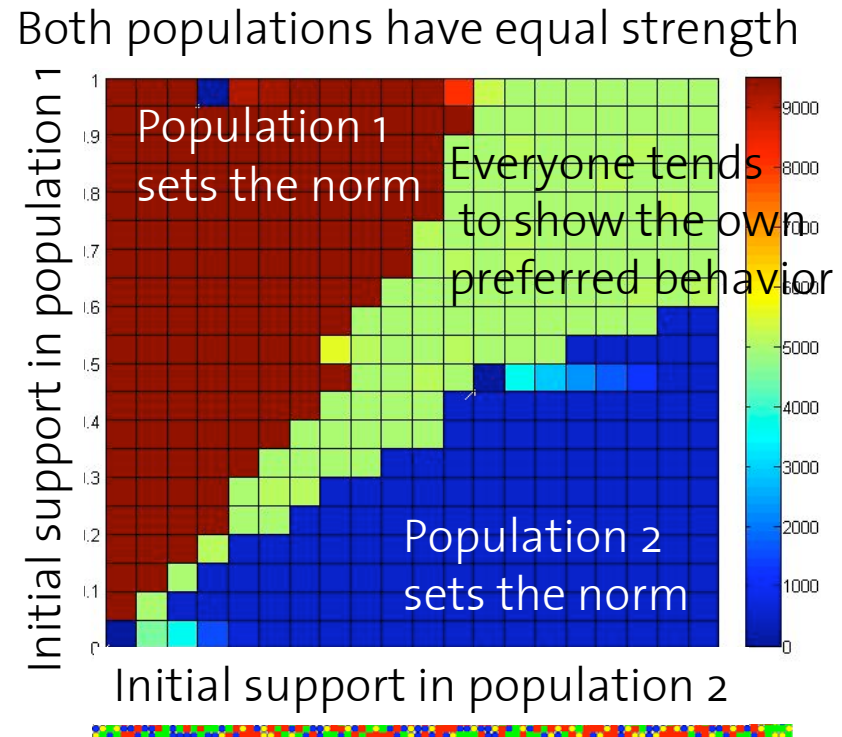
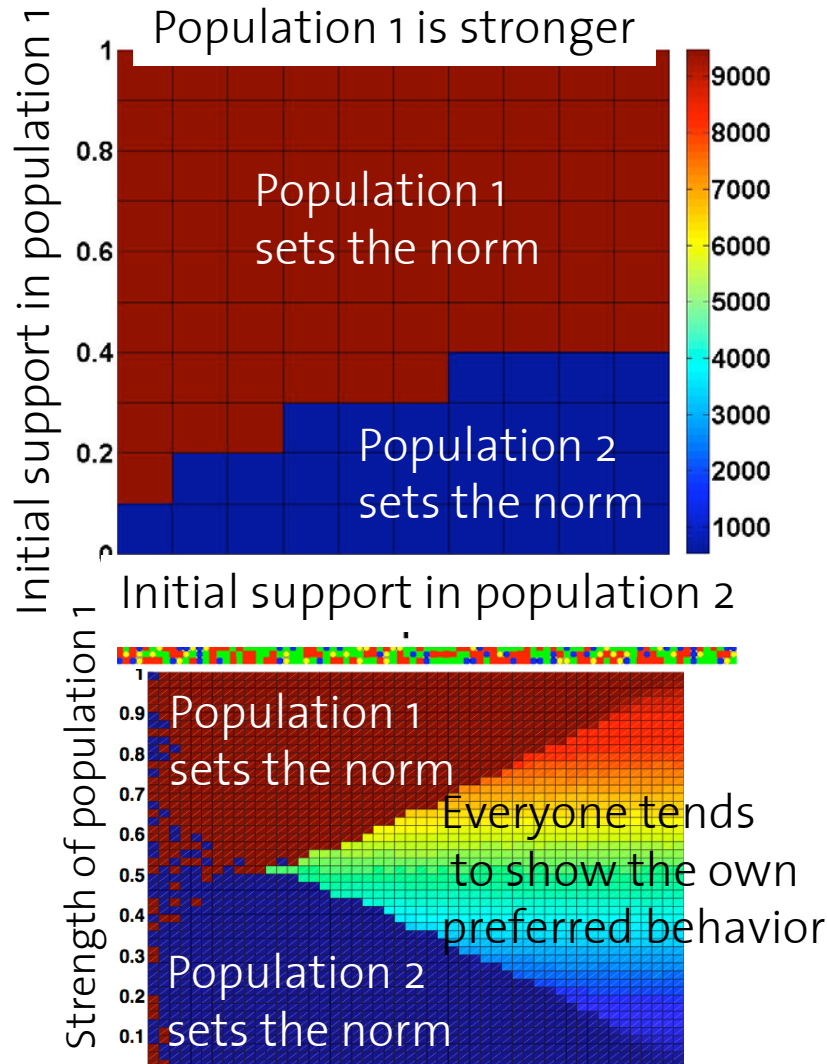
Yellow = individuals adjusting to behavior 1

Blue = individuals preferring behavior 2

Green = individuals adjusting to behavior 2

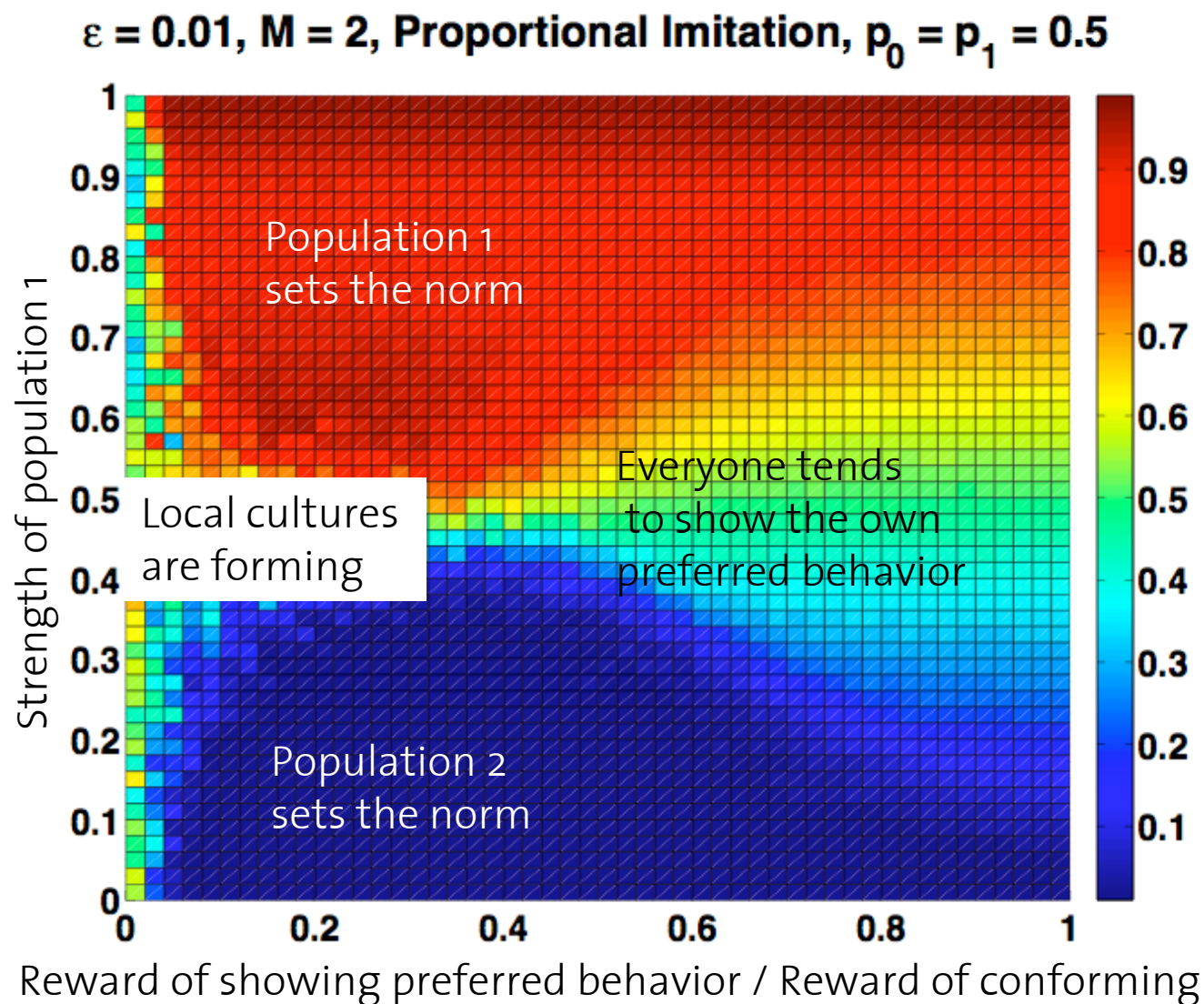
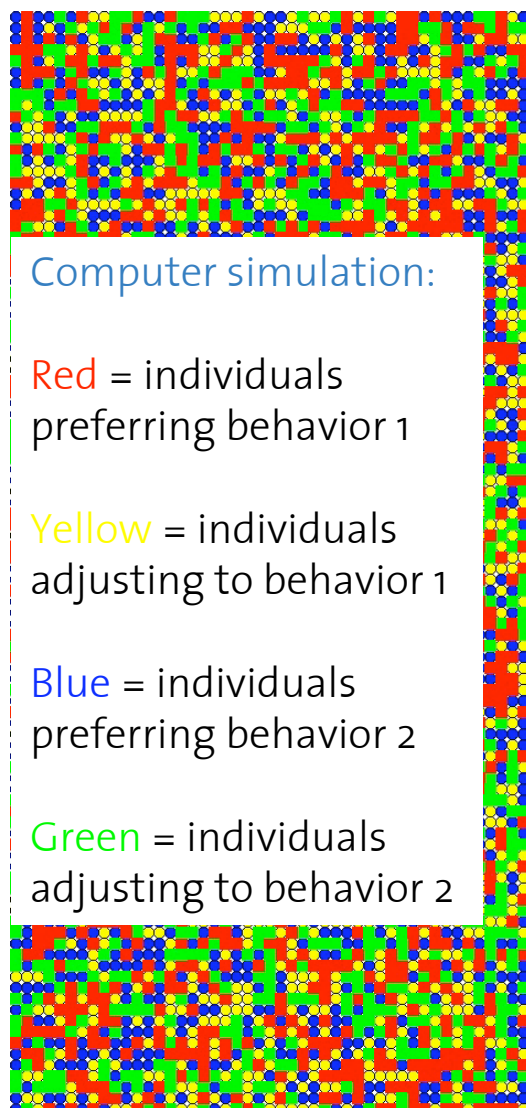


History/Path Dependence - The Initial Condition Matters



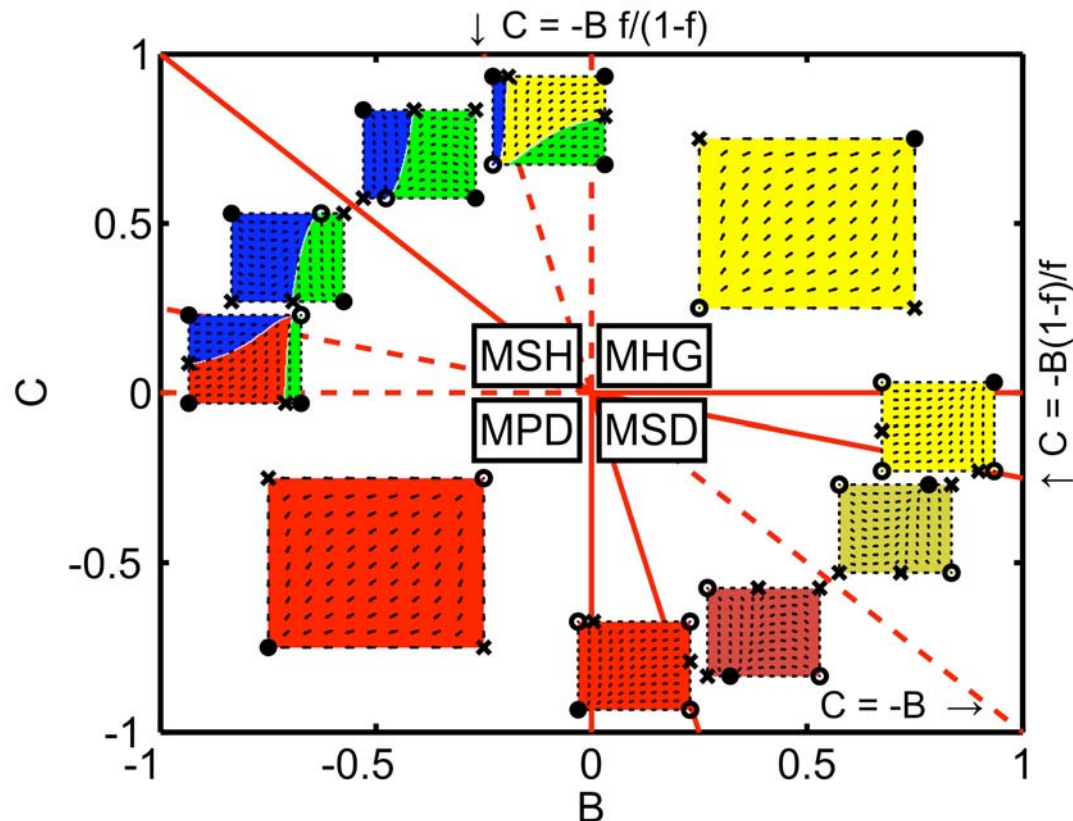
Reward of showing preferred behavior / Reward of conforming

Possible Outcomes in the Norms Game with Local Interactions



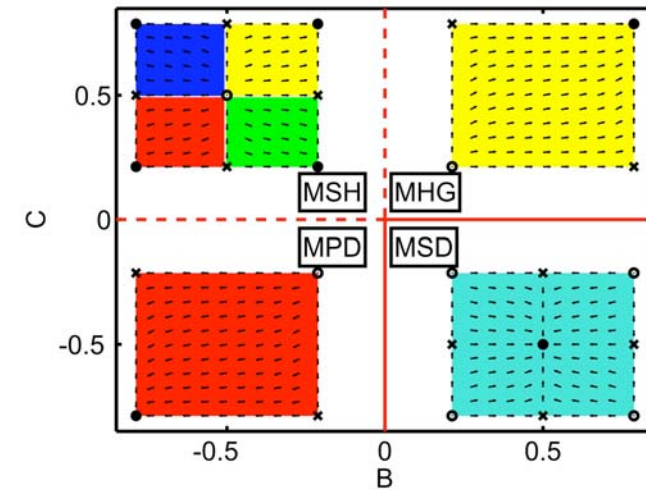
Summary of System Dynamics in Multi-Population Games

with interactions and self-interactions

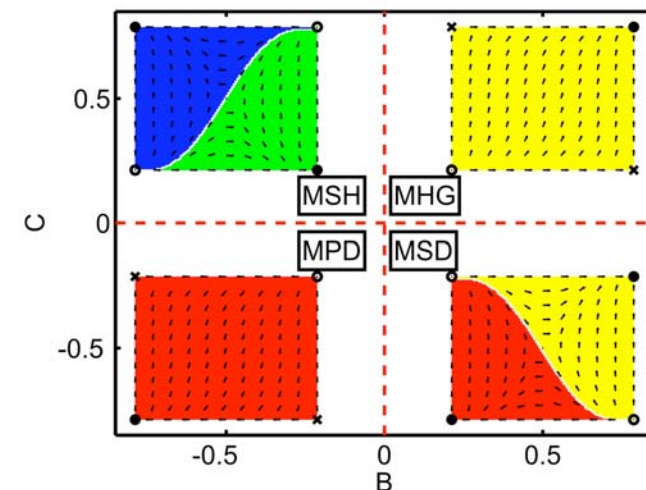


MSH = multi-population stag hunt game
 MPD = multi-population prisoner's dilemma
 MHG = multi-population harmony game
 MSD = multi-population snowdrift game

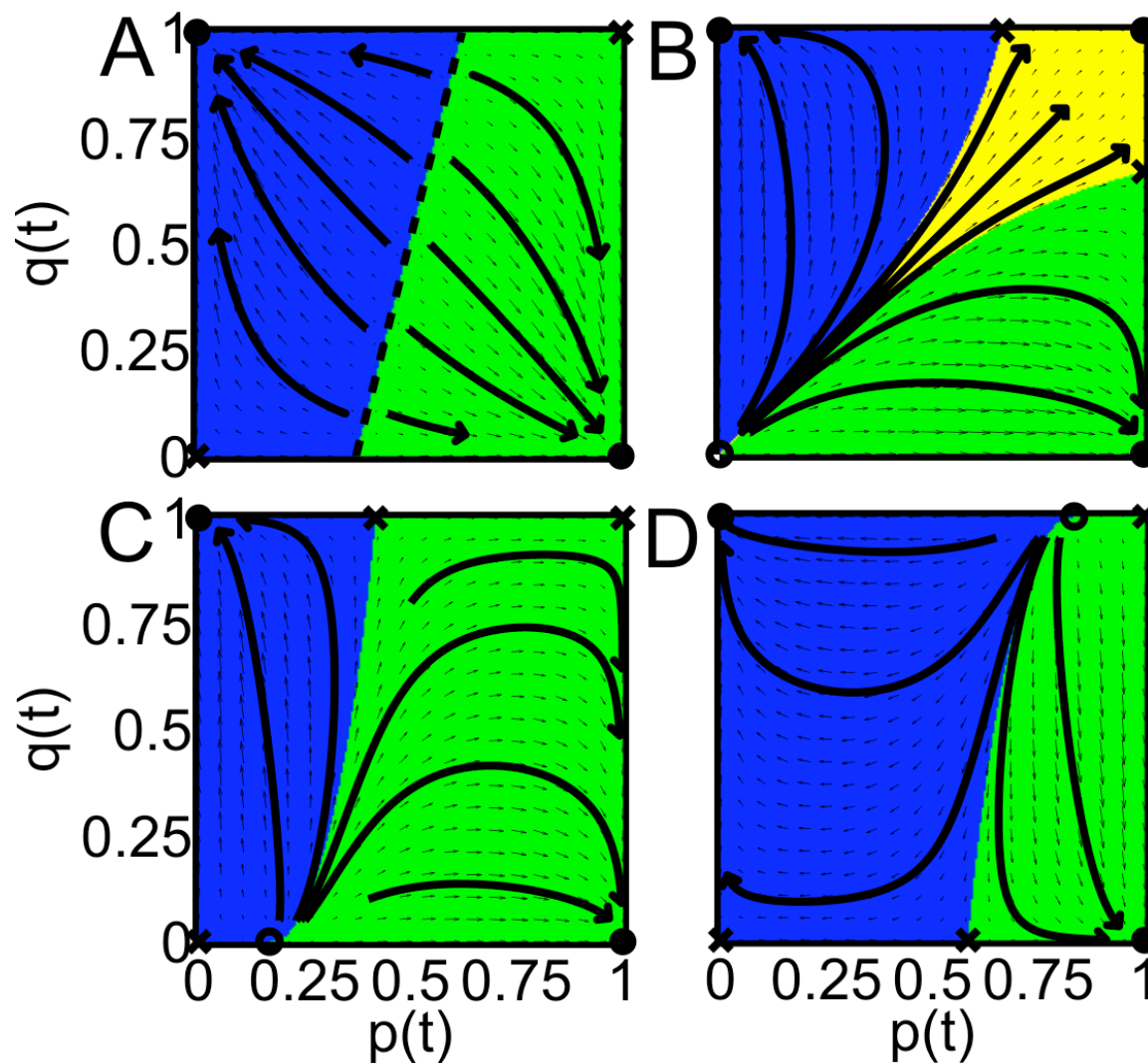
without interactions



without self-interactions

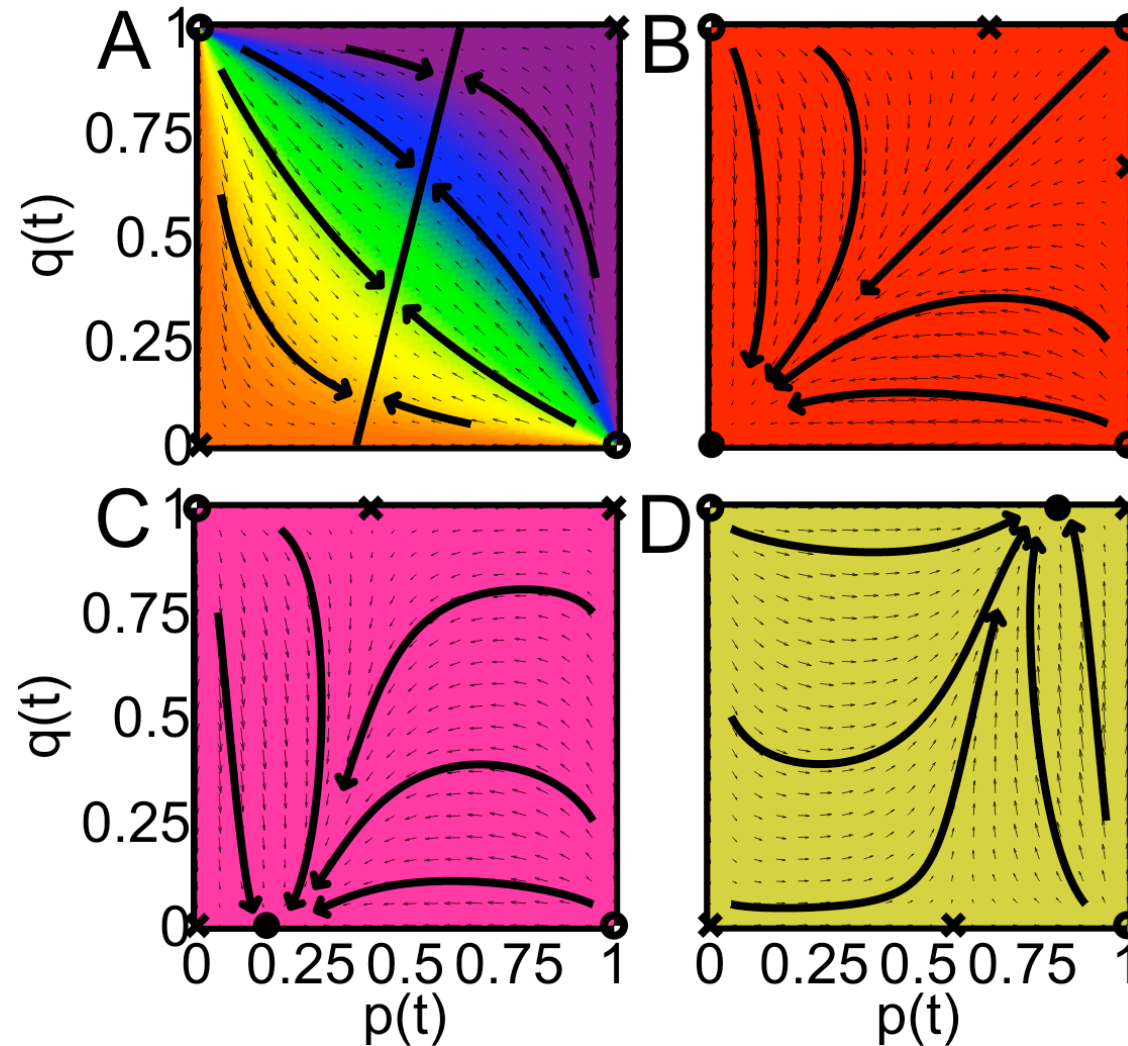


Stag Hunt Game in Two Populations with Incompatible Interests



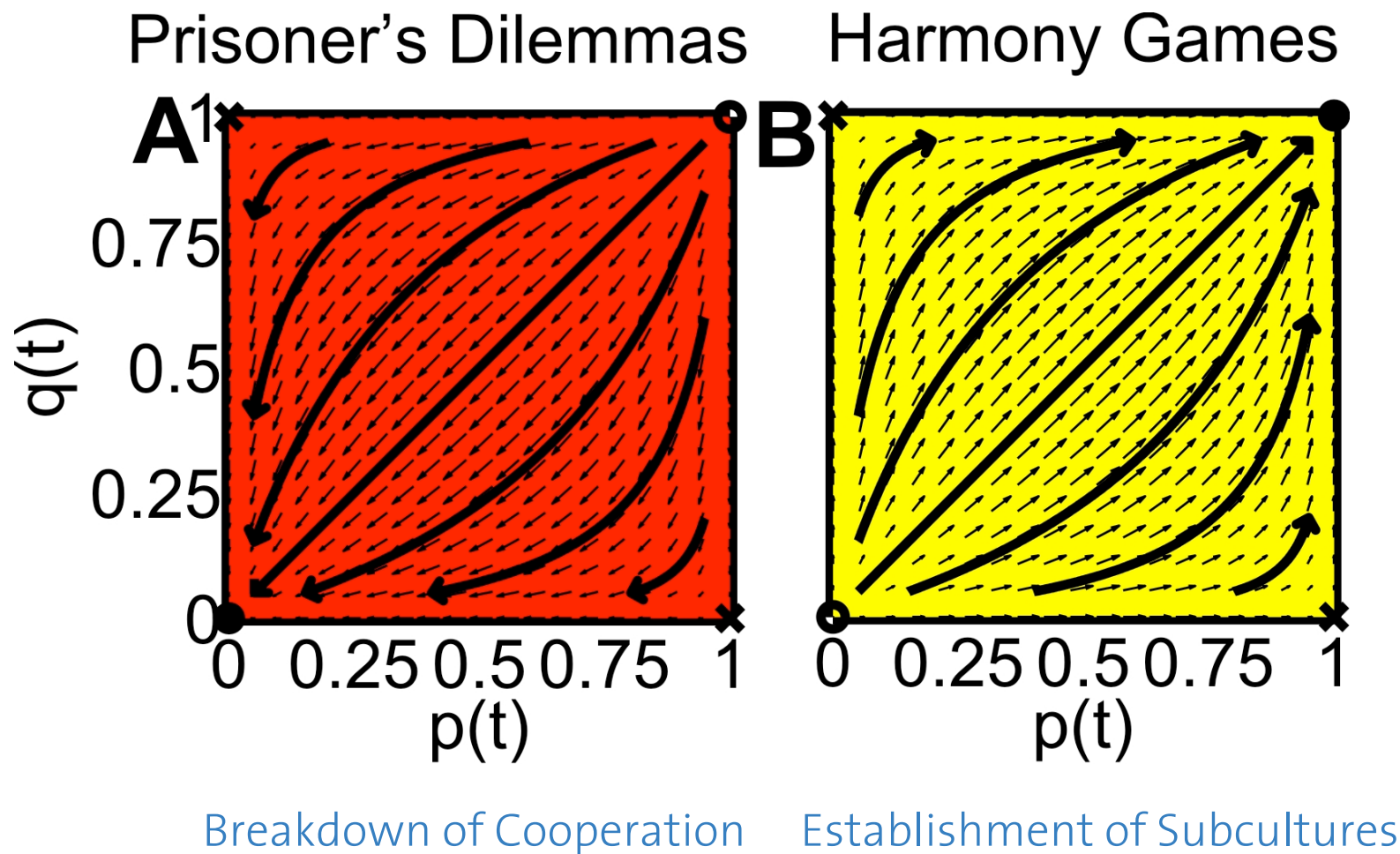
Establishment of commonly shared behavior (norms)

Snowdrift Game in Two Populations with Incompatible Interests

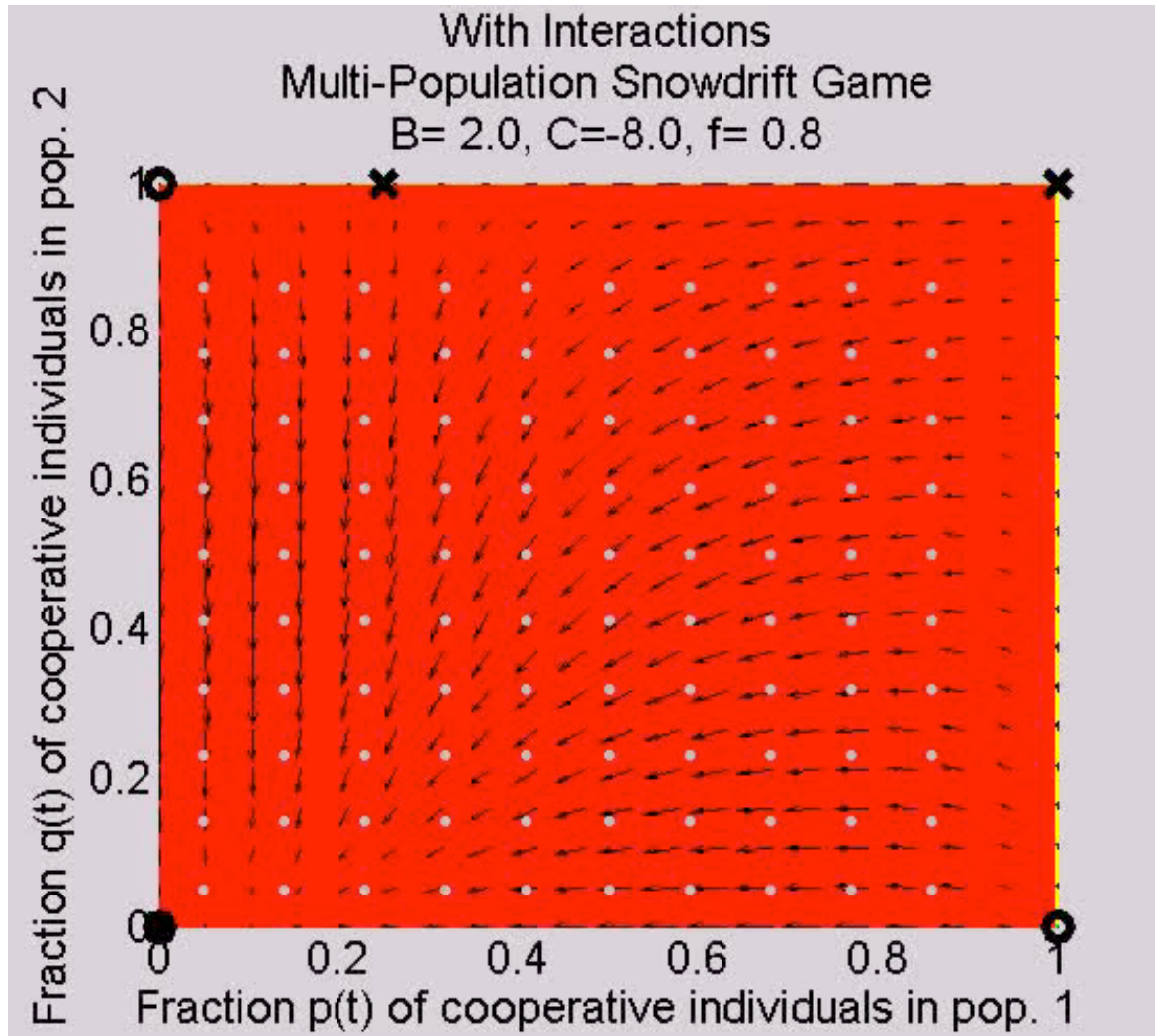


Occurrence of conflicts (or revolutions)

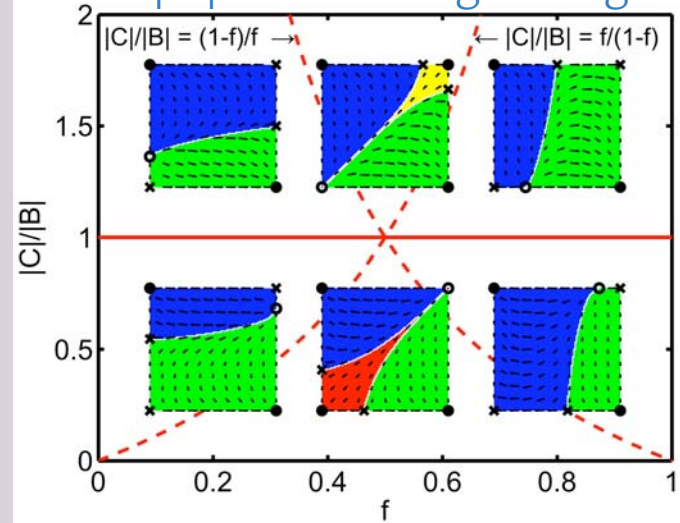
Prisoner's Dilemma and Harmony Game



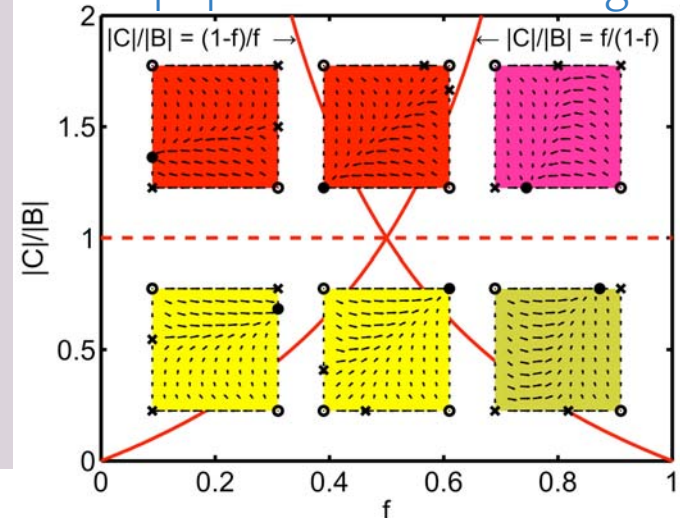
Relevance of the Payoff Parameters and Power



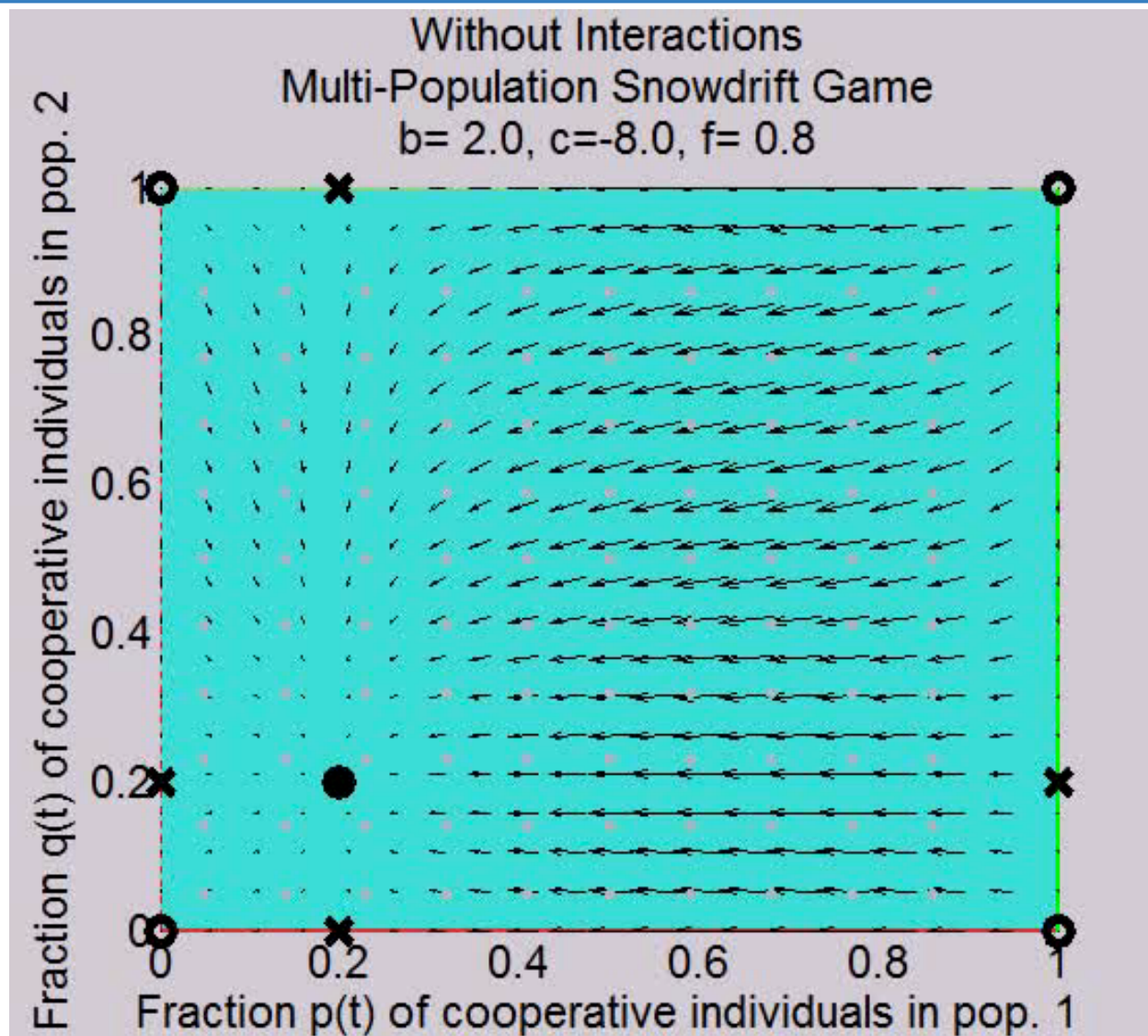
multi-population stag hunt game



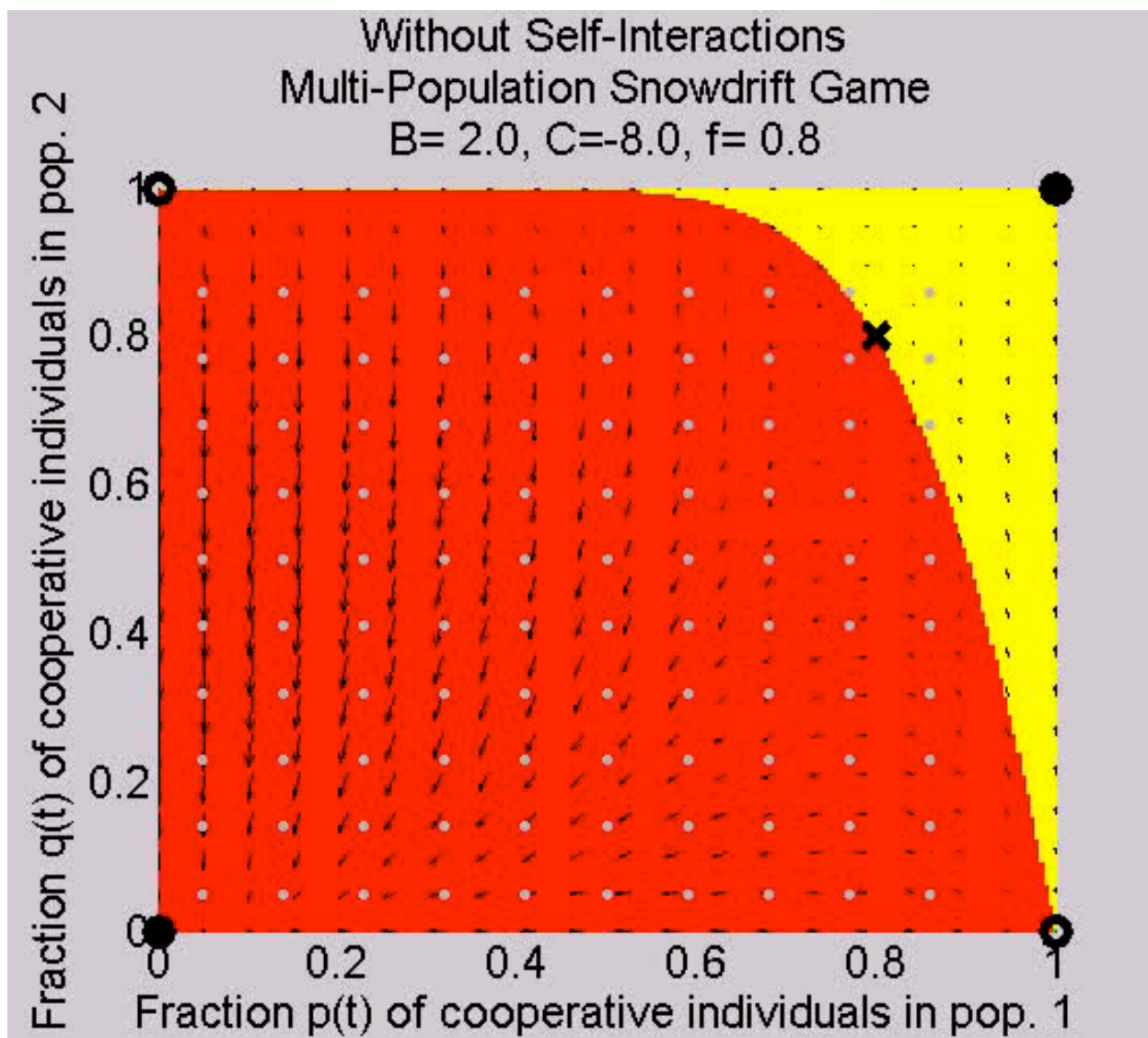
multi-population snowdrift game



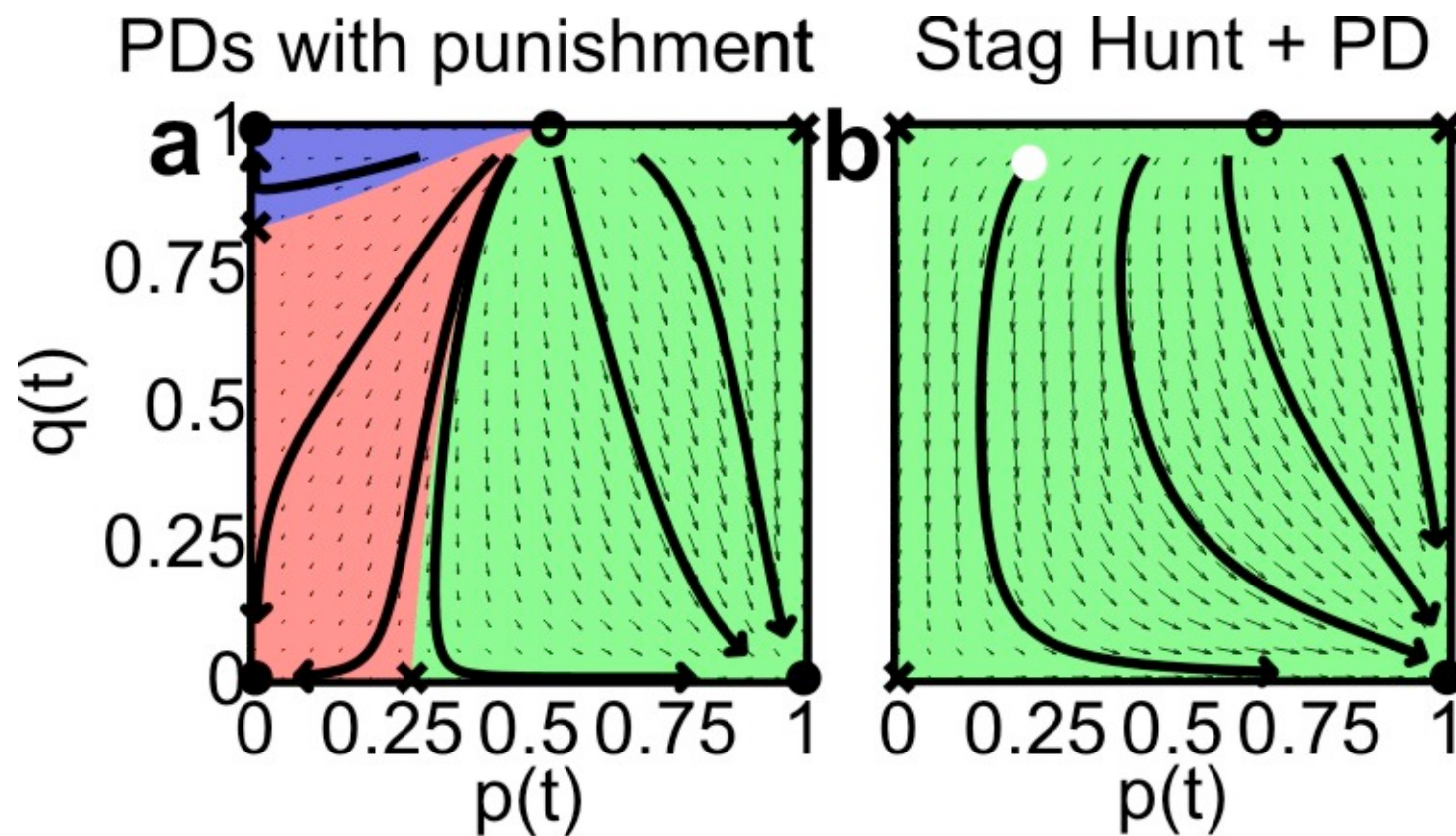
Two Populations without Interactions among Each Other



Two Populations without Self-Interactions

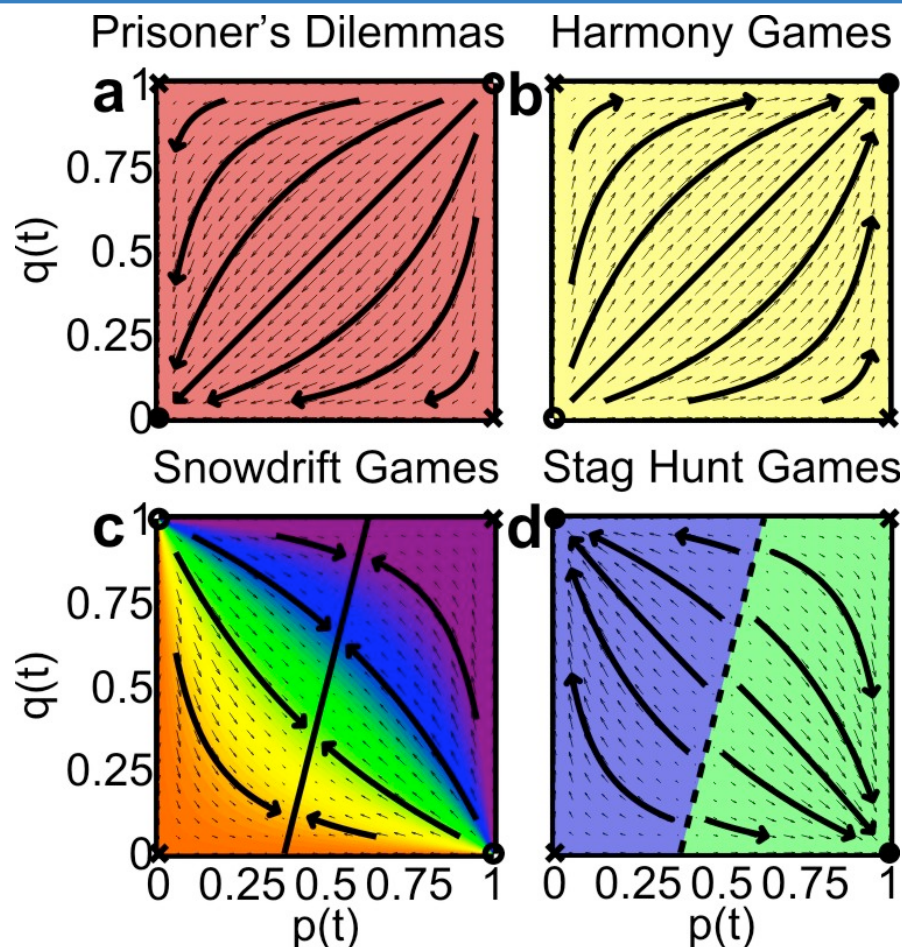


Two Populations with Conflicting Interests Playing Different Games



Two Populations with Incompatible Interests

Breakdown
of cooperation



Formation of
subcultures

Conflict/no
agreement

Formation of shared
behavioral norms

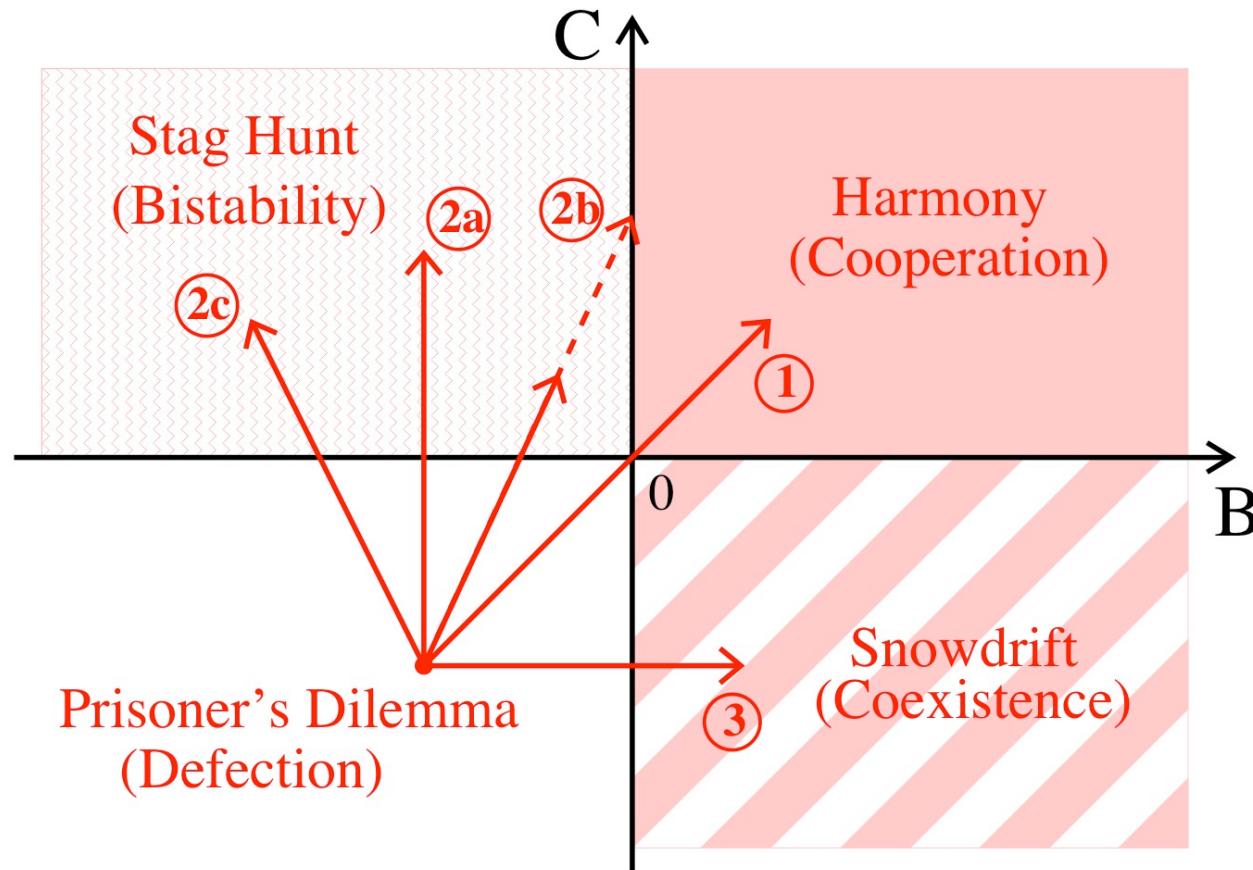
Only in the Stag Hunt Game we find that both populations tend to use the same behavioral strategy, i.e. **a behavioral norm evolves!** The norm-creating mechanism is also important for the **evolution of language.**

Fundamental Mechanisms Supporting Cooperation or Norms

- Genetic inheritance (B)
 - Repeated interaction (S)
 - Abstaining/volunteering (S)
 - Reputation, signaling (S)
 - Spatial interactions, clustering, agglomeration and segregation (B/S)
 - Friendship formation, network effects (S)
 - Group selection (B/S)
 - Costly punishment, group pressure (S)
 - Strong reciprocity (B/S)
 - Mobility (B/S)
 - Inequality, heterogeneity (B/S)
 - Noise, errors, mutation (B/S)
- B = Biological mechanism
S = Social mechanism
- The representative agent /
mean field approach
is misleading

Globalization seems to endanger social cooperation

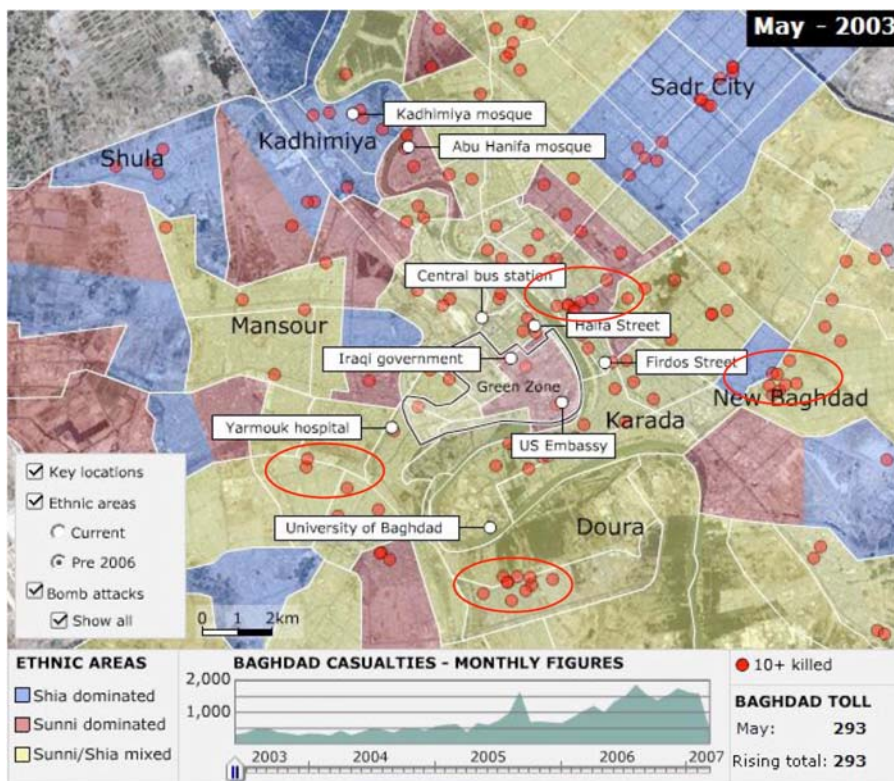
How to Transform the Prisoner's Dilemma into Other Games



Route 1: Kin selection, 3: Network interactions (don't support norms)

2a: Direct reciprocity, 2b: Indirect reciprocity, 2c: Punishment (support norms)

Interrelation of Spatial Interaction, Conflict, and Migration

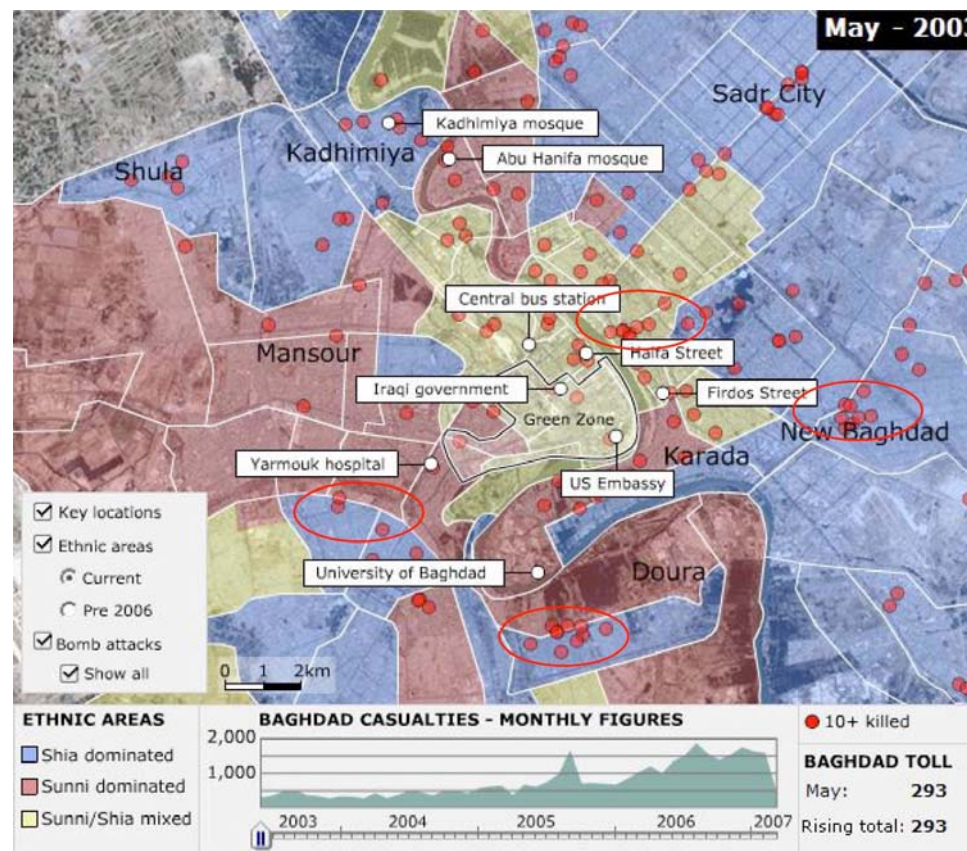


Ethnic areas and bomb attacks before 2006

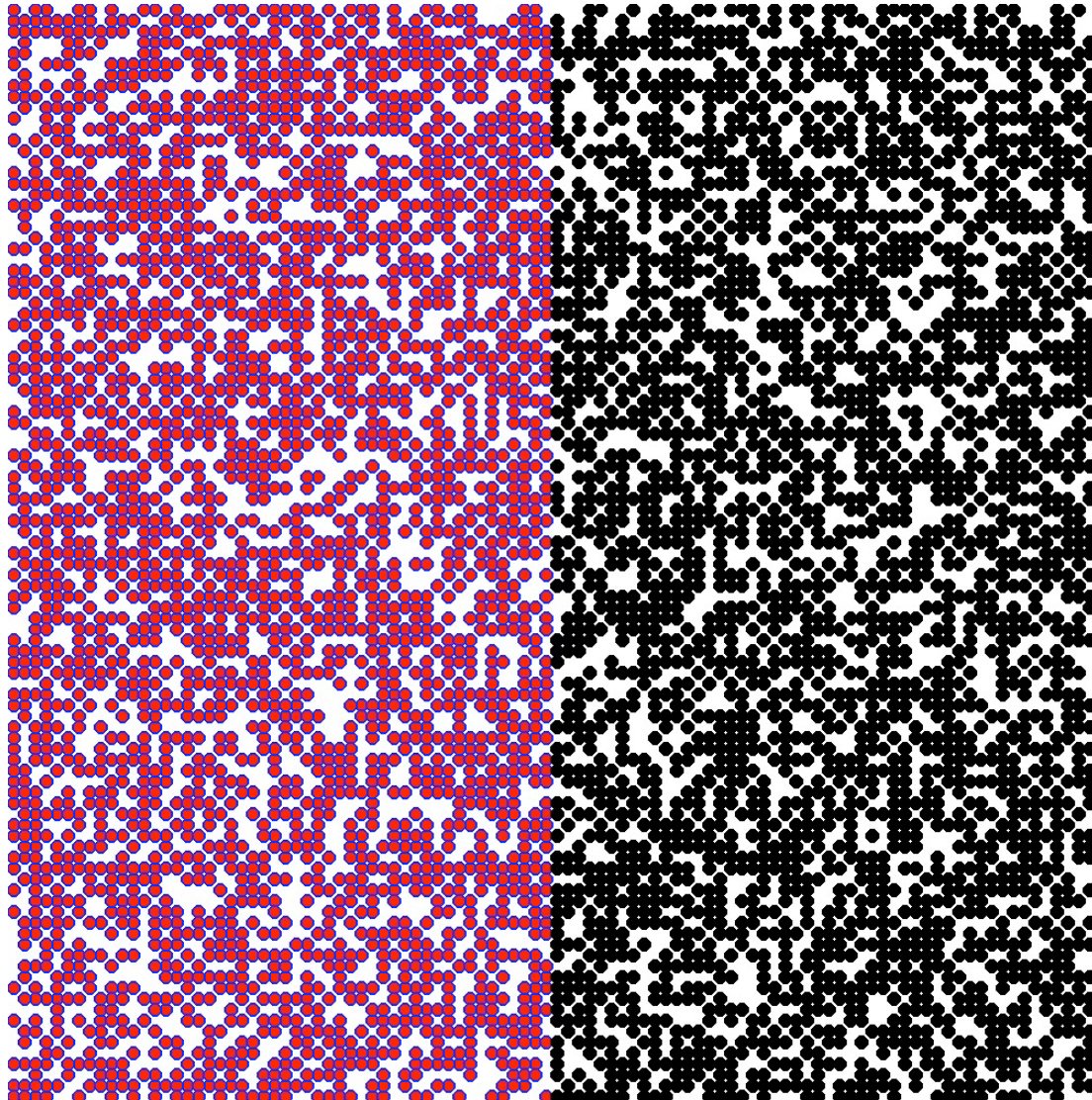
Conflict occurs primarily at boundaries between areas with different ethnic fractions. Mixed areas shrink.

Source: BBC

Ethnic areas and bomb attacks after 2006



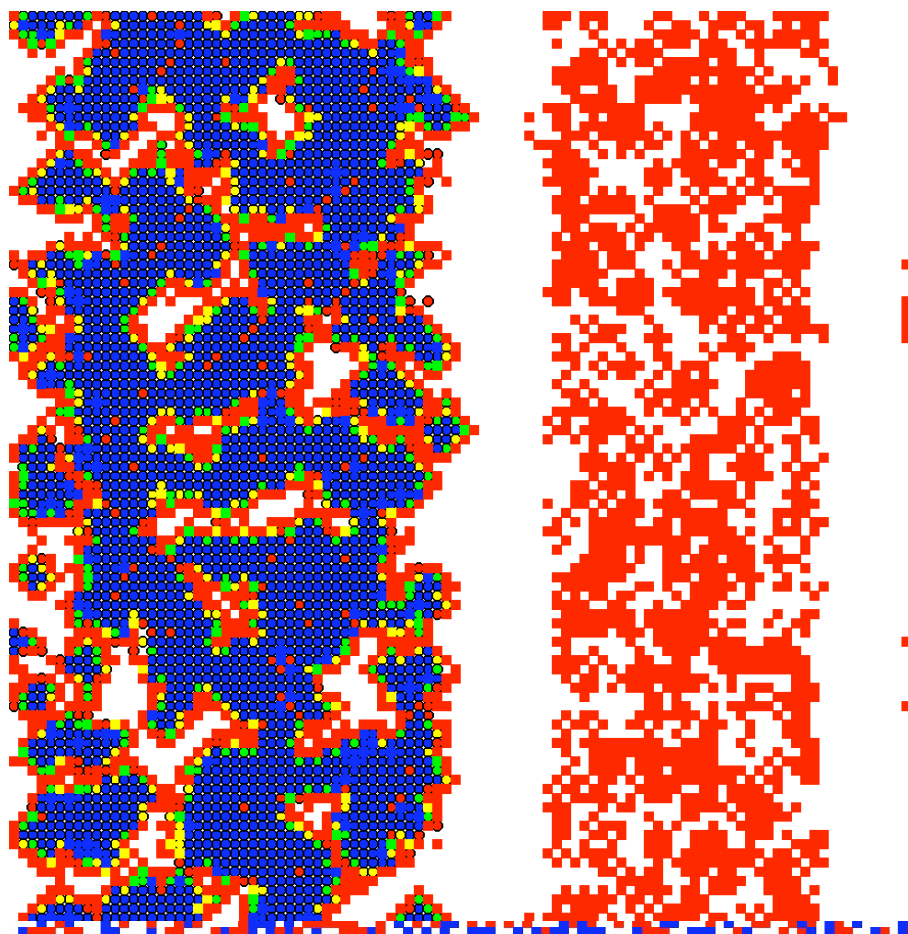
Conflicts: Towards Simulating Conflicts



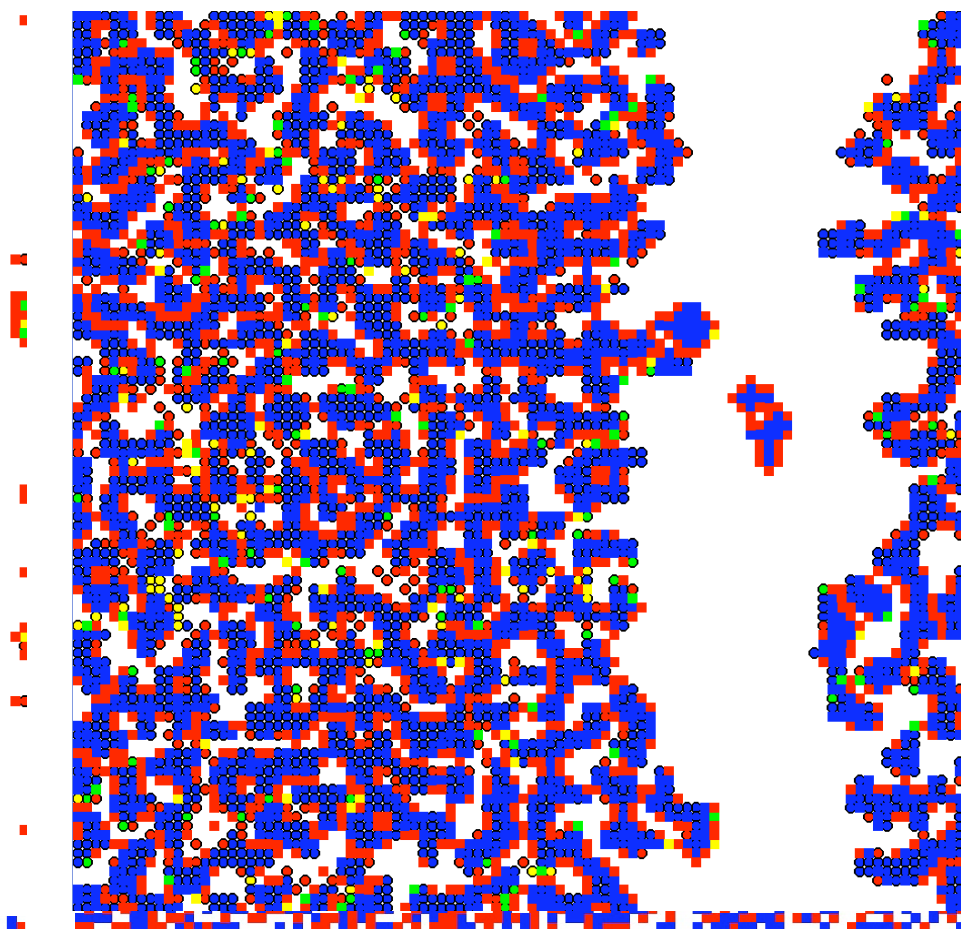
- **Cultures** refer to a set of symbols and meanings, including values and norms. They are regionally different.
- What may happen, if **two populations** with different, partially incompatible cultures start to **mix** (if we allow for migration)?
- **Unilateral adaptation, mutual adaptation, conflict, segregation**, or a combination of them?

Some Preliminary Results

Wealth Gap



Education Gap



blue = cooperator, red = defector, yellow = turned to defection, green = turned to cooperation

Summary, Discussion and Outlook

- Simple models can produce complex behavior and promise to gain surprisingly interesting insights into the mechanisms underlying socio-economic systems
- Linear models do not allow to explain emergent self-organization phenomena
- The representative agent (mean field) approach is misleading
- Considering time-dependence, spatial interactions, and heterogeneity lead to different conclusions regarding the behavior of socio-economic systems
- Puzzles such as the occurrence of cooperation among selfish individuals (the victory of cooperators over free-riders) or the establishment of costly punishment (or the disappearance of second-order free-riders) are naturally resolved
- Mobility is essential for the co-evolution of social environment and social behavior
- It seems possible to formulate a unified model describing (1) the breakdown of cooperation, (2) the coexistence of different behaviors (subcultures), (3) the evolution of commonly shared behaviors (norms), and (4) the occurrence of social polarization or of revolutions.
- Globalization seems to endanger social cooperation. Are we on the way to a punishment society or to a reputation society?

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Thank you for your interest!

Any questions?

