



Research at the Chair of Sociology, in particular of Modeling and Simulation

Dirk Helbing

with Michael Mäs, Karsten Donnay, Stefano Balietti,
and many others

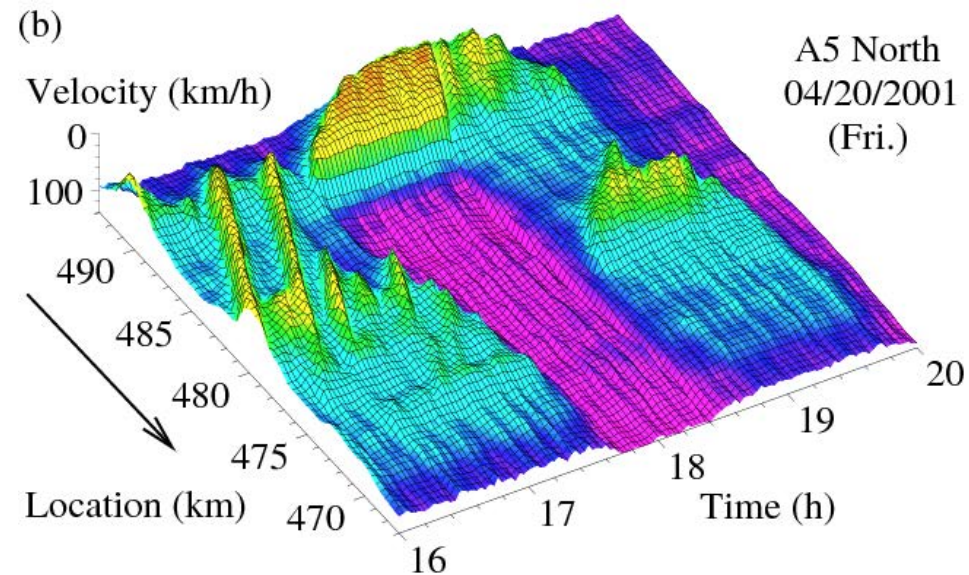
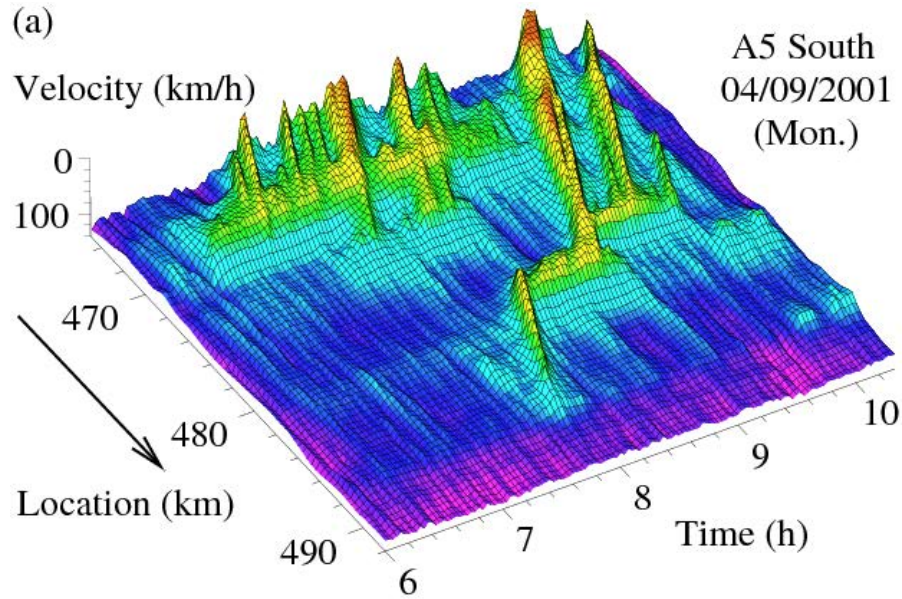


Understanding the Complexity of Traffic Dynamics on Freeways

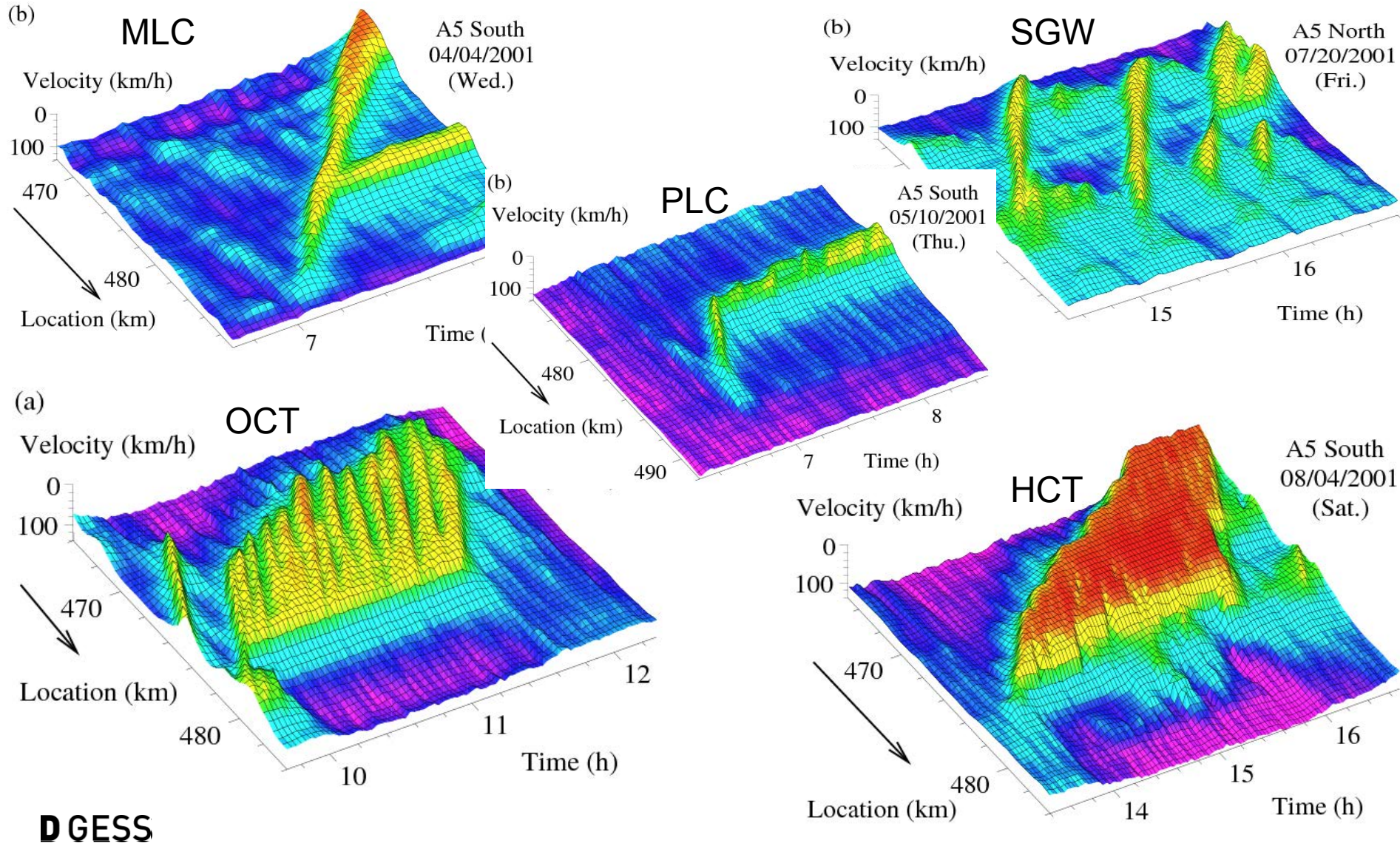
Dirk Helbing

with Martin Treiber, Arne Kesting,
Stefan Lämmner, Martin Schönhof, and others

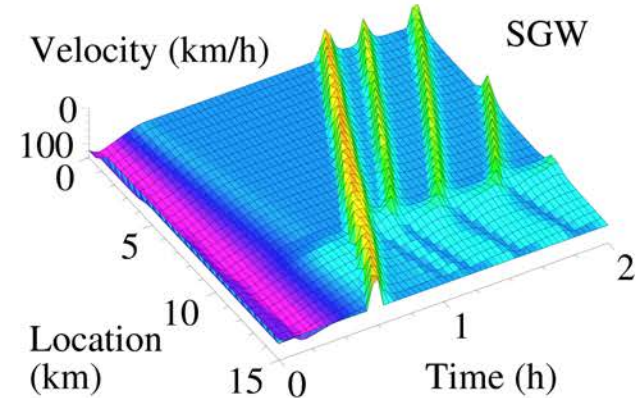
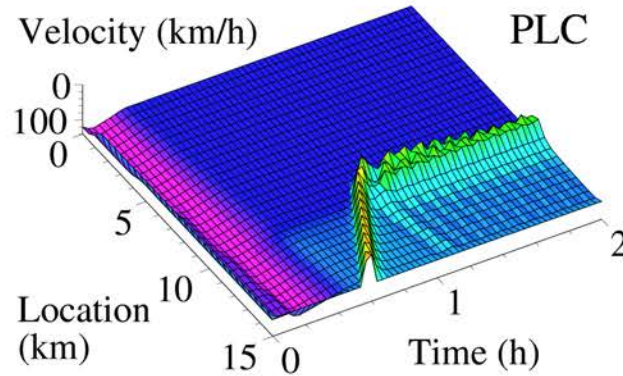
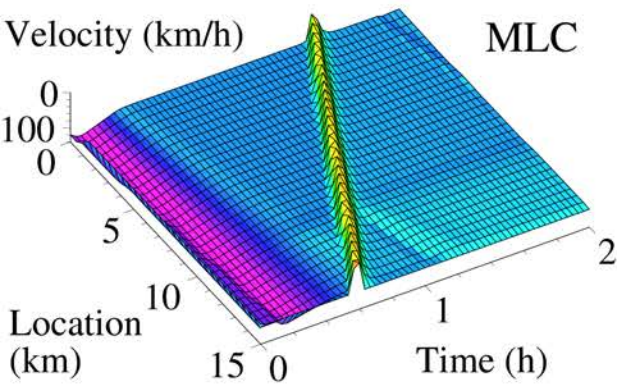
Complexity of Congestion Patterns



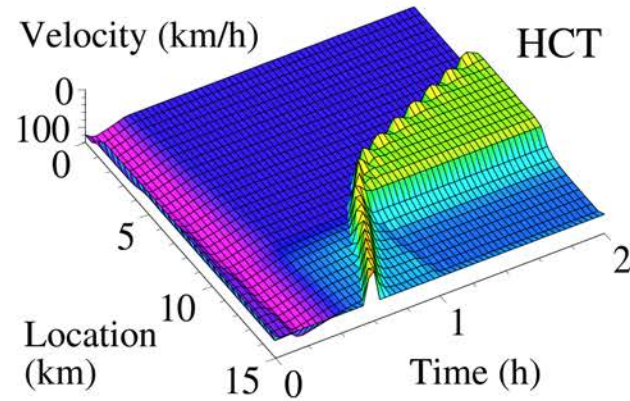
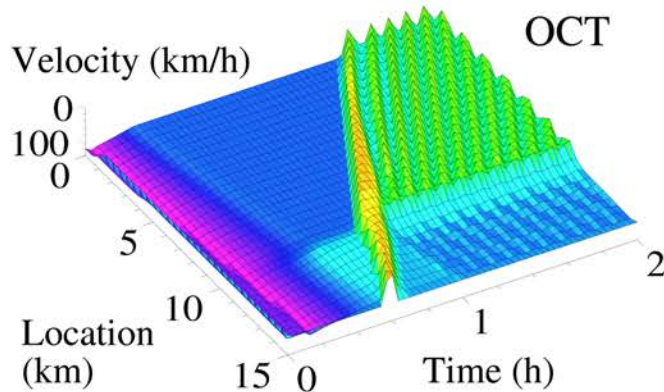
Surprising Variety of Congestion Patterns



Computer Simulated Congestion Patterns

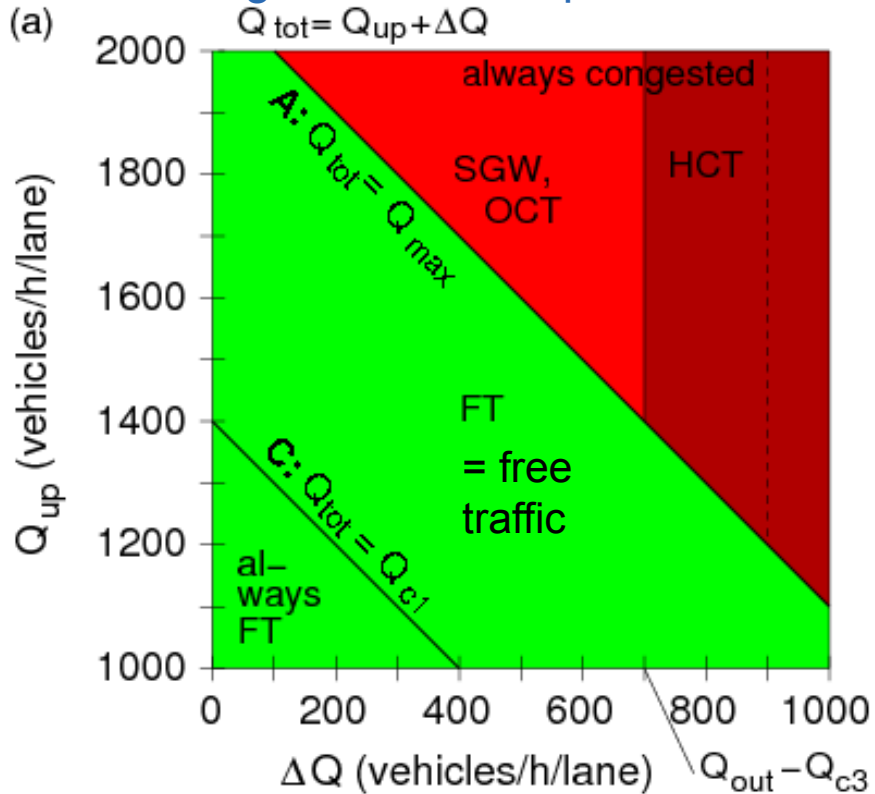


Phys. Rev. Lett. **82**,
4360
(1999).

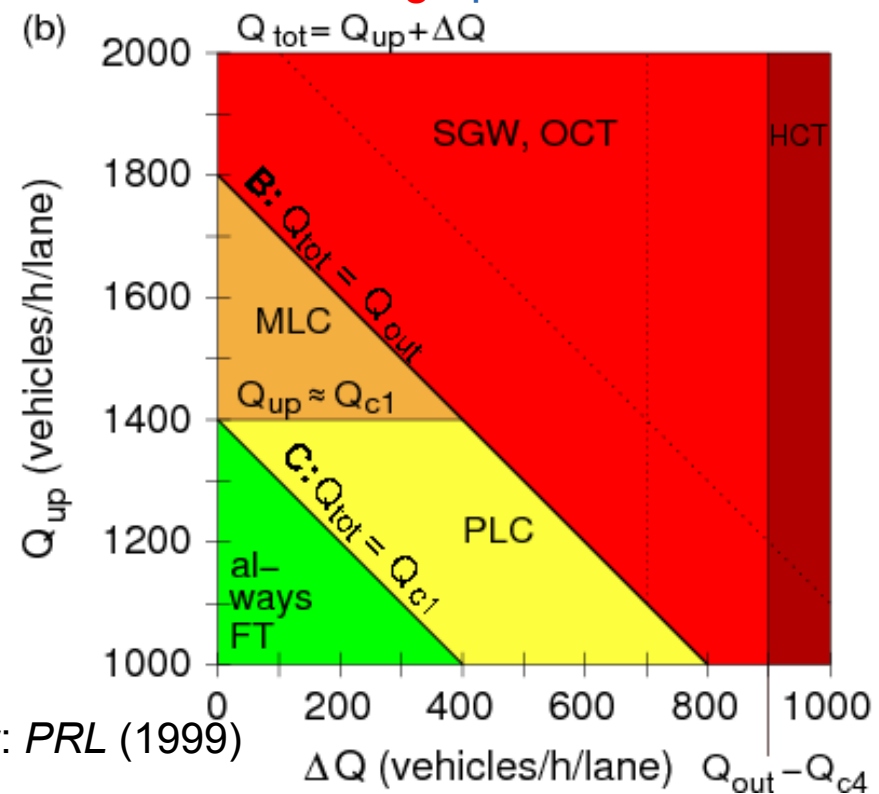


Phase Diagram of Traffic States and Universality Classes

Phase diagram for **small** perturbations

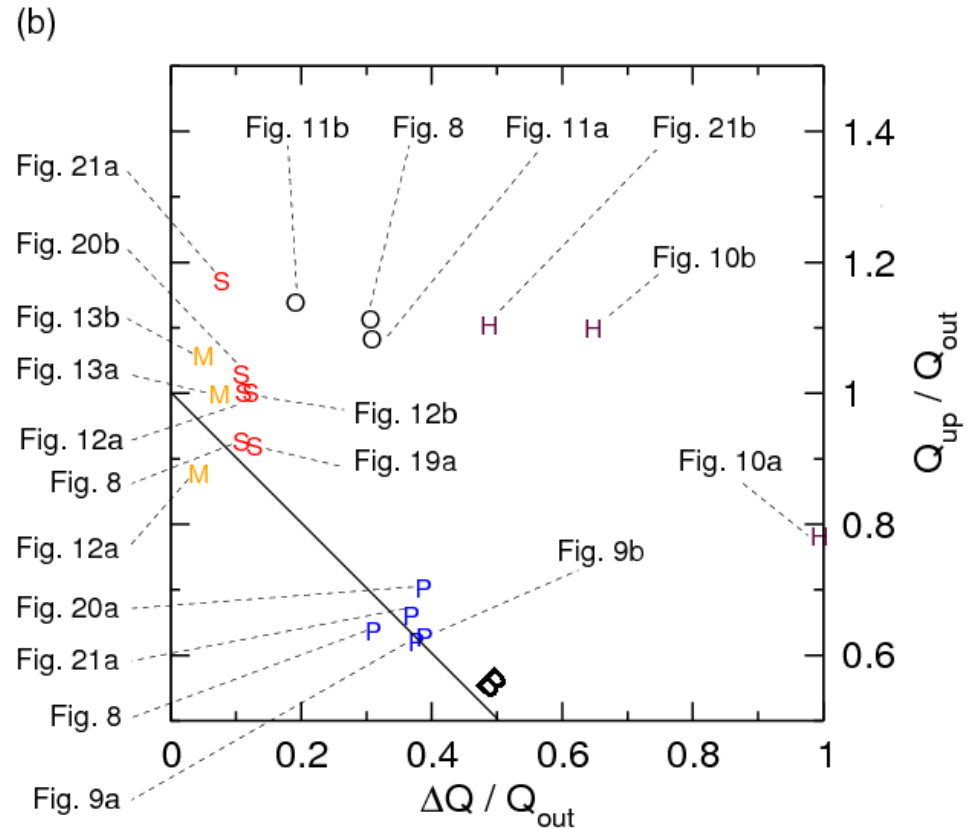
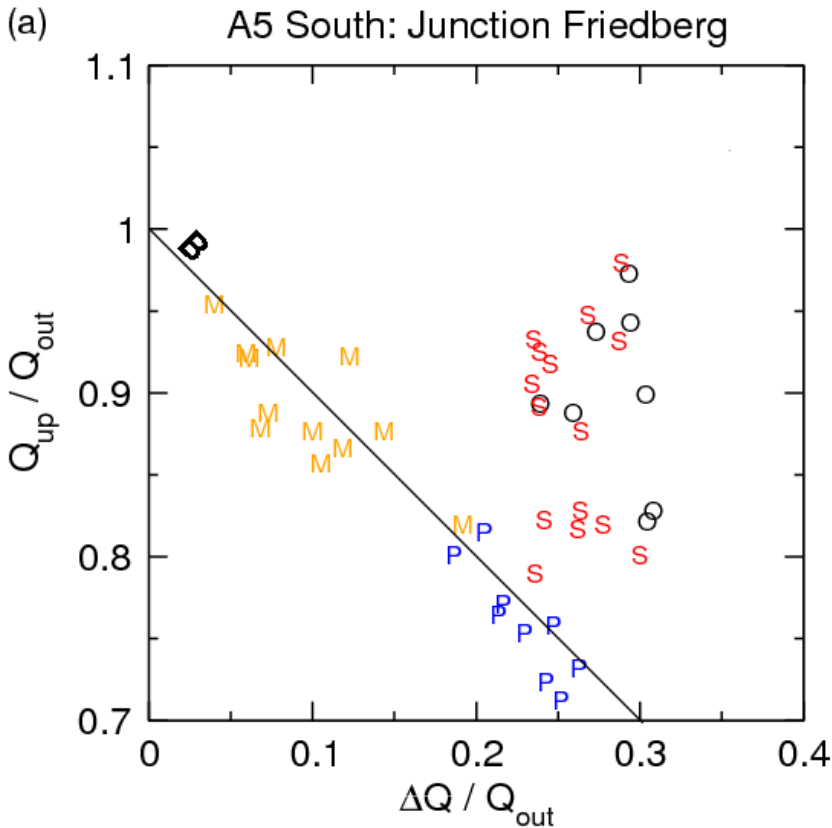


for **large** perturbations



After: PRL (1999)

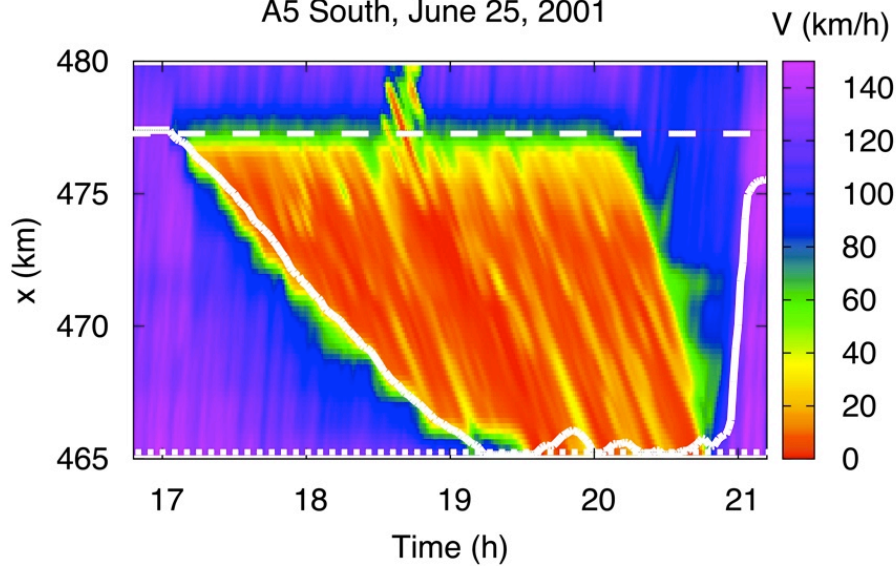
Empirical Phase Diagram



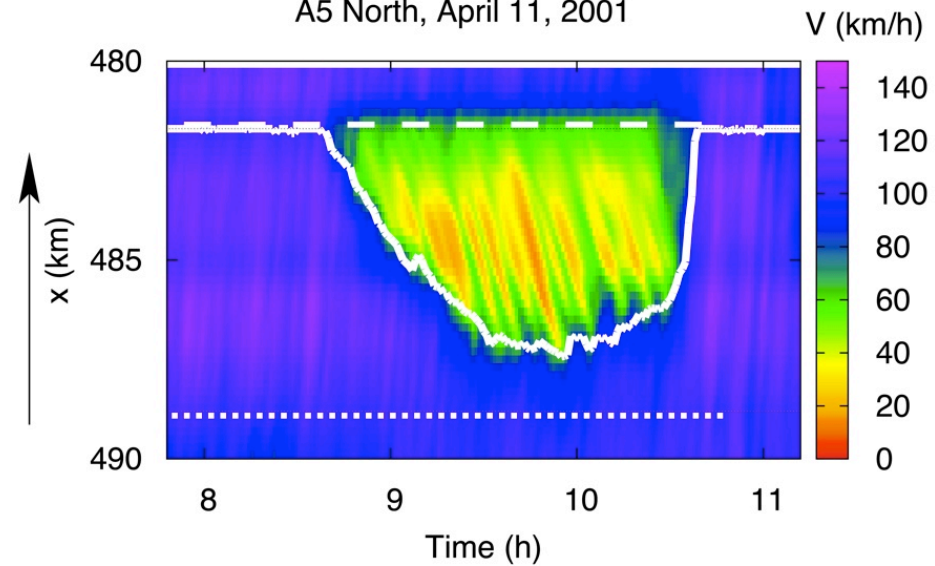
M = MLC = moving localized cluster, P = PLC = pinned localized cluster
 O = OCT = oscillating congested traffic, S = SWG = stop-and-go waves
 H = HCT = homogeneous congested traffic

Traffic Congestion and Travel Times Are Predictable

A5 South, June 25, 2001



A5 North, April 11, 2001





Pedestrian, Crowd, and Evacuation Dynamics

Dirk Helbing

with Anders Johansson, Wenjian Yu, Mehdi Moussaid,
Illes Farkas, Peter Molnar, Tamas Vicsek and others

Lane Formation in Pedestrian Counterflows



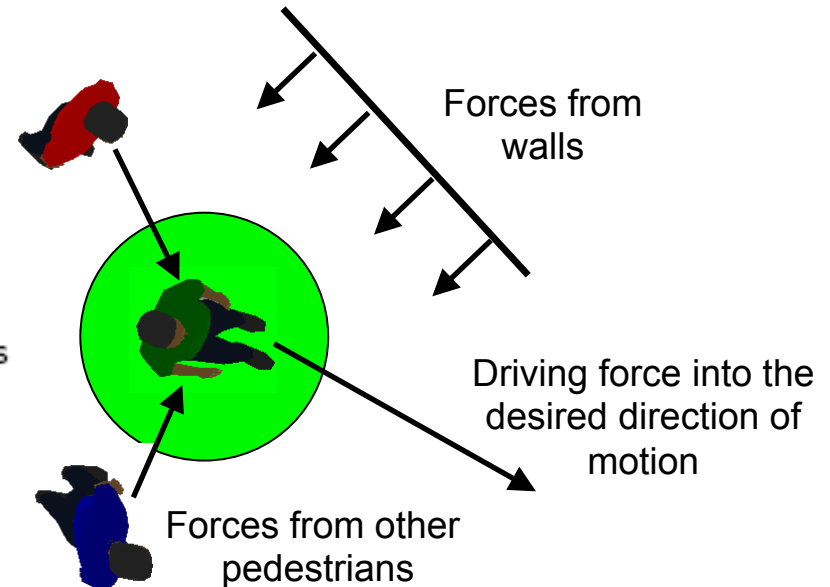
The Social Force Model

The social force model assumes **individual goals** (to reach a certain destination efficiently), **social interactions** (e.g. avoidance of collisions), and **institutional setting** (e.g. walls).

$$\frac{dx_\alpha}{dt} = v_\alpha(t) \quad (\text{equation of motion})$$

$$\underbrace{\frac{dv_\alpha}{dt}}_{\text{acceleration}} = \underbrace{\frac{1}{\tau_\alpha}(v_\alpha^0 e_\alpha^0 - v_\alpha)}_{\text{driving force}} + \underbrace{\sum_{\beta(\neq\alpha)} F_{\alpha\beta}^{\text{int}}}_{\text{interactions}} + \underbrace{F_\alpha^{\text{walls}}}_{\text{boundaries}}$$

(acceleration equation)



Experimental Study of Individual Avoidance Behavior



Avoidance of a static pedestrian

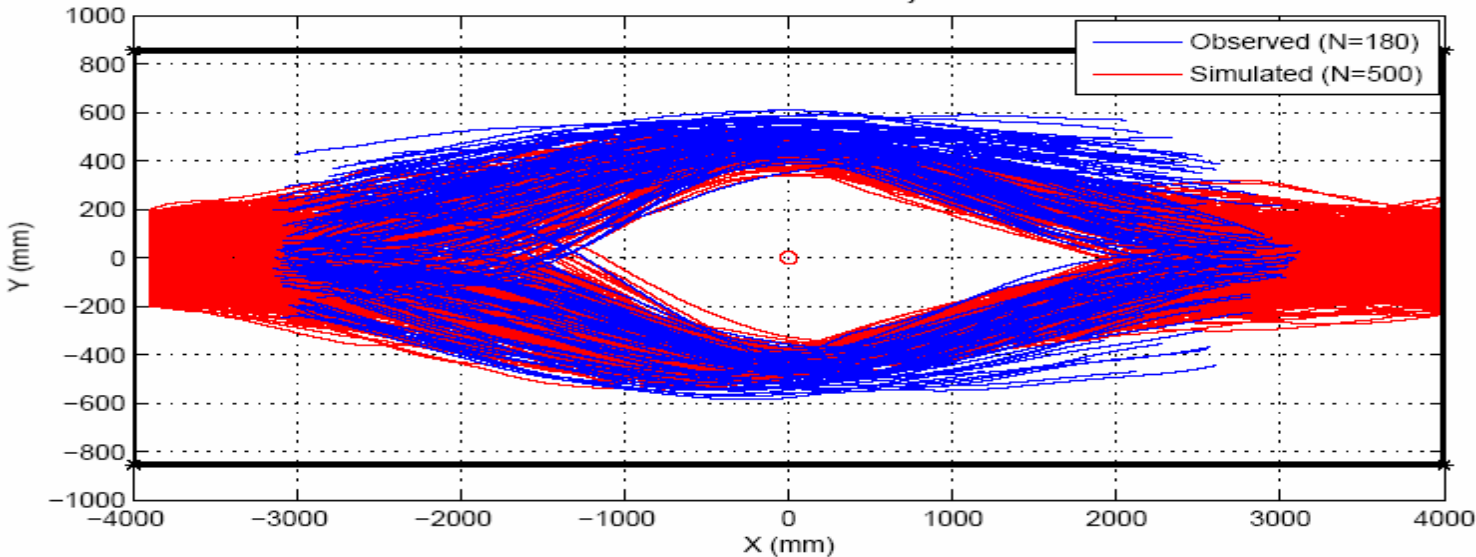


Avoidance of a moving pedestrian

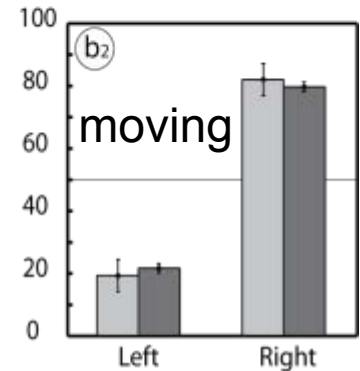
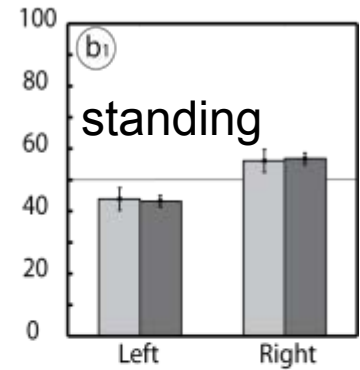
Validation 1: Corridor Experiment

Observed and simulated pedestrian trajectories

Observed and simulated trajectories



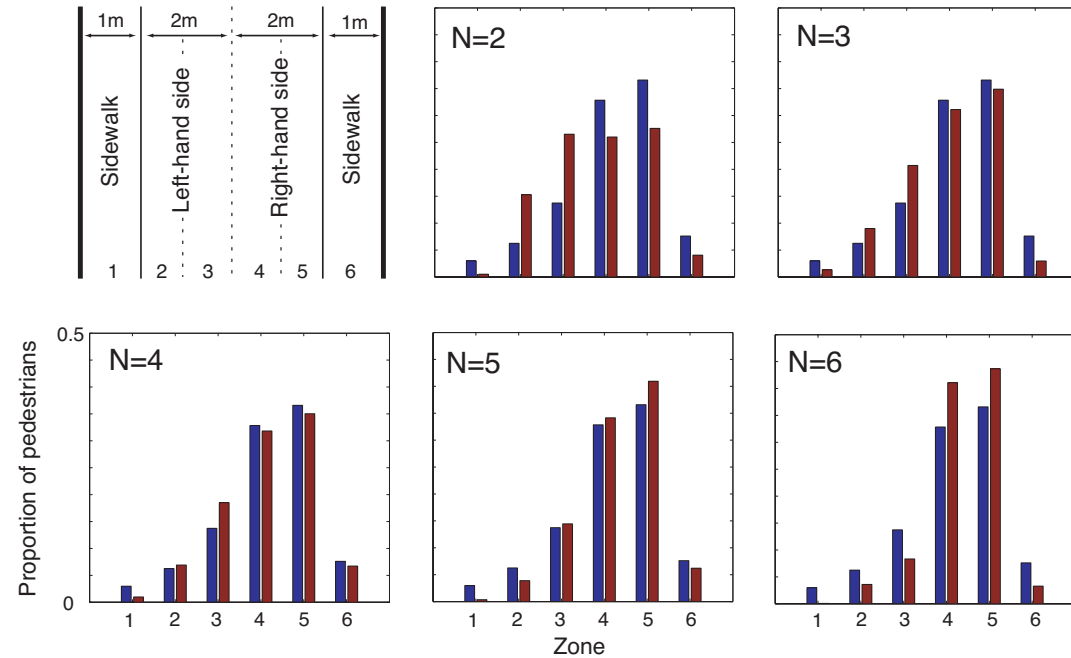
preferred avoidance side



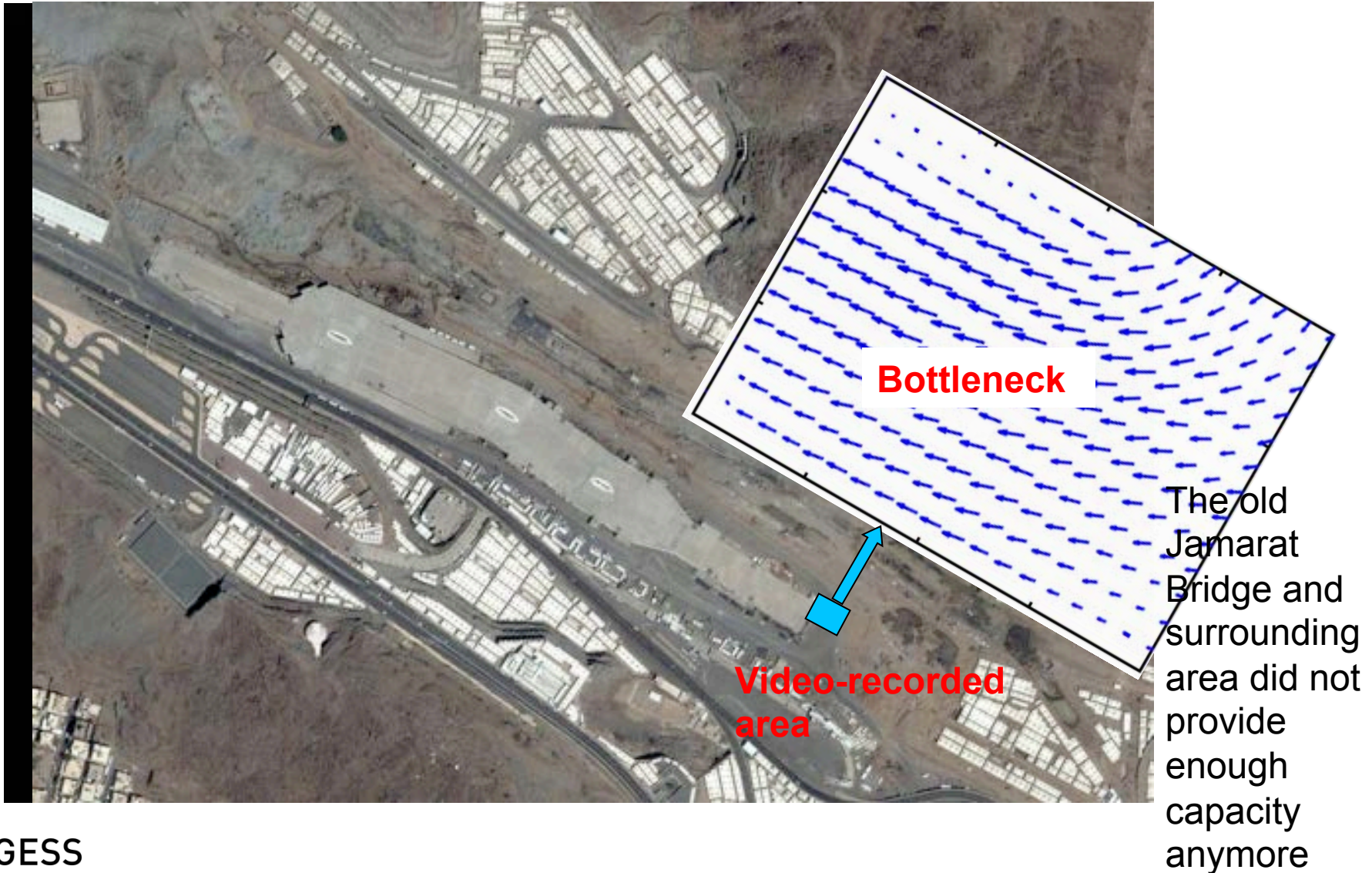
Validation 2: Collective Dynamics



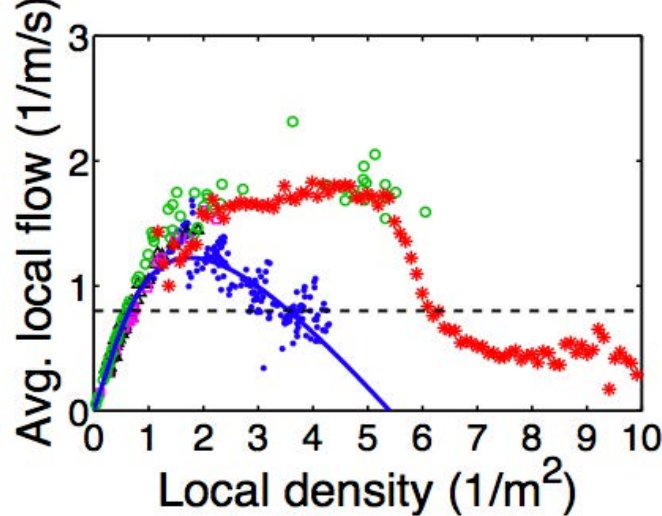
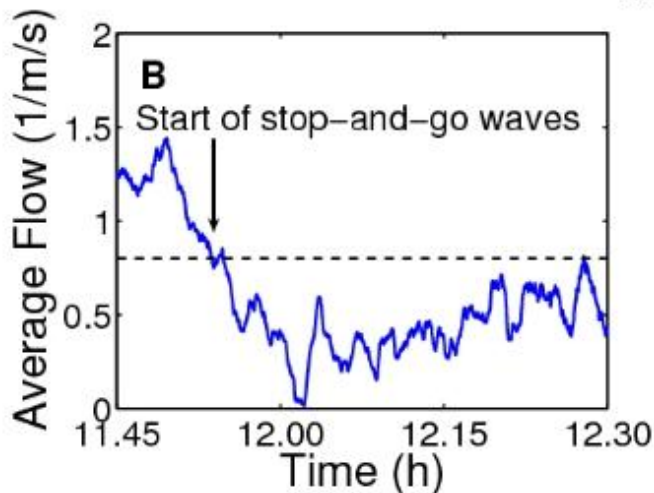
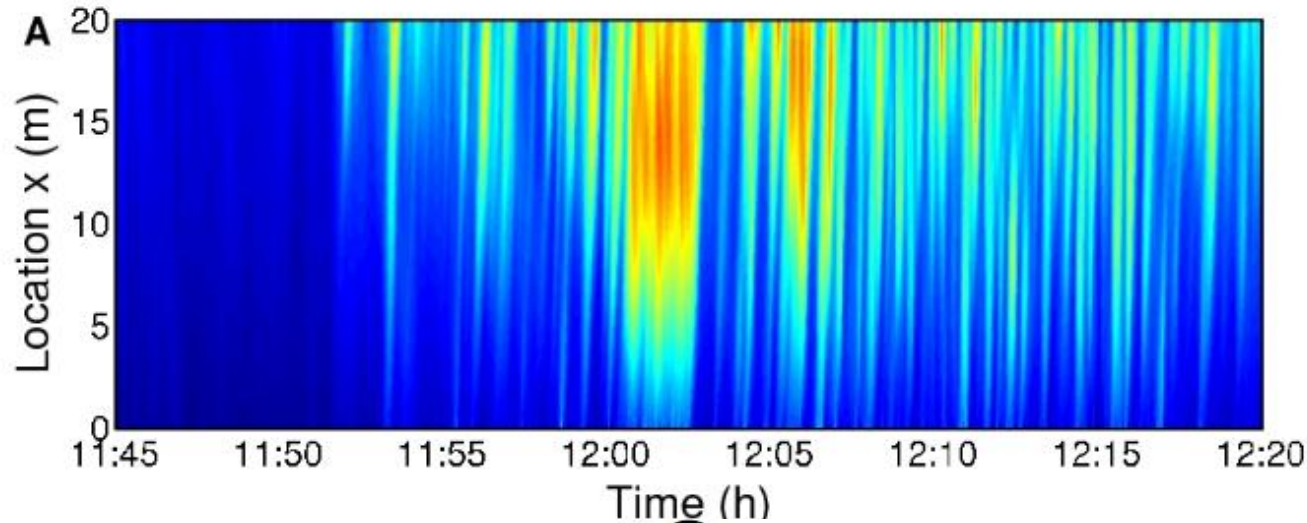
Observations in a crowded street



The Jamarat Bridge (as of January 2006)

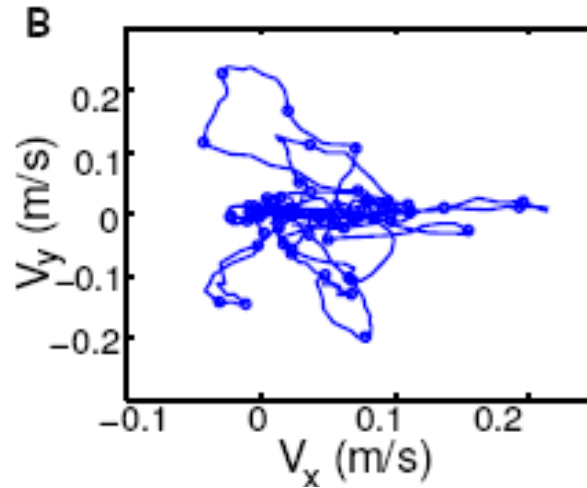
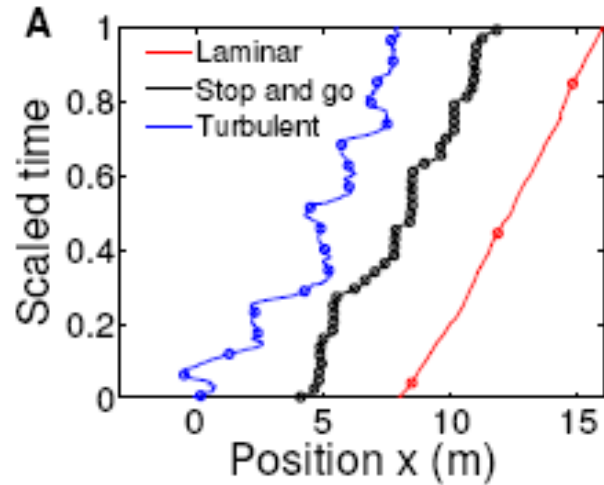


Transition from Smooth to Stop-and-Go Flow

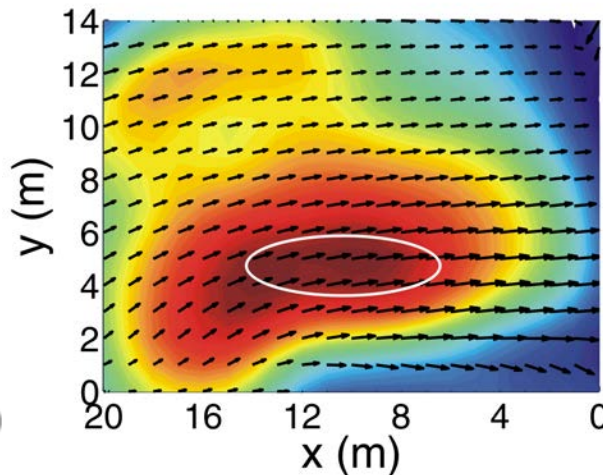
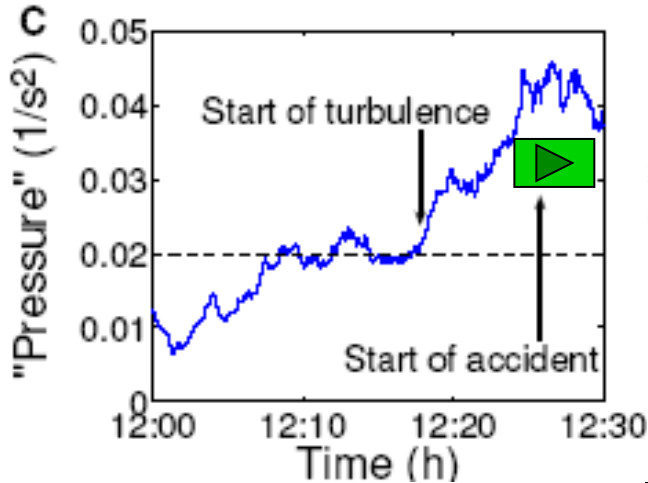


Mechanism is very different from stop-and-go waves in vehicle traffic!

Transition from Stop-and-Go Flow to “Crowd Turbulence”



The density times the variation in speeds constitutes the hazard!
Pressure fluctuations cause turbulent motion and potentially the falling and trampling of people.



Increased driving forces occur in crowded areas when trying to gain space, particularly during “crowd panic”

The Change in Organization from 2006 to 2007



2006: Large accumulations, dense crowds, and long exposure times to intensive sun.

2007: **Unidirectional and smooth flows.**

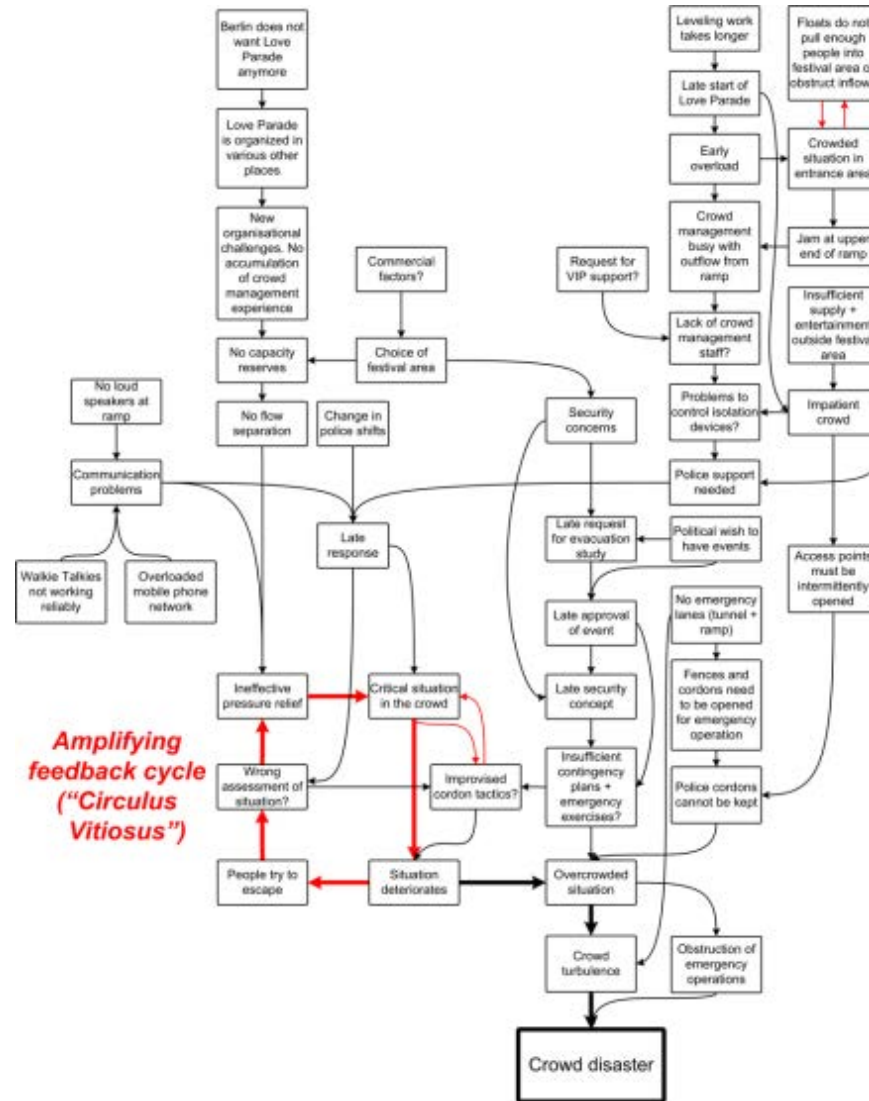
Pilgrims liked and supported the new organization.



Everyone Was Happy with the Result



Crowd Disasters as Systemic Failures



Crowd Turbulence as Final Cause of the Love Parade Disaster





The Micro-Macro Problem

Dirk Helbing
and Michael Mäs

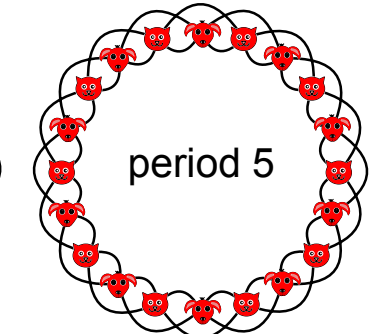
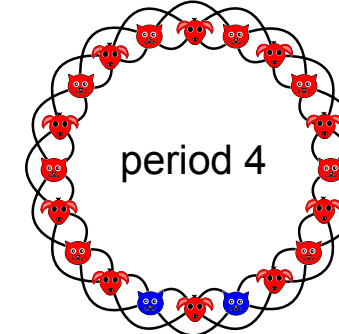
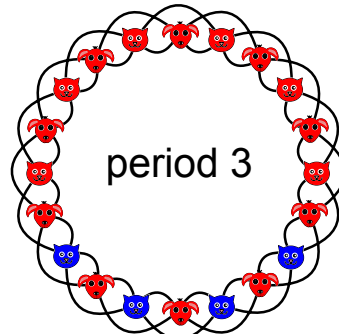
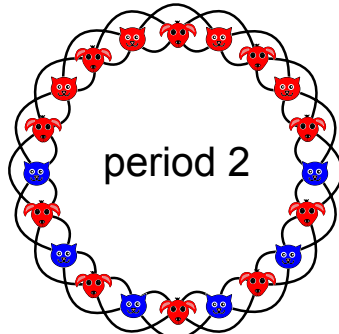
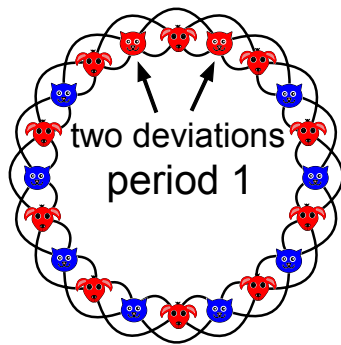
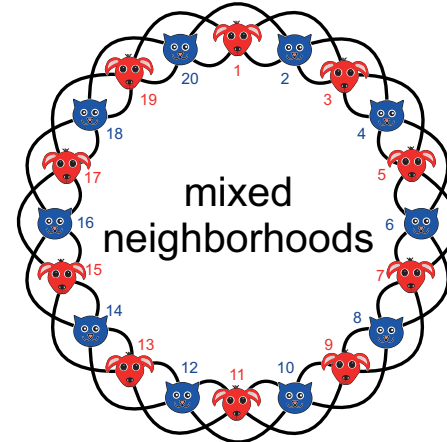
“The whole is more than the sum of its parts”

The “whole does not equal the sum of its parts; it is something different, whose properties differ from those displayed by the parts from which it is formed.” (Durkheim 1982:128)

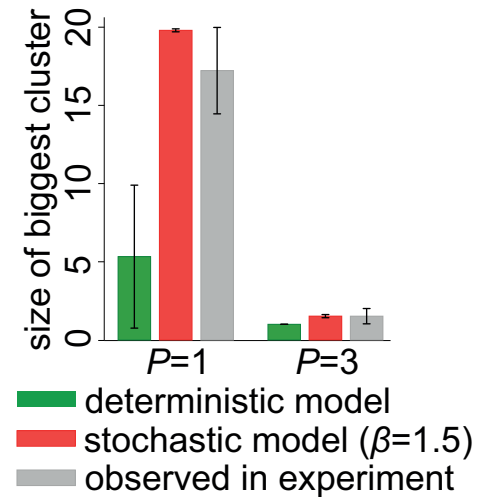
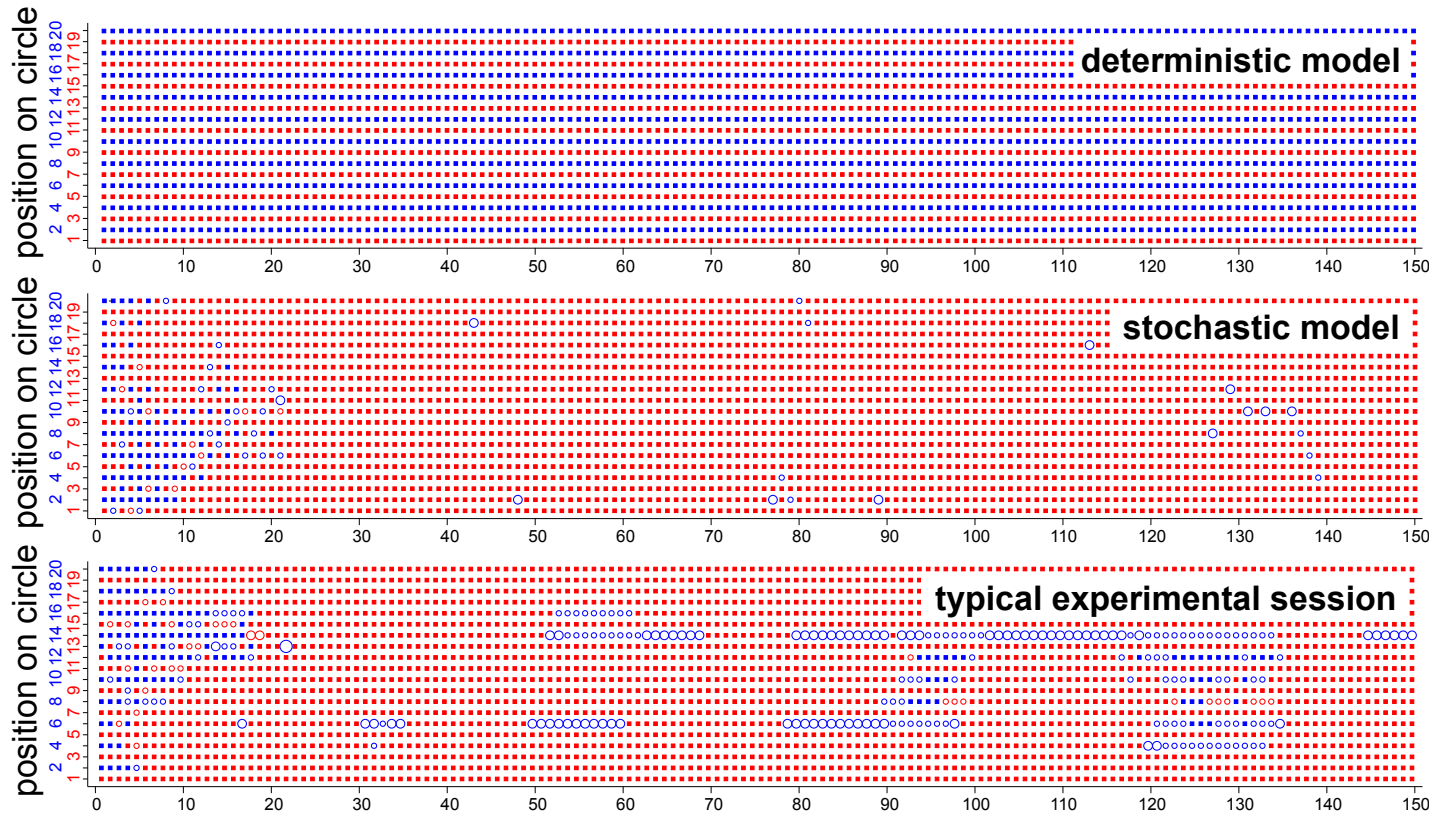
“The determining cause of a social fact must be sought among antecedent social facts and not among the states of the individual consciousness.” (Durkheim 1982:134)



Noise on the Micro-Level Can Affect Macro-Level



To Understand Macro-Level Outcomes of Decision-Making, Noise Must Be Considered





Opinion Formation: Differentiation and Cultural Diversity

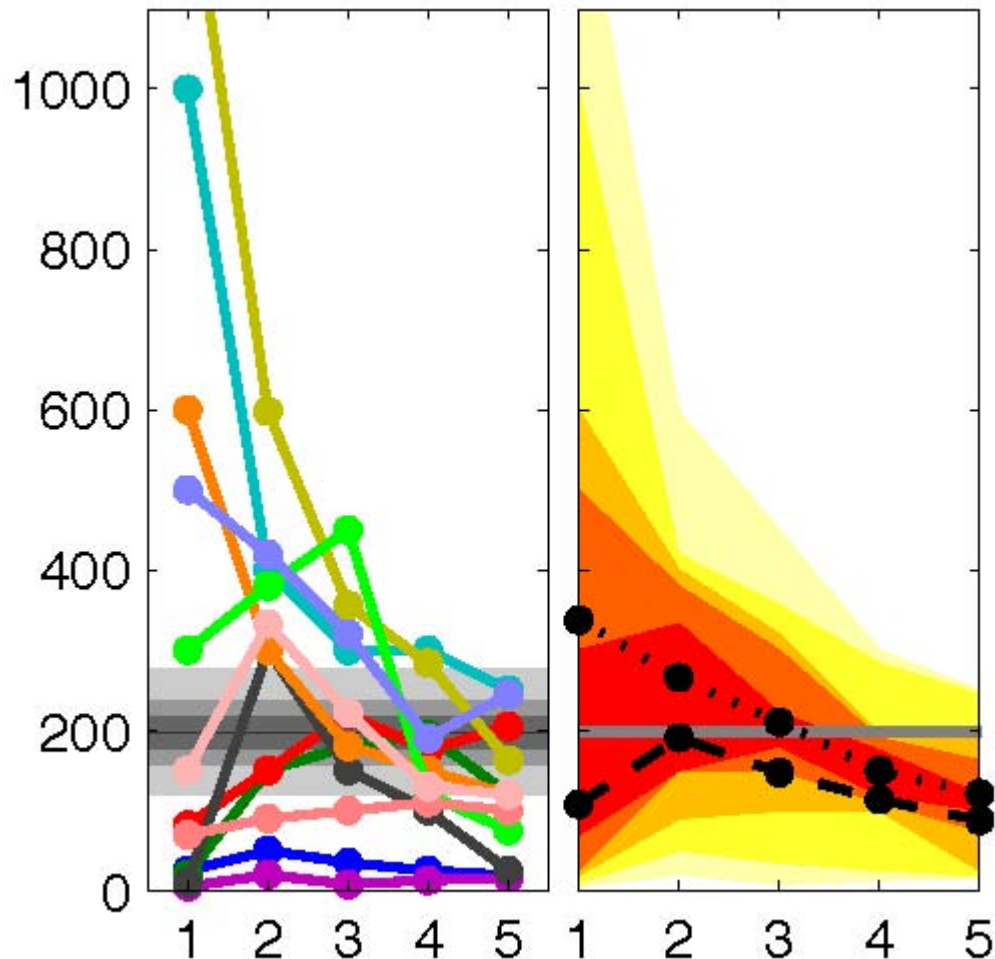
Dirk Helbing

with Michael Mäs, Andreas Flache, Heiko Rauhut,

Jan Lorenz, Frank Schweitzer

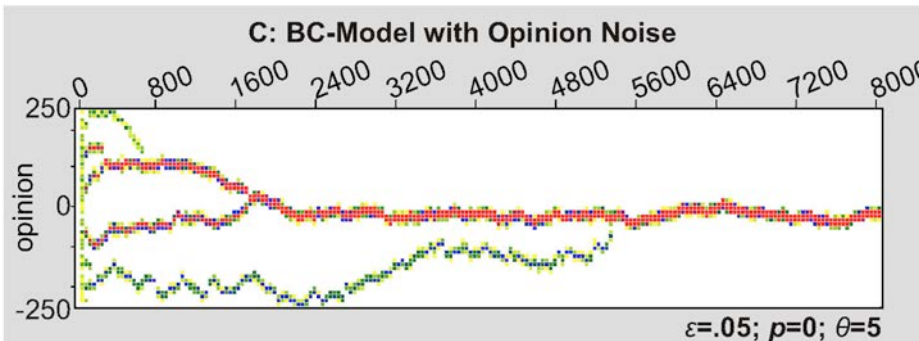
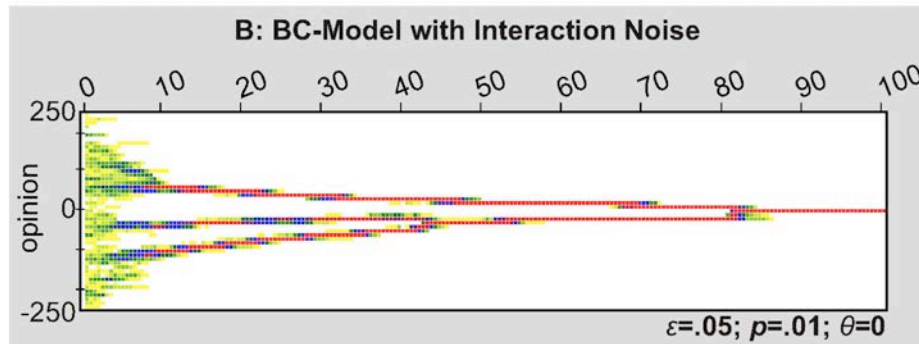
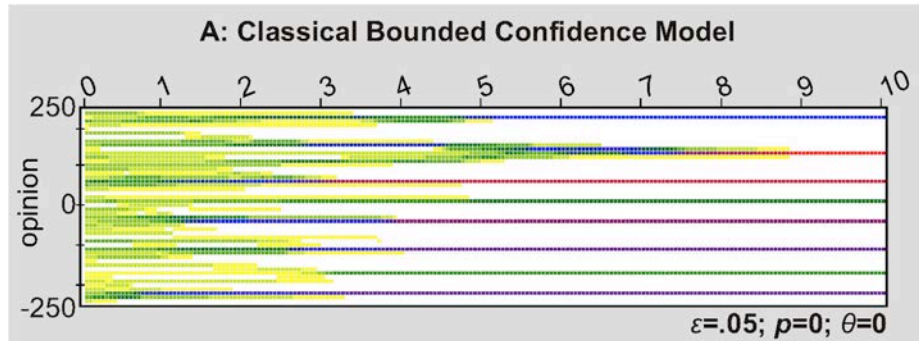
and others

Social Influence Causes Convergence of Beliefs



PNAS

Diversity despite social influence



Research questions:
Why doesn't diversity disappear,
but often increase?

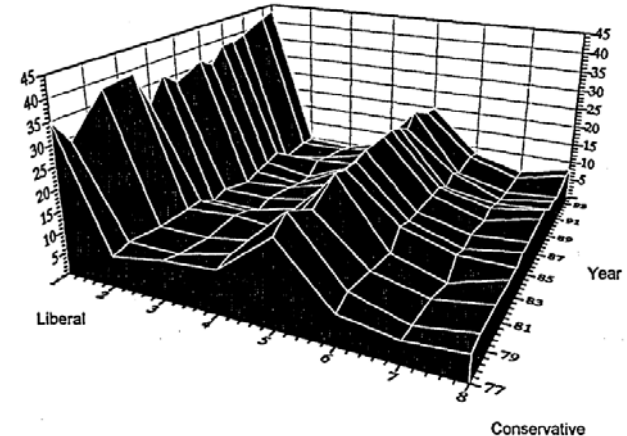
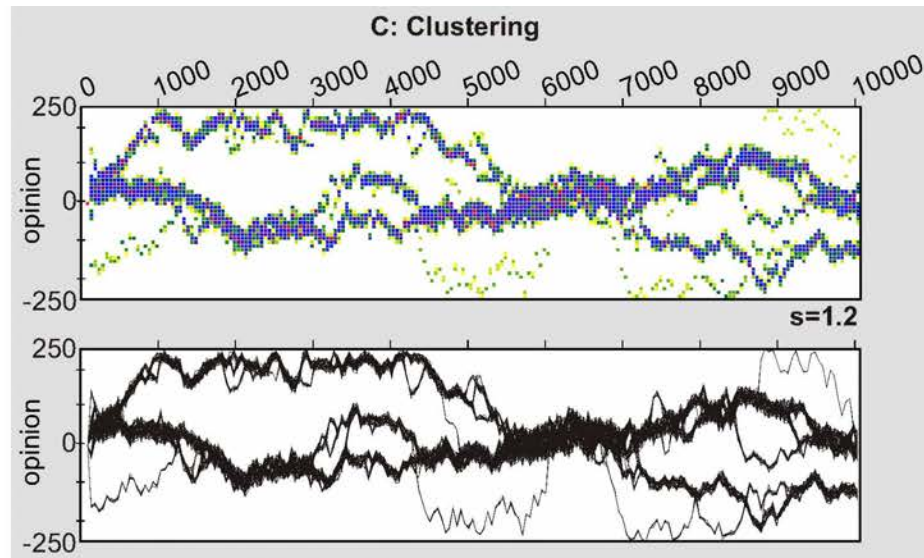
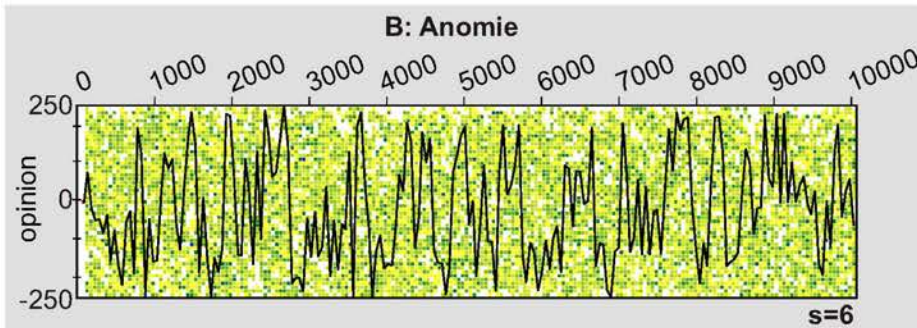
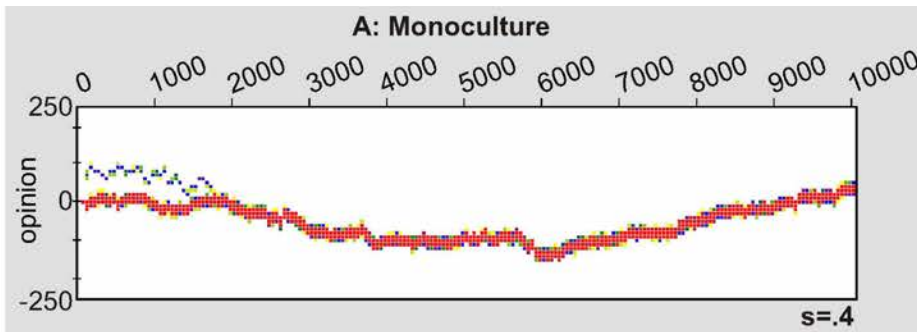


FIG. 4.—Distributions by year, attitudes toward abortion, full sample, GSS 1977-94.

A Classical Theory Guides the Way to the Answer

“...there is in the consciousness of each one of us two consciousnesses: one that we **share in common** with our group in its entirety ... the other that makes us an **individual**. Here there are two opposing forces, the one centripetal, the other centrifugal” (Durkheim 2003a: 258-259)





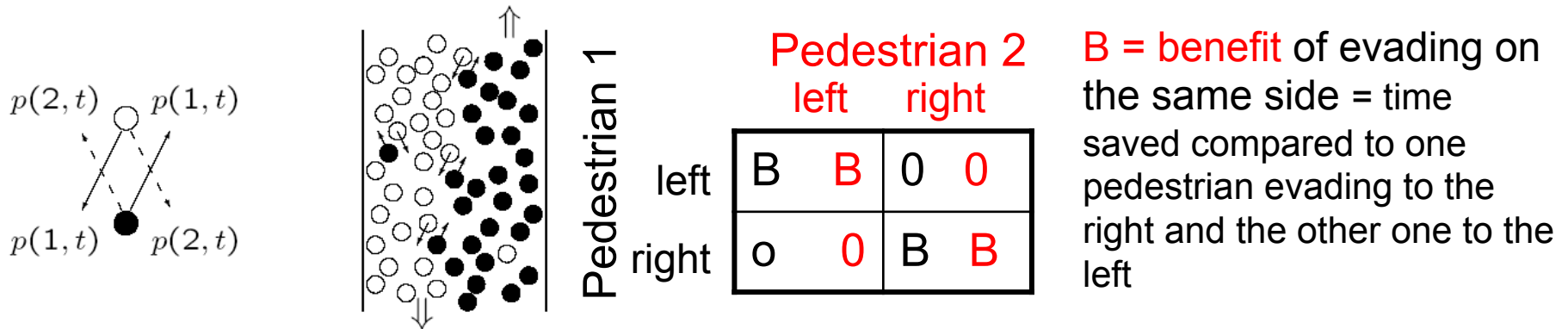
Modeling the Breakdown and Emergence of Coordination or Cooperation

Dirk Helbing

with Thomas Chadeaux, Wenjian Yu, Thomas Grund, Christian Waloszek,
Carlos Roca, Sergi Lozano, Matjaz Perc, Attila Szolnoki,
and others

Self-Organization of A Behavioral Convention

The result of a social interaction between two individuals is characterized by the “payoff”

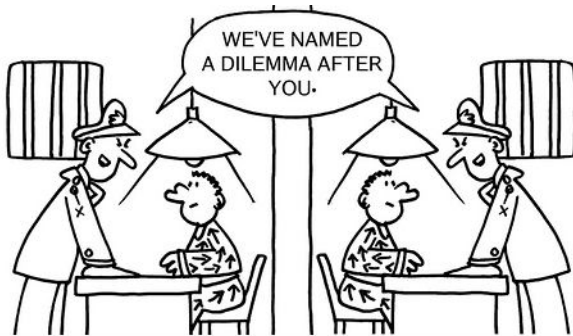


$$dp(i,t)/dt = -2rB[p(i,t)-1/2] p(i,t) [1-p(i,t)] \quad i=1: \text{right}, i=2: \text{left}$$

Only the stationary solutions $P(i,t)=0$ or 1 are stable, i.e. one evading side will become a **behavioral convention** (Helbing, 1990, 1991, 1992; Young 1993)

The Prisoner's Dilemma

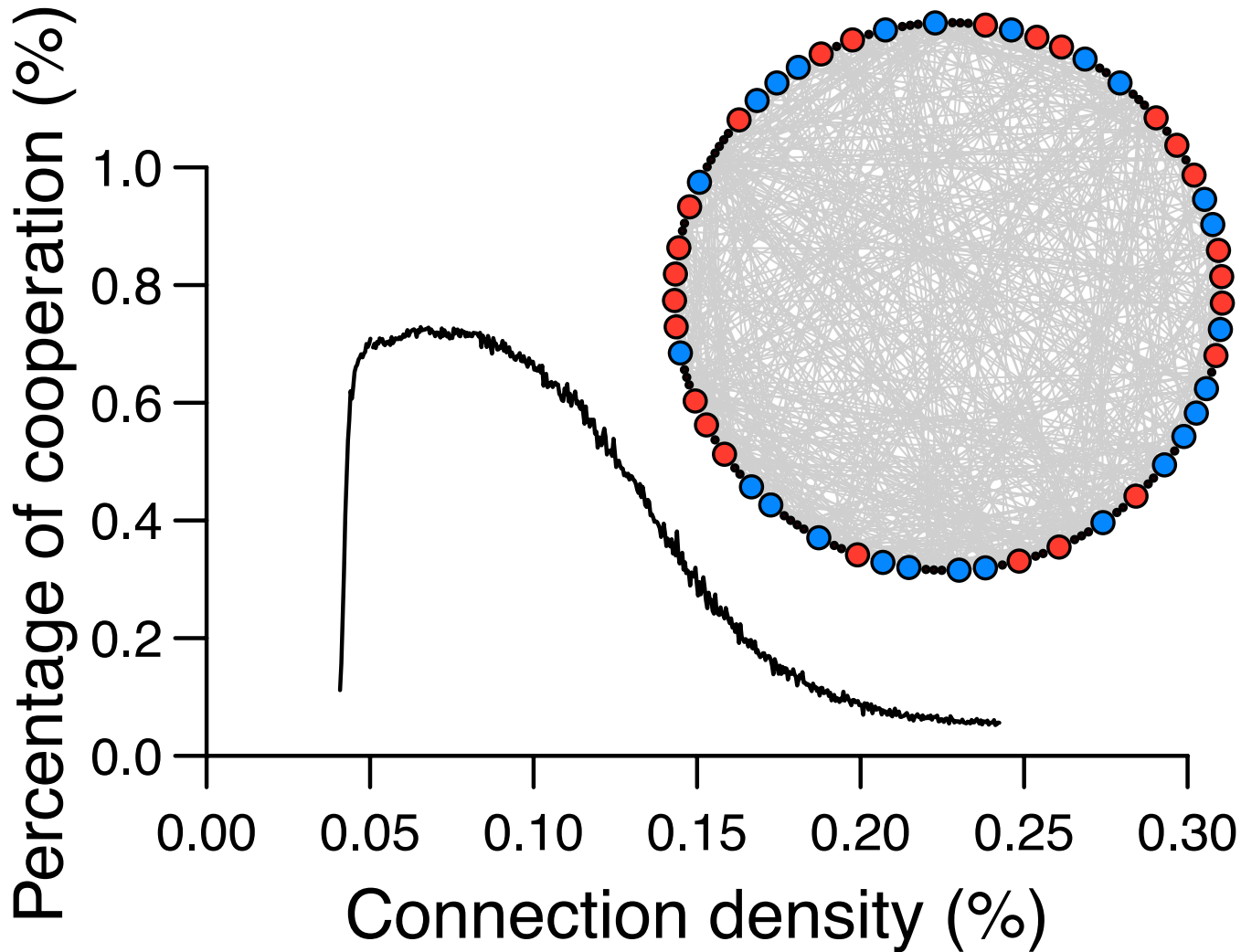
The prisoner's dilemma assumes that, when two individuals cooperate, both get the “reward” R , while both receive the “punishment” $P < R$, if they defect. If one of them cooperates (“C”) and the other one defects (“D”), the cooperator suffers the “sucker’s payoff” $S < P$, while the payoff $T > R$ for the second individual reflects the “temptation” to defect. Additionally, one typically assumes $S + T < 2R$.



	Player 2	
	Cooperate	Defect
Cooperate	R_1 R_2	S_1 T_2
Defect	T_1 S_2	P_1 P_2

For example:
 $S_1 = S_2 = S = -5$
 $P_1 = P_2 = P = -2$
 $R_1 = R_2 = R = -1$
 $T_1 = T_2 = T = 0$

Prisoner's Dilemmas in an Increasingly Connected World



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Period: [Past 6 months](#)

Feedback	From/price	Date/time
Order arrived with postage due with no communication from seller beforehand.	Buyer: chimera-studios (27 ★)	Feb-26-13 17:02
<ul style="list-style-type: none"> • Reply by med_express_sales (Feb-28-13 04:54): Sorry- no idea there was postage due. This has happened alot from USPS lately. 		

© eBay Olympus G92104 Microscope Light Source with Shutter Attachment

US \$175.00

[View Item](#)

Pool Punishment



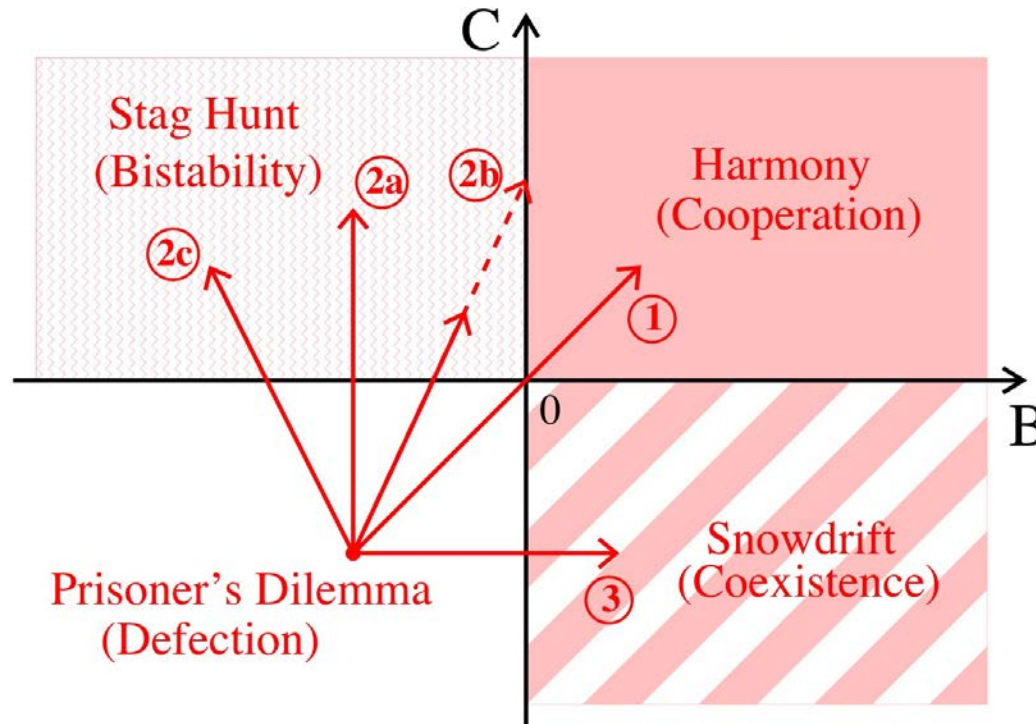
Peer Punishment



*"We're from the Neighborhood Watch committee.
We've heard you're wearing a fake Rolex."*

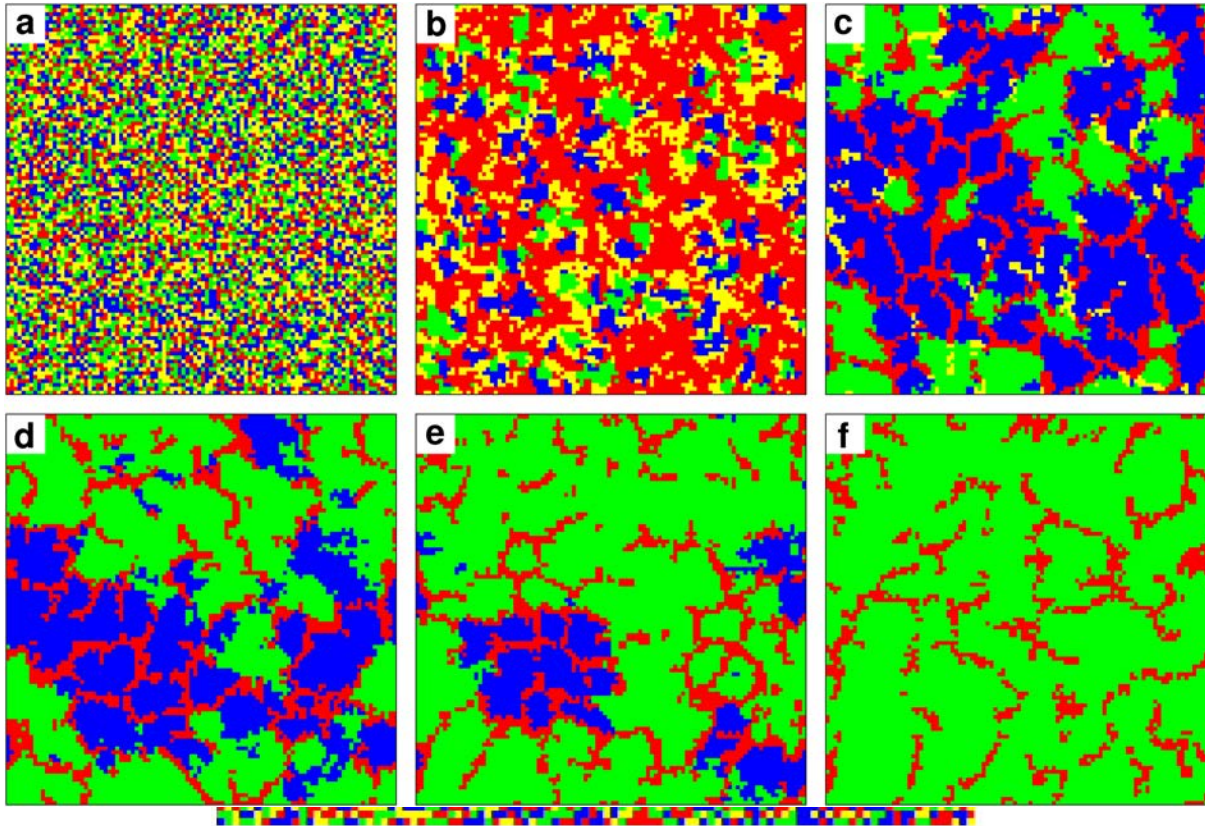
Routes to Cooperation

Routes to cooperation require to **destabilize defection** (PD \rightarrow SD) or to **stabilize cooperation** (PD \rightarrow SH) or both (PD \rightarrow HG)



Route 1: Kin selection **2a:** Direct reciprocity, **2b:** Indirect reciprocity, **2c:** Costly peer punishment, **3:** Network interactions

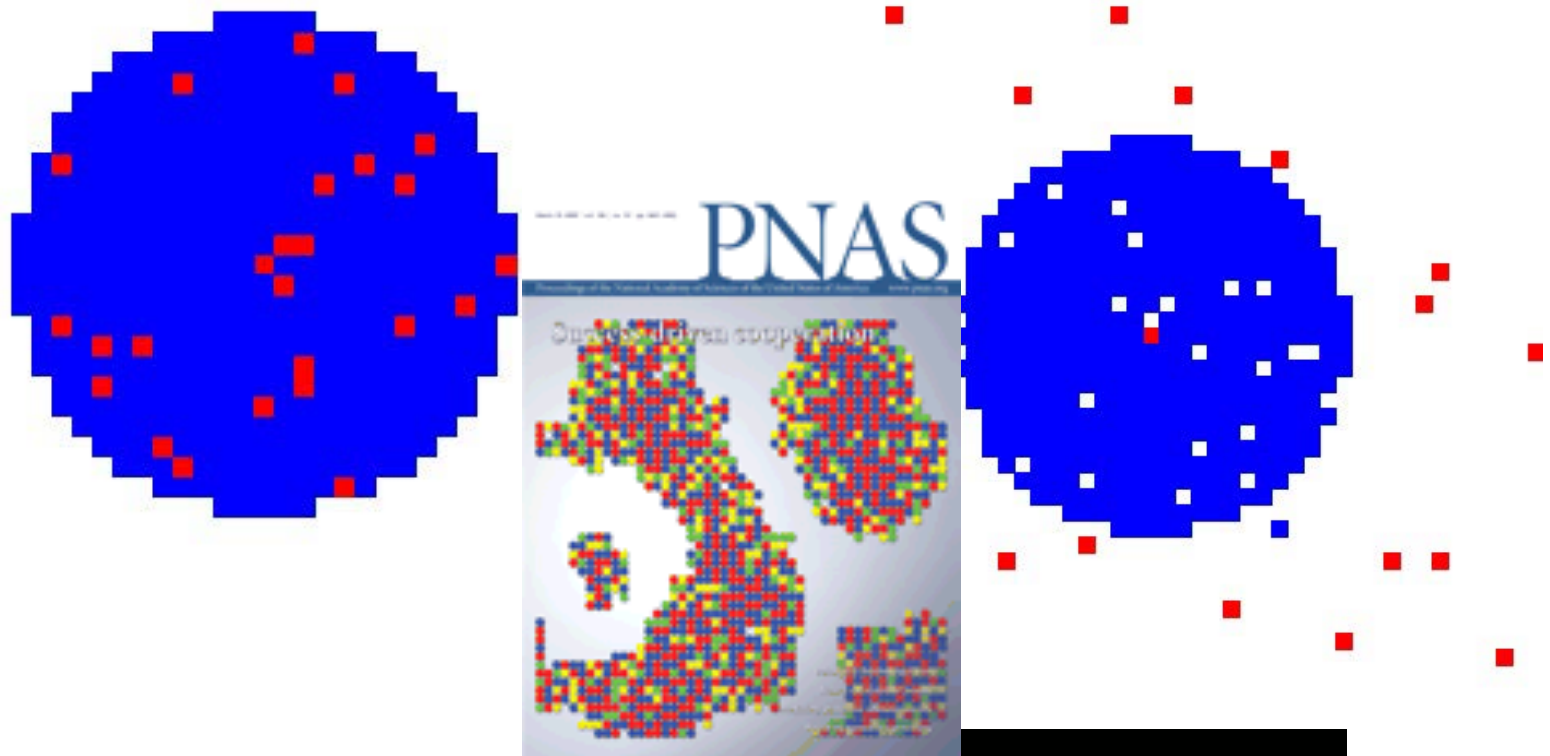
How Second-Order Free-Riders Are Eliminated and Punishment Spreads



D = Defectors (free-riders), M = Moralists = cooperators punishing defectors, C = non-punishing Cooperators (second-order free-riders), I = Immoralists = defectors punishing other defectors

The Breakdown and Outbreak of Cooperation with Imitation, Migration, and Noise

Red, yellow: defectors (cheaters)
Blue, green: cooperators
Yellow, green: changed in last time step



Public Good Game with Mobility: Experimental Design

ETH

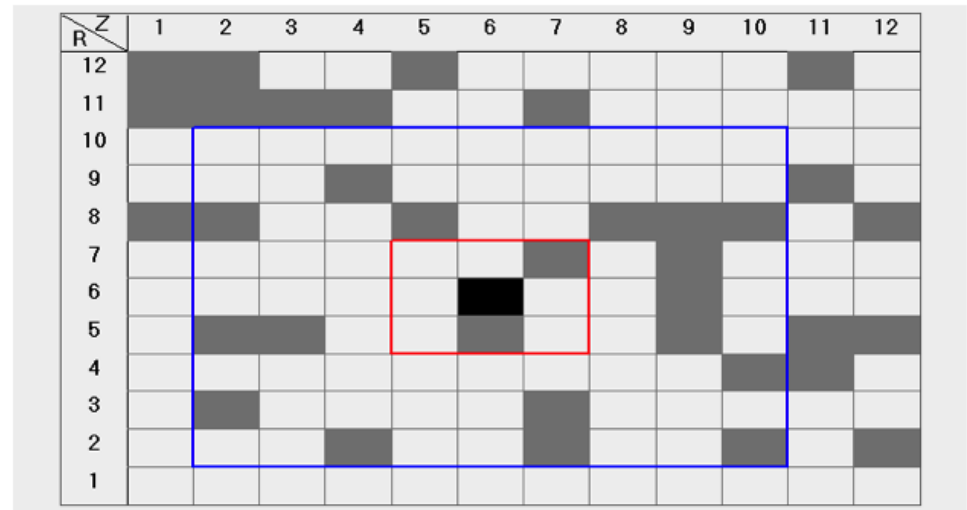
Eidgenössische Technische Hochschule Zürich
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Joint work with Carlos Roca,
 Charles Efferson and Sonja Vogt



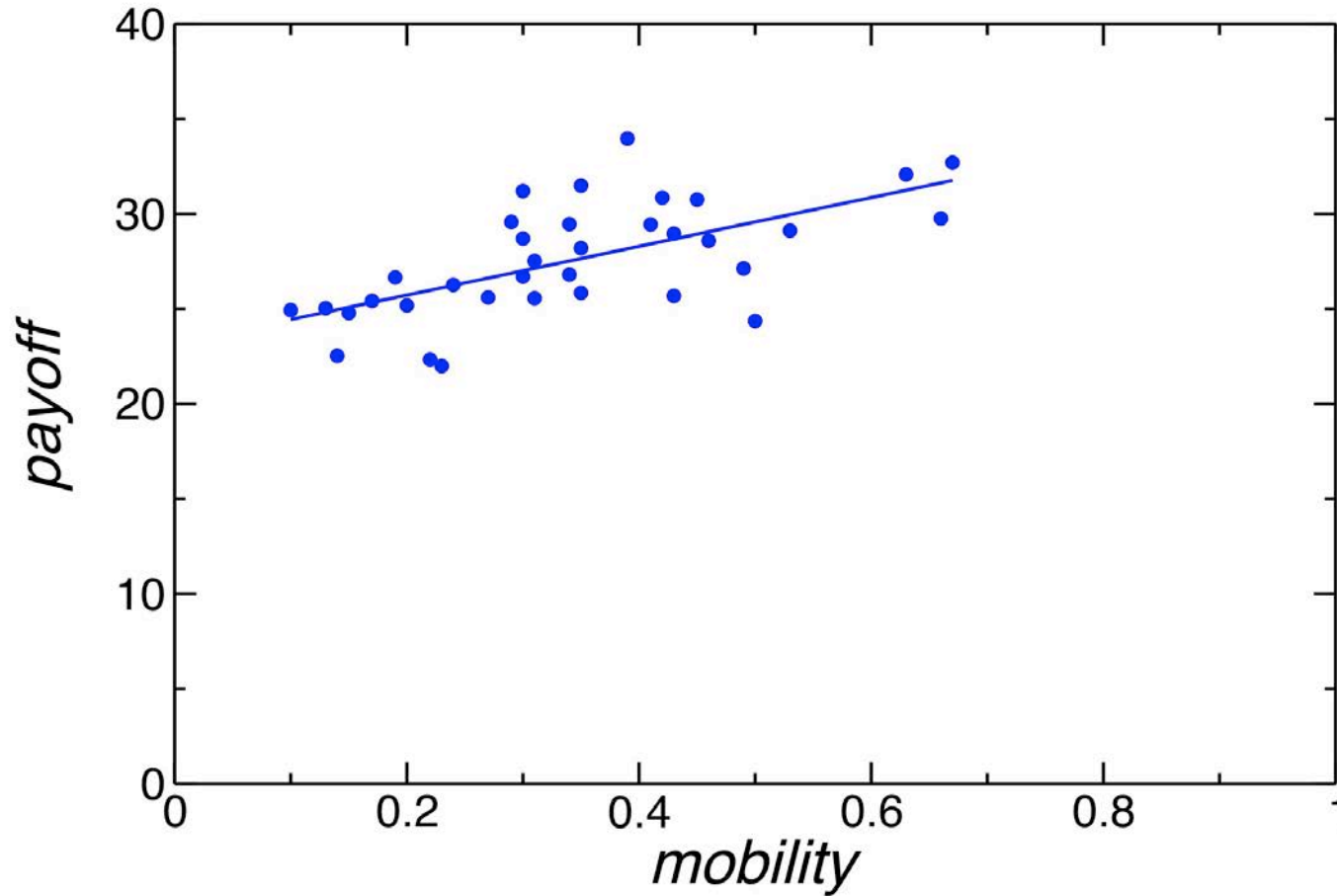
Möchten Sie gerne das Feld wechseln?

- Nein
- Ja

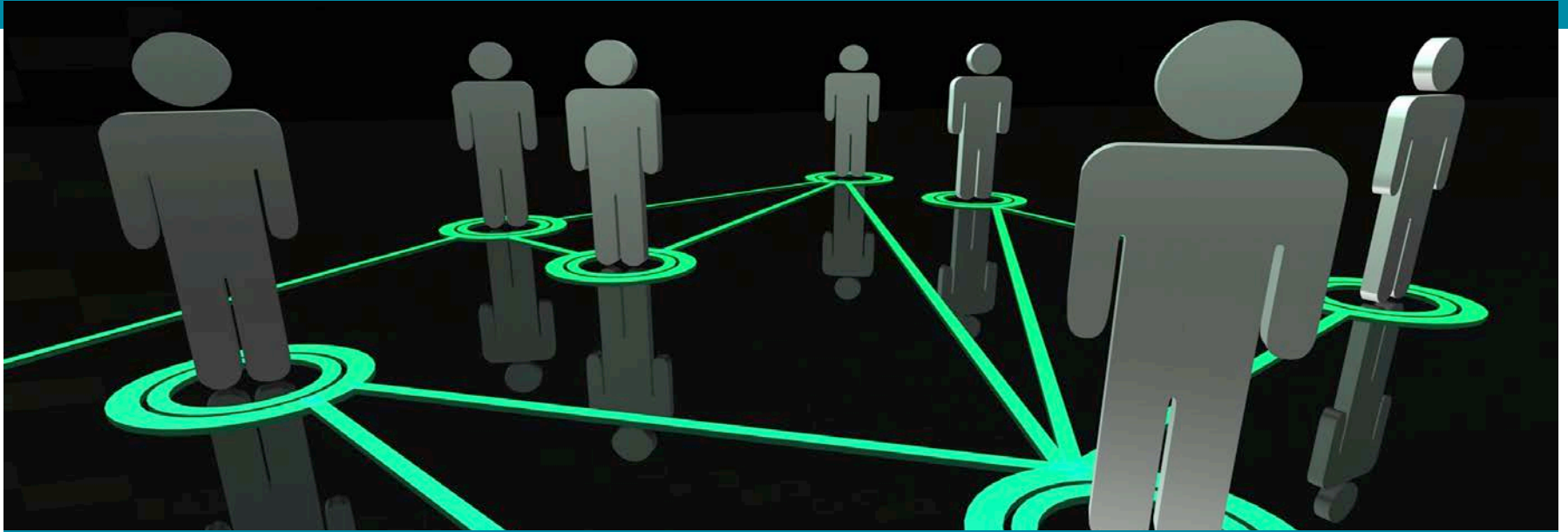
Wie entscheiden Sie sich?

- Ich gebe die 20 Punkte ab.
- Ich behalte die 20 Punkte.

Payoff as Function of Mobility



Mobility is key to success!



Why Humans Are Social: The Emergence of the „Homo Socialis“

Dirk Helbing

with Thomas Grund, Christian Waloszek,

Matthias Leiss, Heinrich Nax,

and others

Evolutionary Model of Human Decision-Making

- Agents decide according to a best-response rule that strictly maximizes their utility function, given the behaviors of their interaction partners (their neighbors).
- The utility function considers not only the own payoff, but gives a certain weight to the payoff of their interaction partner(s). The weight is called the "friendliness" and set to zero for everyone at the beginning of the simulation.

Evolutionary Model of Human Decision-Making

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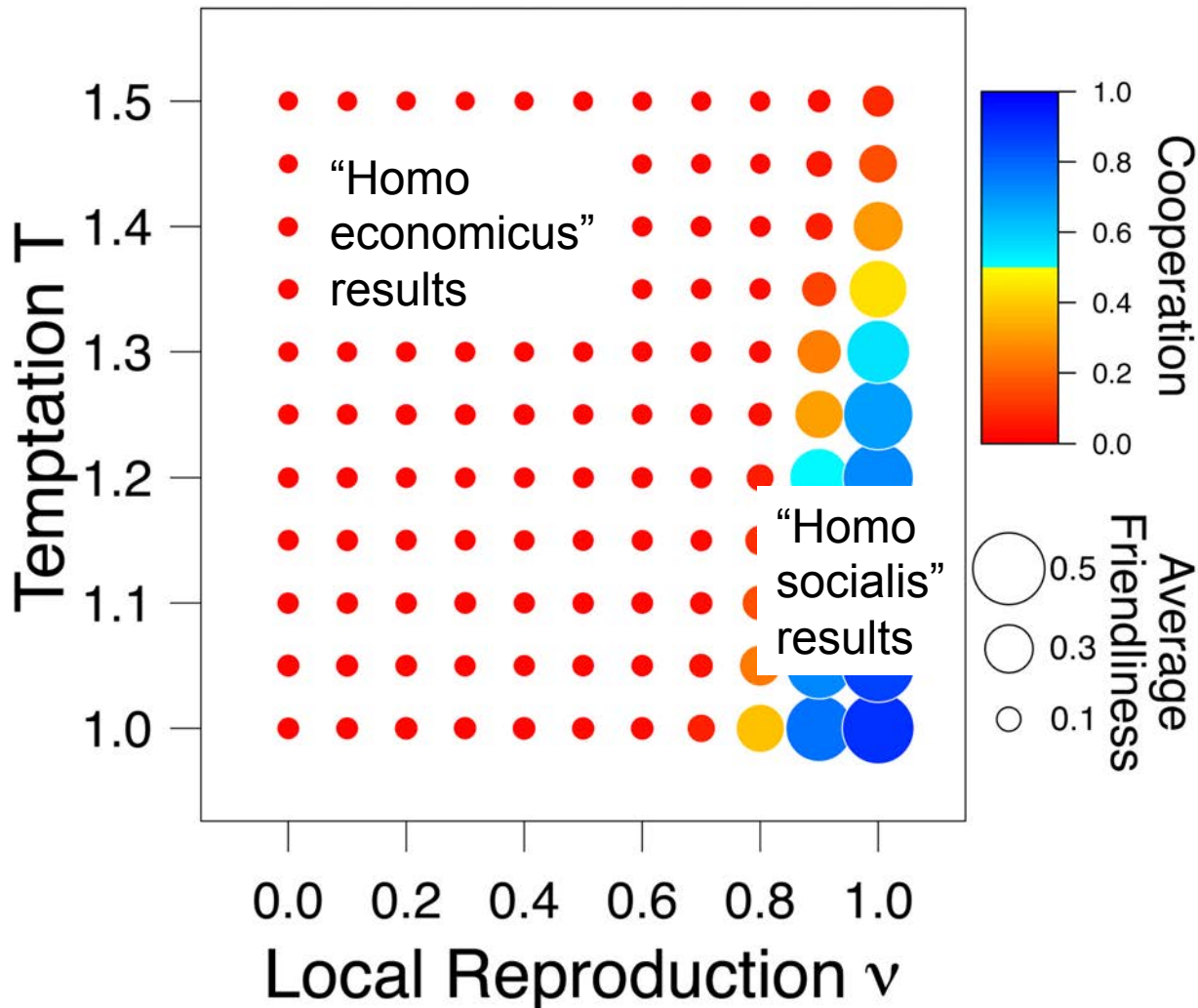
Evolutionary Model of Human Decision-Making

- Friendliness is a trait that is inherited (either genetically or by education) to offspring. The likelihood to have an offspring increases exclusively with the own payoff, not the utility function. The payoff is assumed to be zero, when a friendly agent is exploited by all neighbors (i.e. if they all defect). Therefore, such agents will never have any offspring.
- The inherited friendliness value tends to be that of the parent. There is also a certain mutation rate, but it does not promote friendliness. (In the simulation results discussed here, mutations were specified such that they imply an average friendliness of 0.2, which cannot explain the typically observed value of 0.4.)

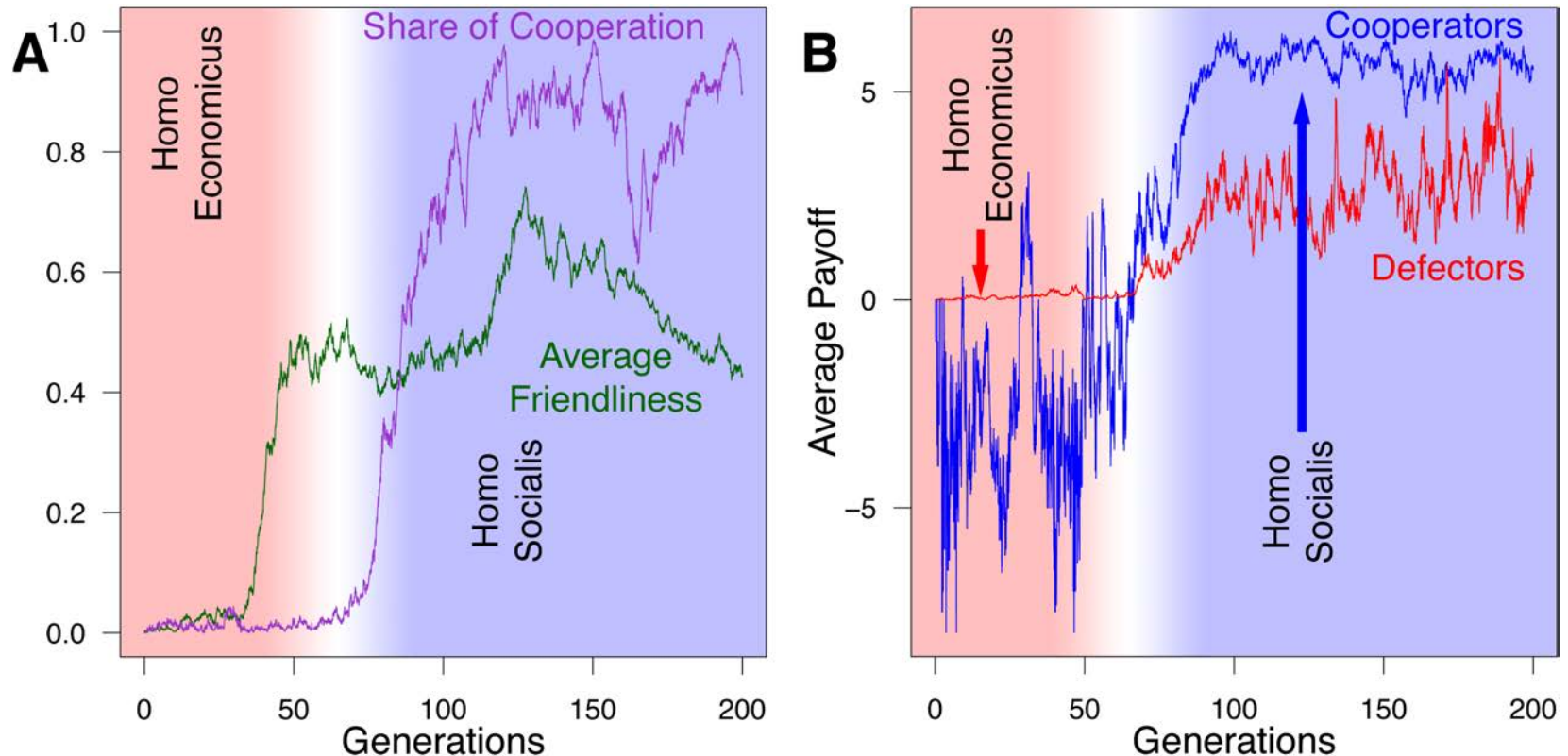
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Phase Diagram: Parameter-Dependent Outcome



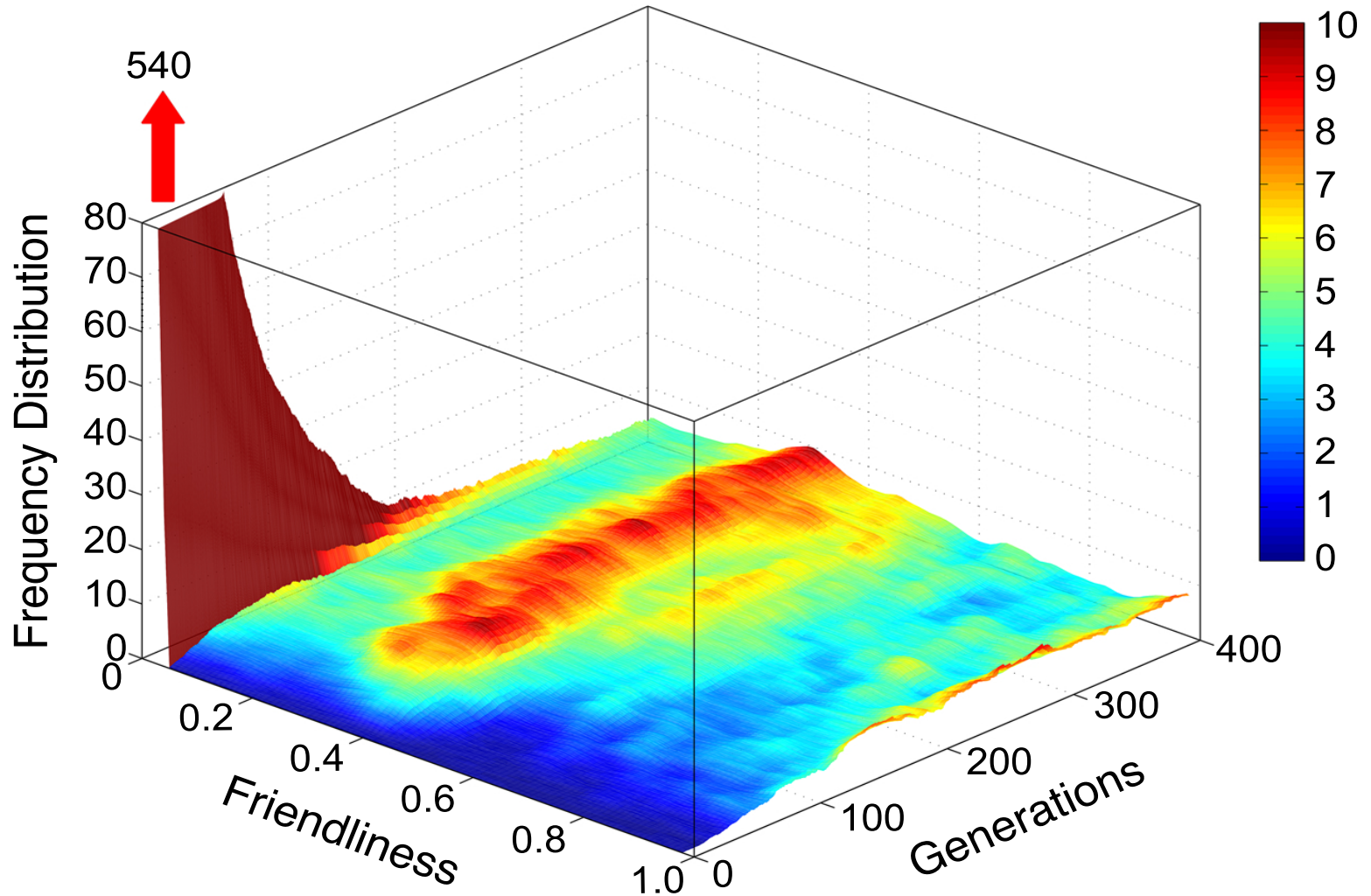
Emergence of the „Homo Socialis“



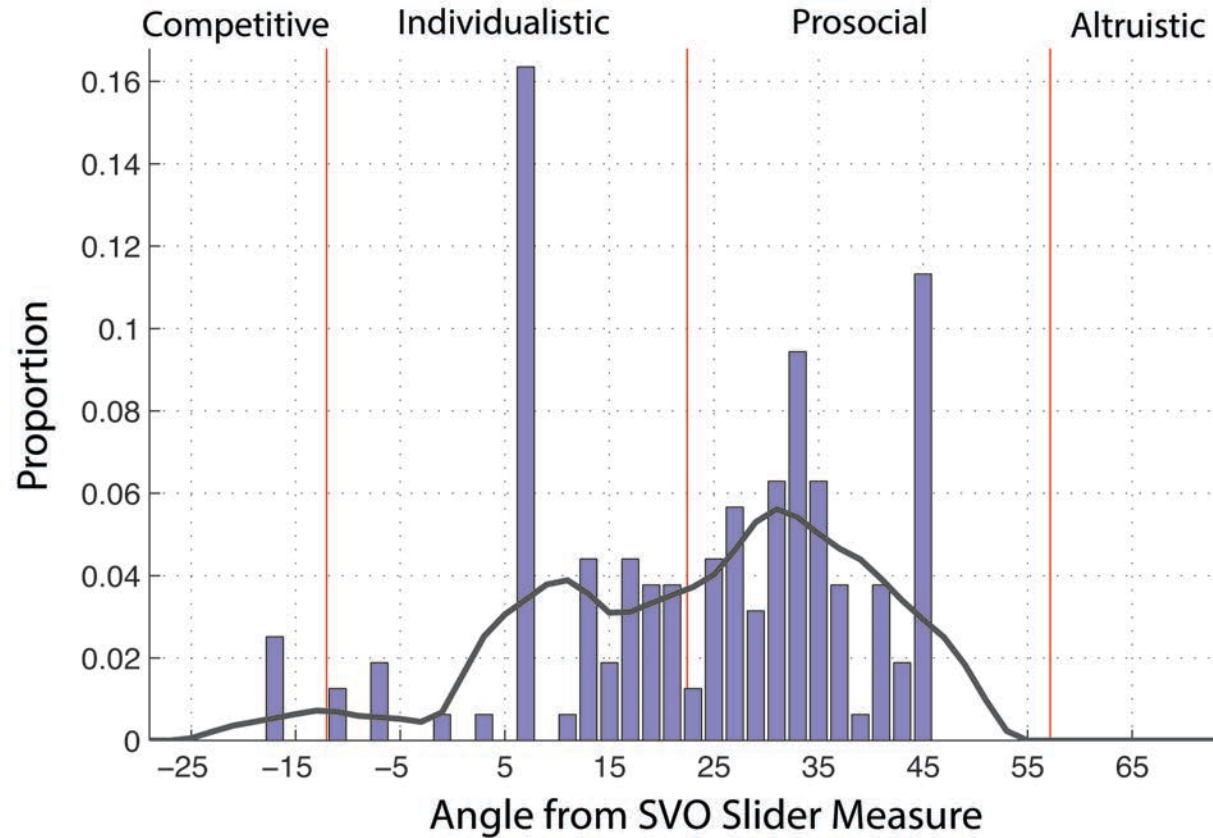
The “homo socialis” is conditionally cooperative, takes self-determined but other-regarding decisions (considering the impact on others).

This implies interdependent decisions, “networked minds”.

Distribution of Friendliness Values



Empirical Measurement of Prosocial Preferences



Experimental work of Ryan Murphy *et al.*

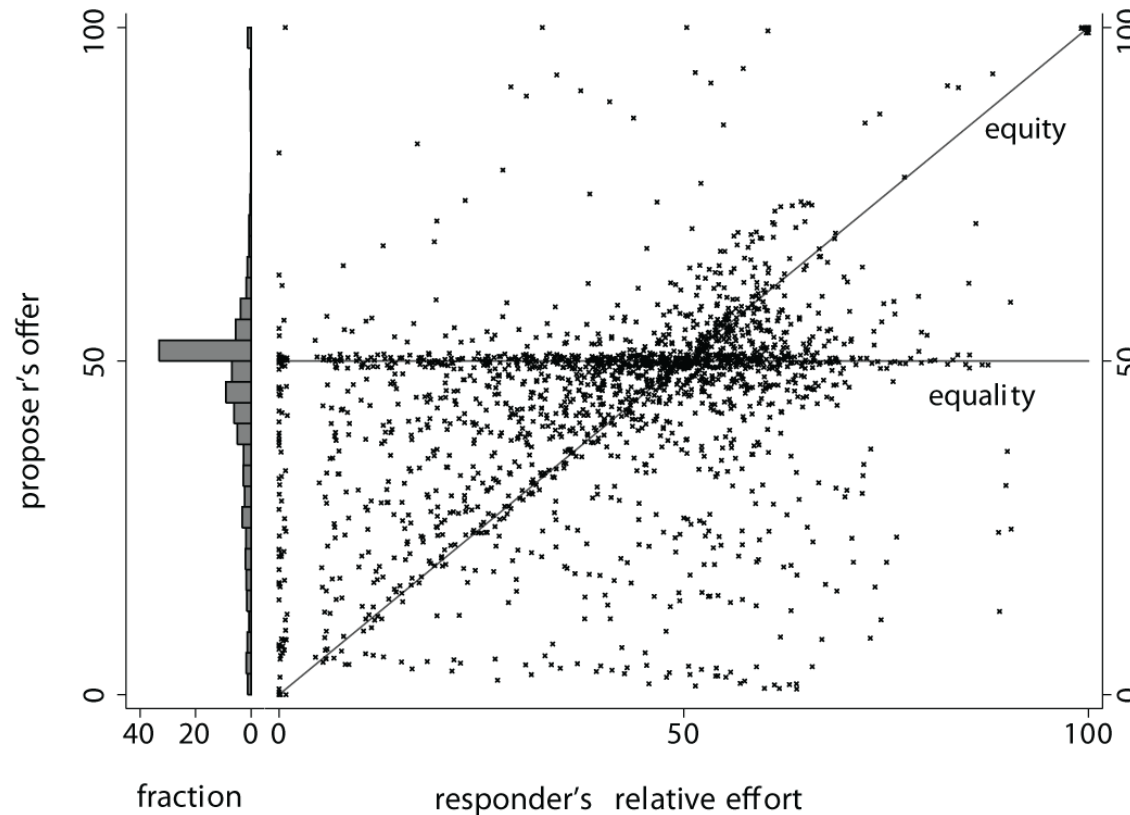


Modeling the Emergence of Social Norms when Preferences are Incompatible

Dirk Helbing

with Michael Mäs, Anders Johansson,
Heiko Rauhut, Fabian Winter,
and others

Conflict between Individuals with Equity and Equality Preferences



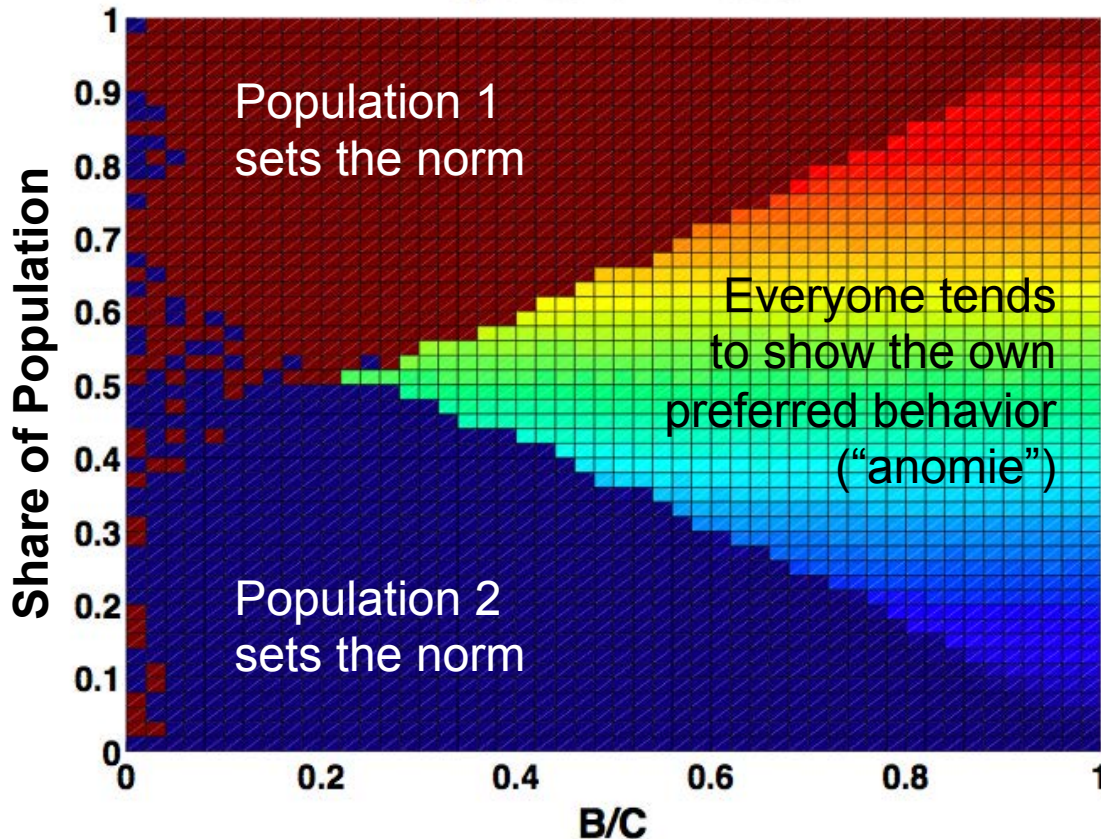
Results of an Ultimatum Game Experiment

Joint 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



Computer simulations:

Red = individuals preferring behavior 1

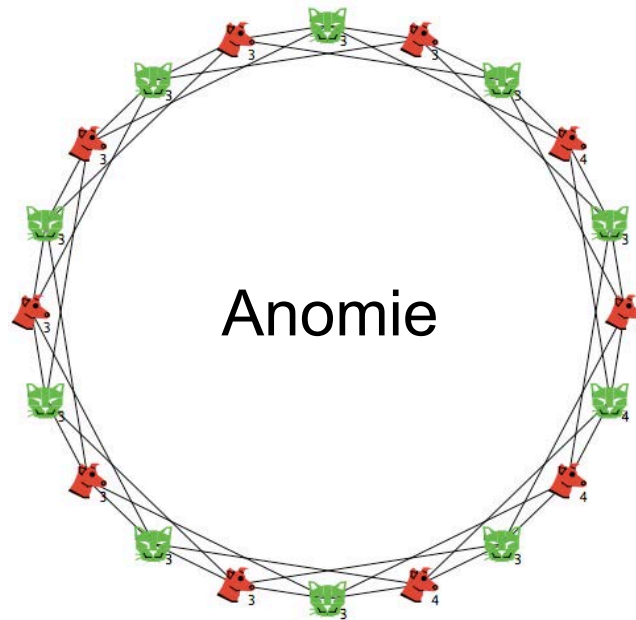
Yellow = individuals adjusting to behavior 1

Blue = individuals preferring behavior 2

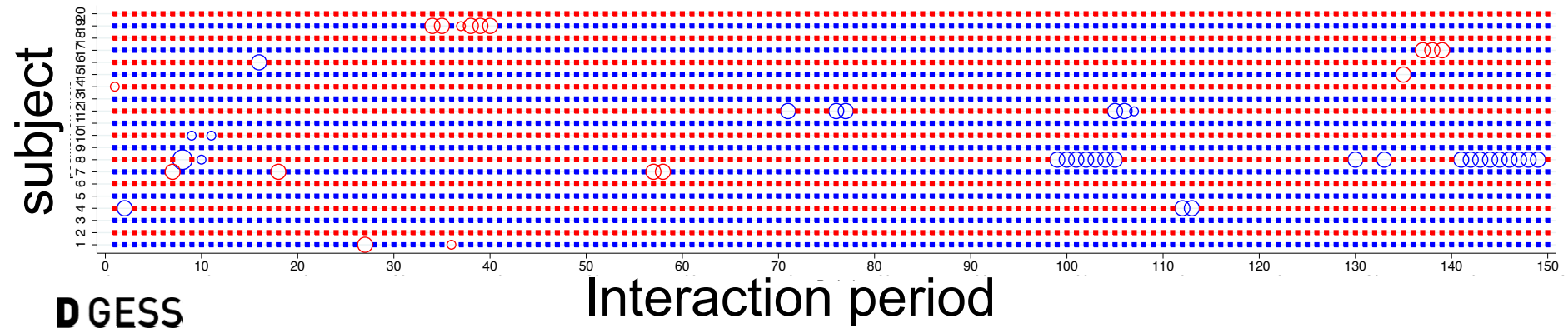
Green = individuals adjusting to behavior 2

Reward of showing preferred behavior / Reward of conforming

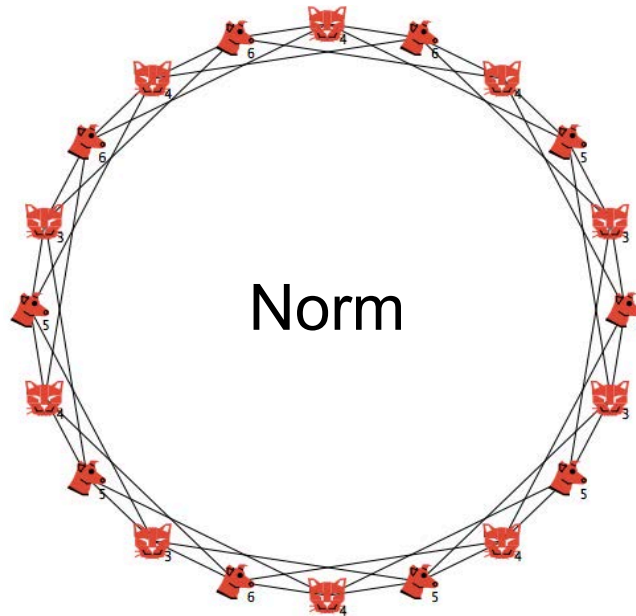
Occurrence of Anomie: Experimental Results



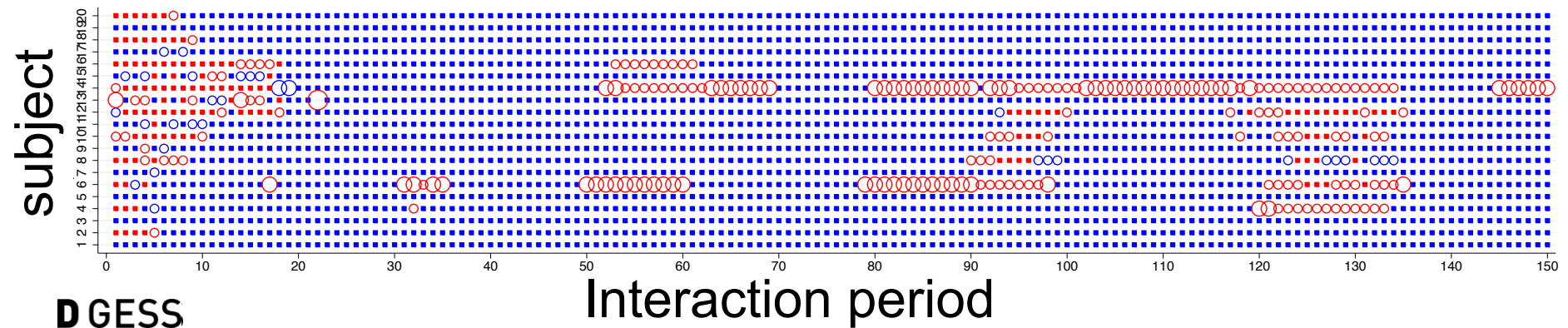
Results from the lab: anomie



Emergence of Social Norms: Experimental Results



Results from the lab: norm





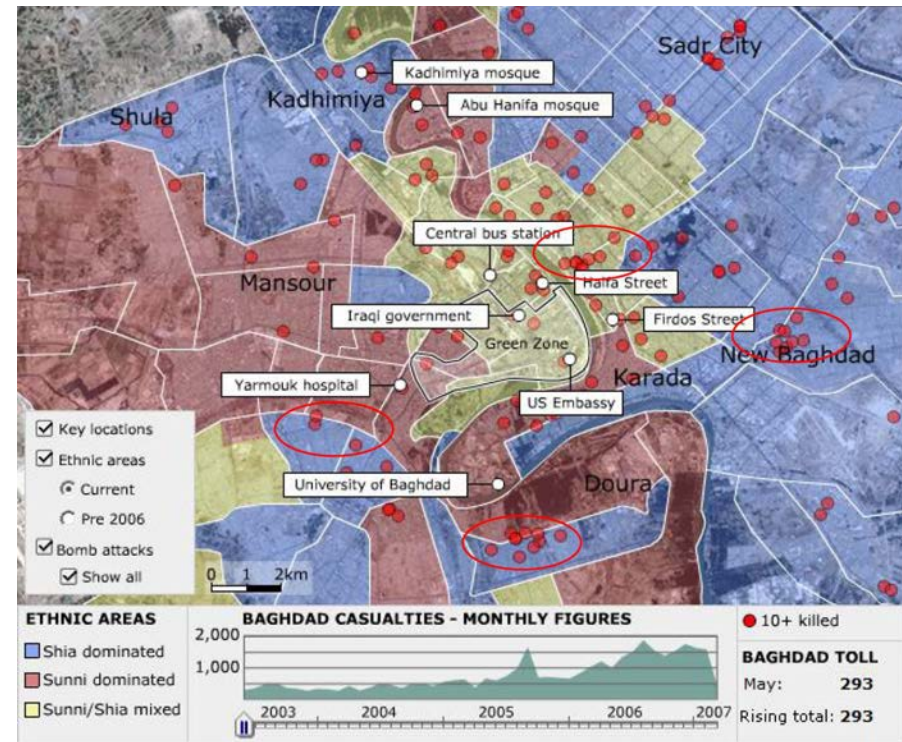
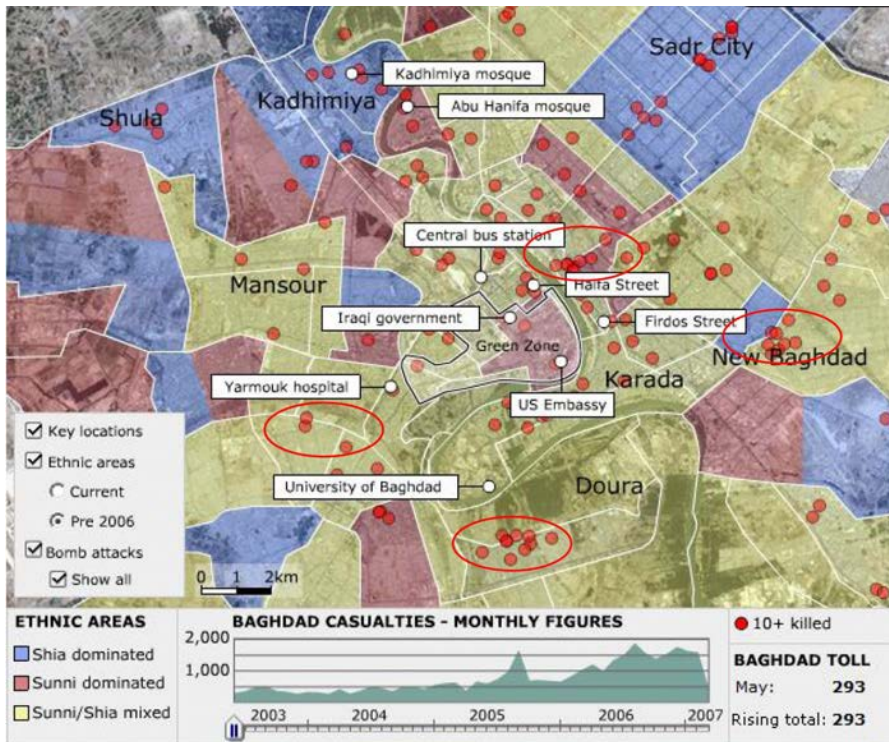
Studying Intercultural and International Conflict

Dirk Helbing

with Karsten Donnay, Thomas Chadefaux,
Ravi Bhavnani, Dan Miodownik,
and others

Interrelation of Spatial Interaction, Conflict, and Migration

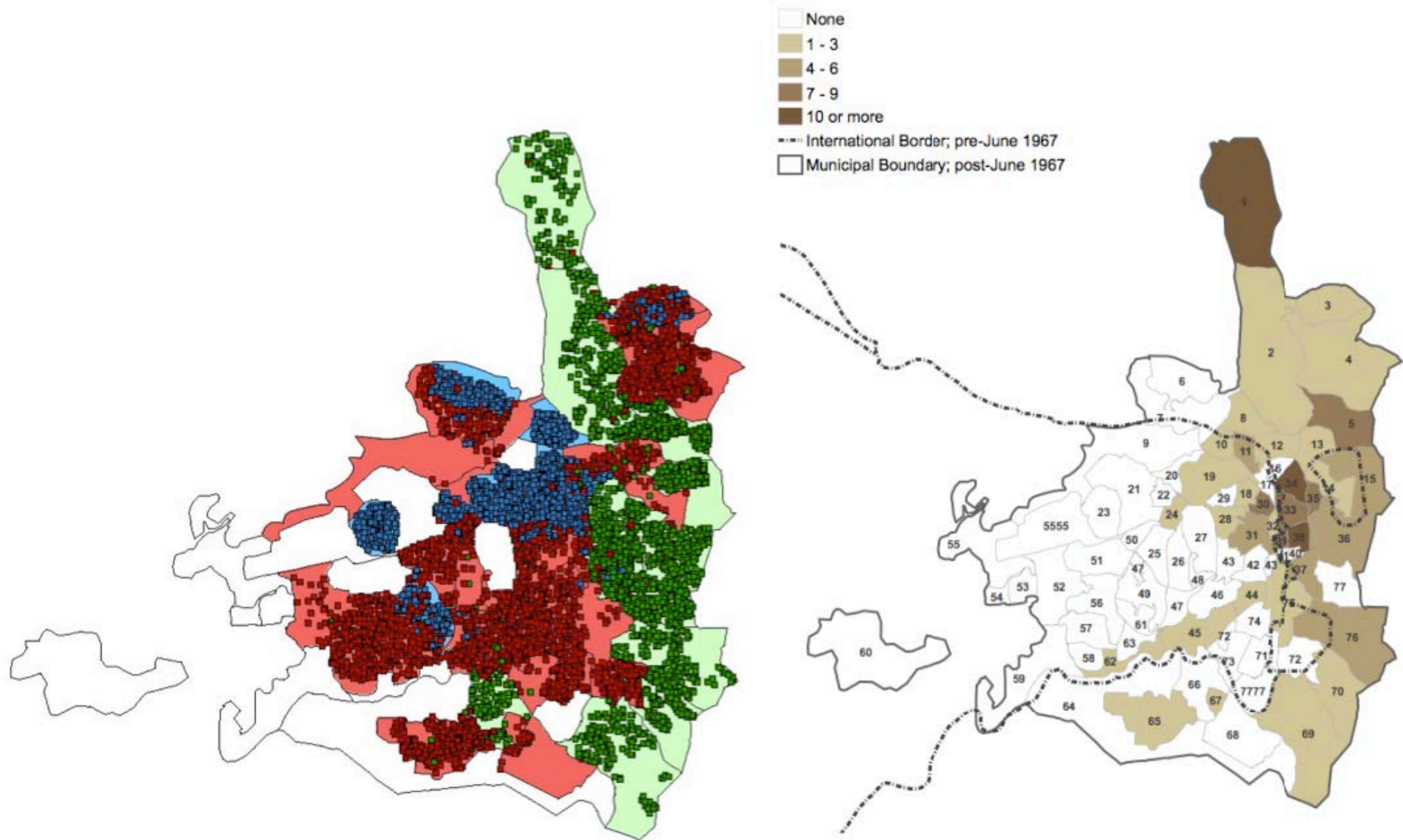
Source: BBC



Ethnic areas and bomb attacks before 2006 Ethnic areas and bomb attacks after 2006

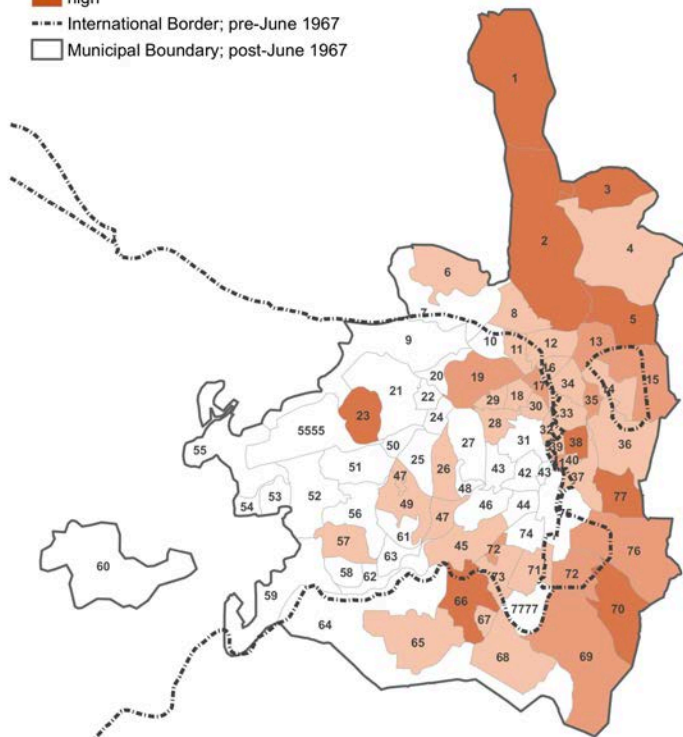
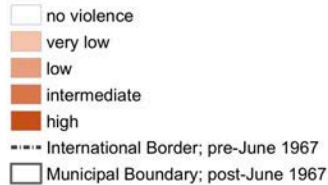
Conflict occurs primarily at boundaries between areas with different ethnic fractions. Mixed areas shrink.

Agent-Based Model of Conflict in Jerusalem



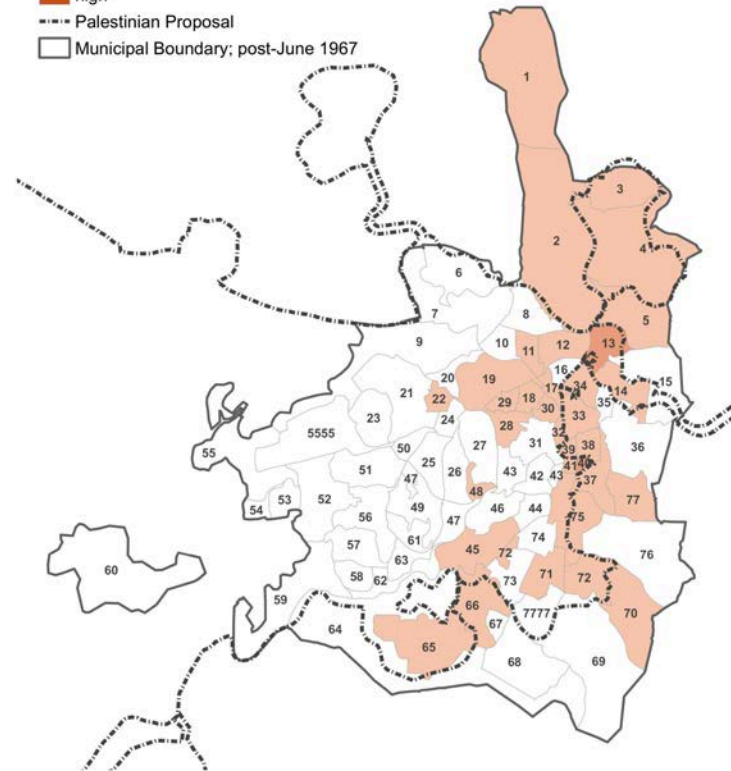
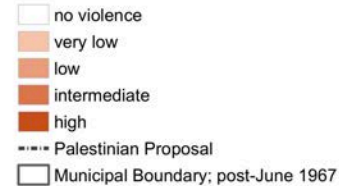
Conflict in the Jerusalem: Possible Future Scenarios

Levels of Violence



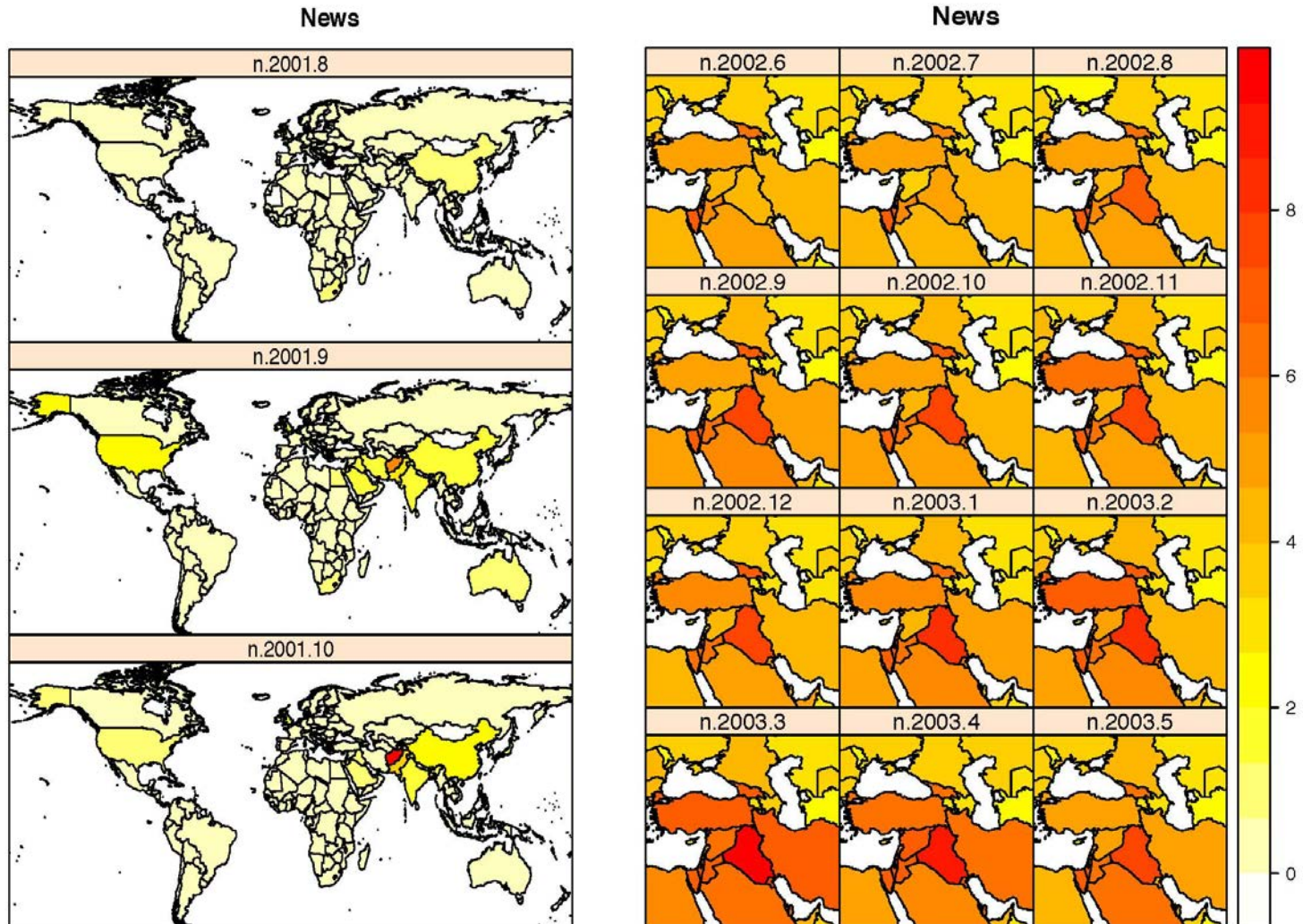
'Business as Usual'

Levels of Violence



Clinton Parameters

Spreading of International Tensions





Understanding Social Dynamics by Analyzing Human Activity Data

Dirk Helbing

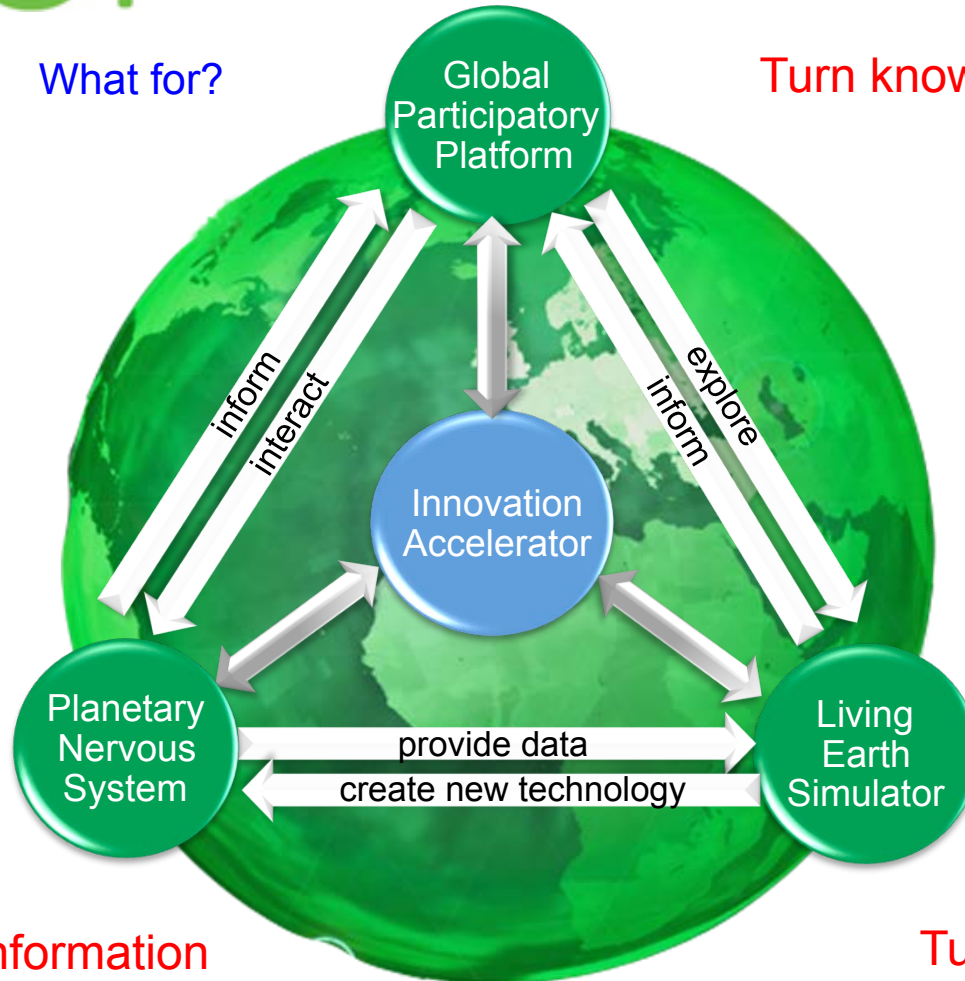
with Dirk Brockmann, Maximilian Schich,
Laszlo Barabasi, Bogdan State,
and others

FuturiCT

Build platforms
to explore & interact

What for?

Turn knowledge into wisdom



What is?

Create systems
to sense &
understand

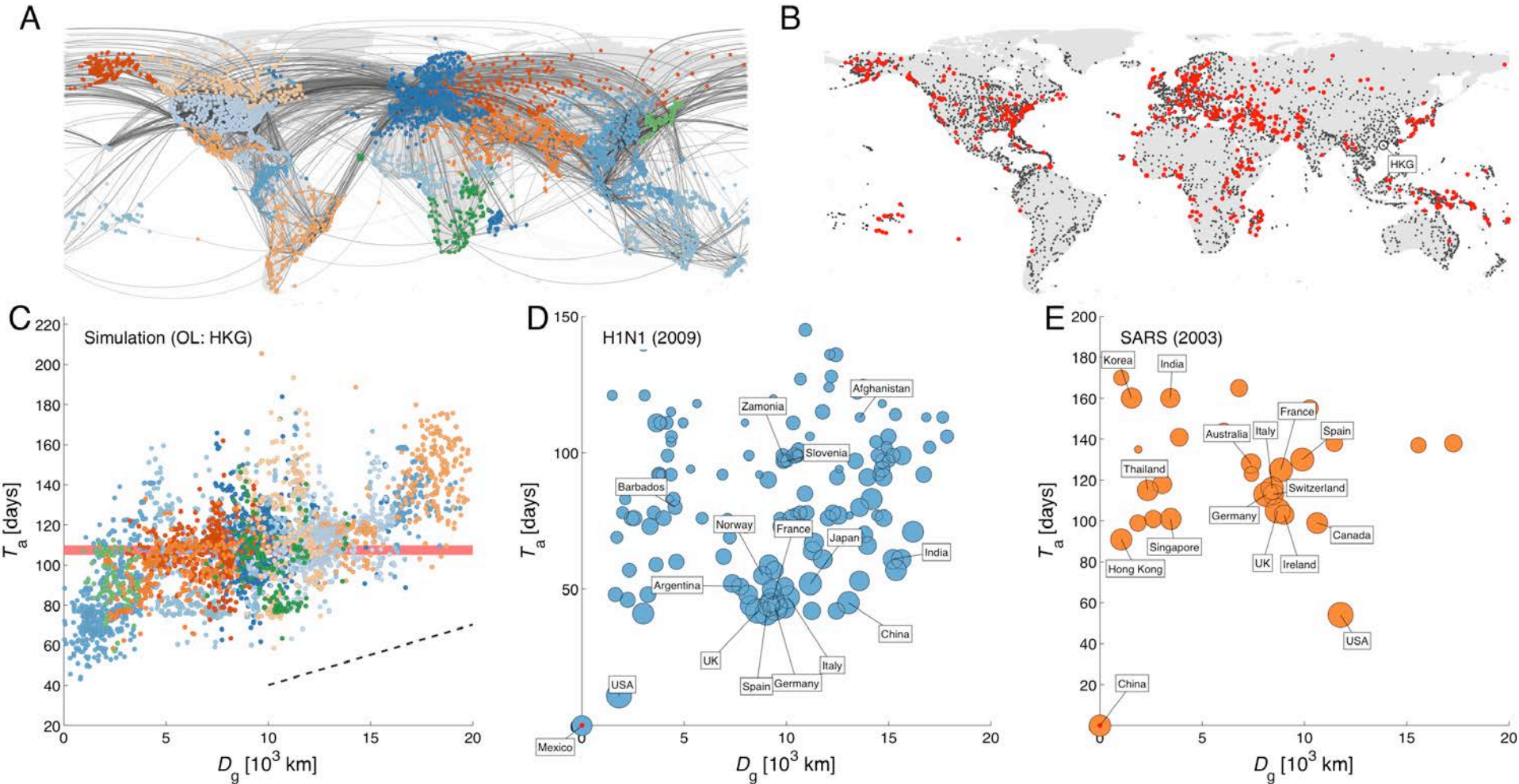
What if?

Develop models
to simulate &
predict

Turn data into information

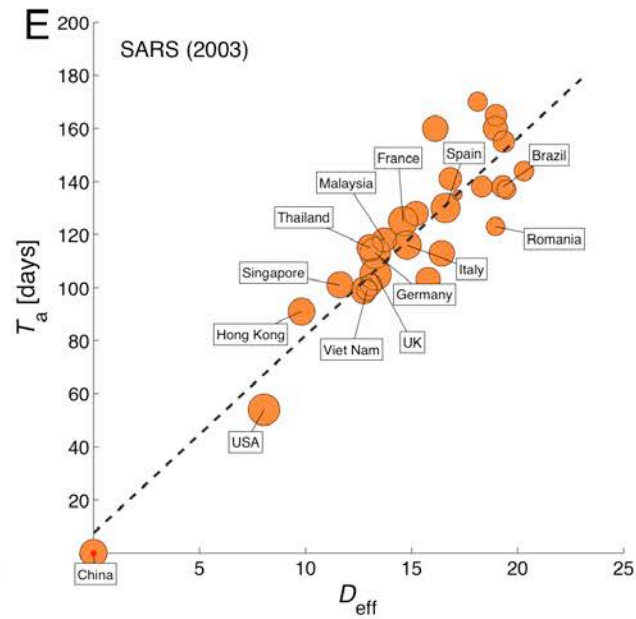
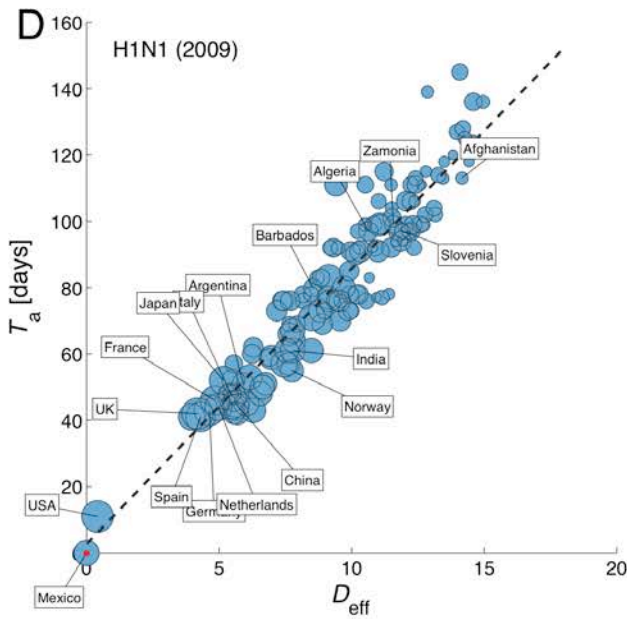
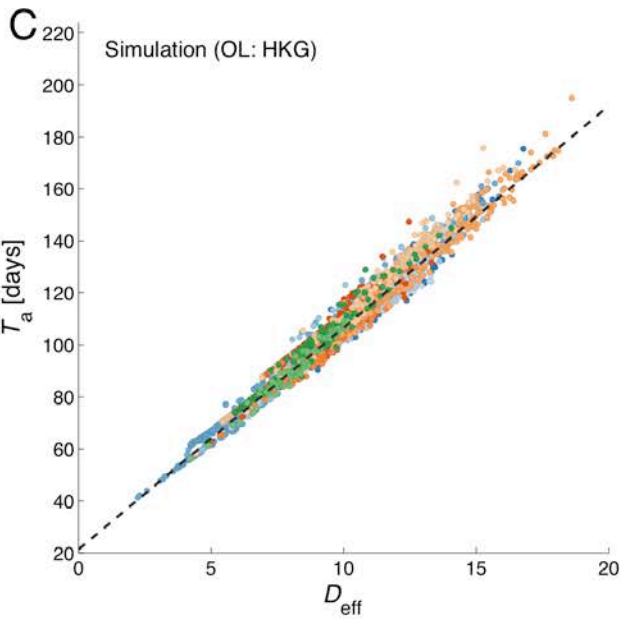
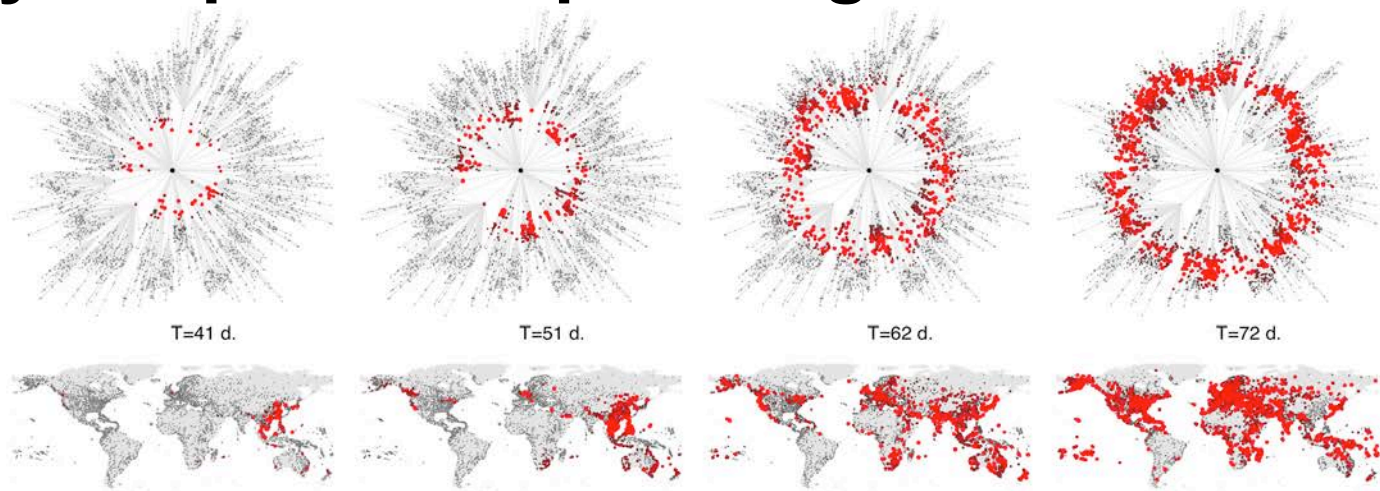
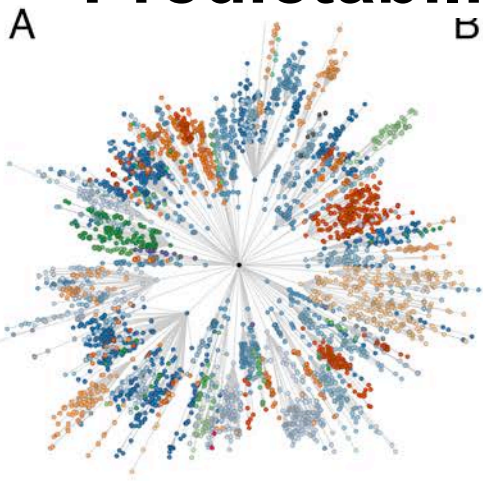
Turn information into
knowledge

Complexity of Epidemic Spreading

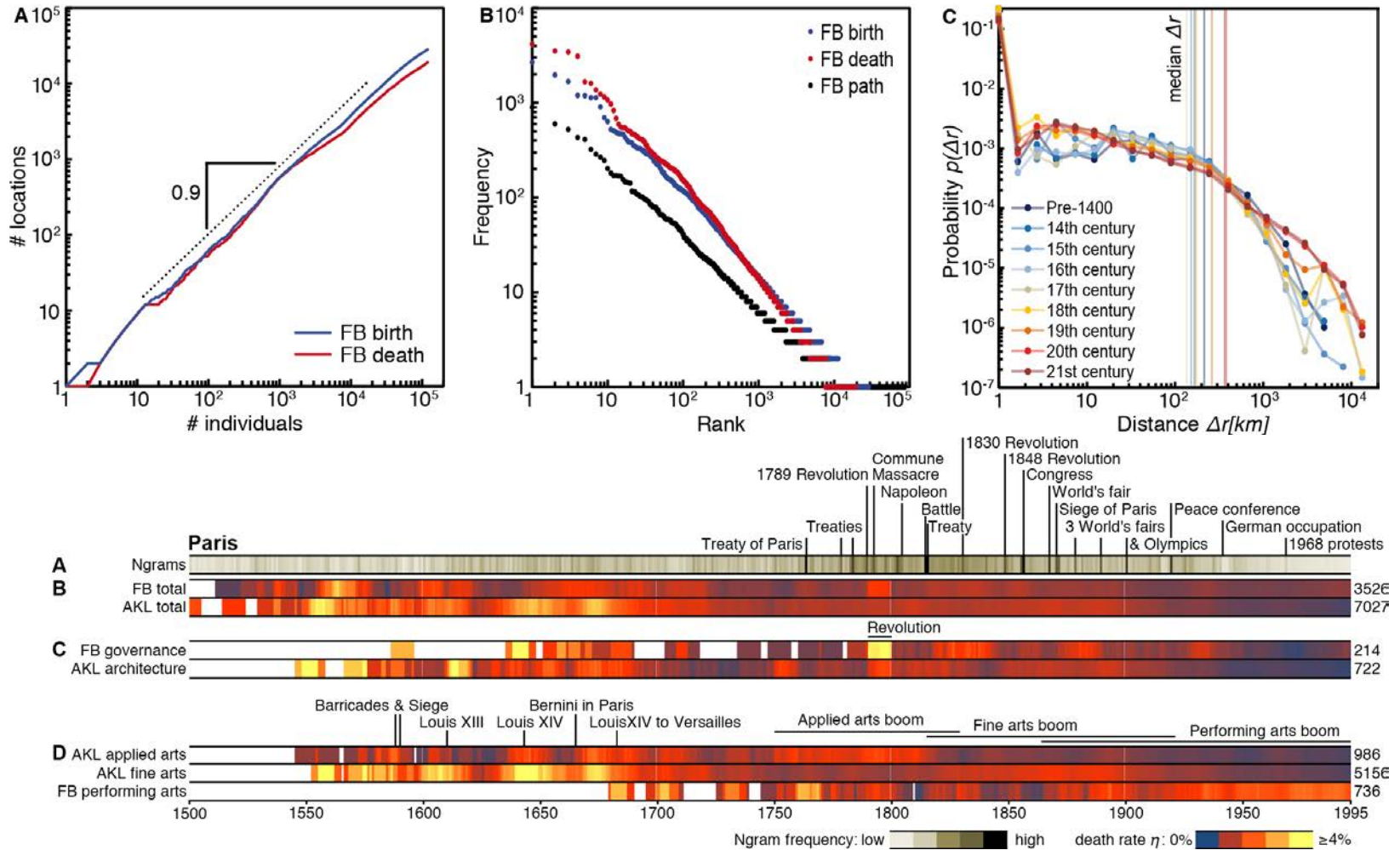


Dirk Brockmann and DH (2013) in print.

Predictability of Epidemic Spreading

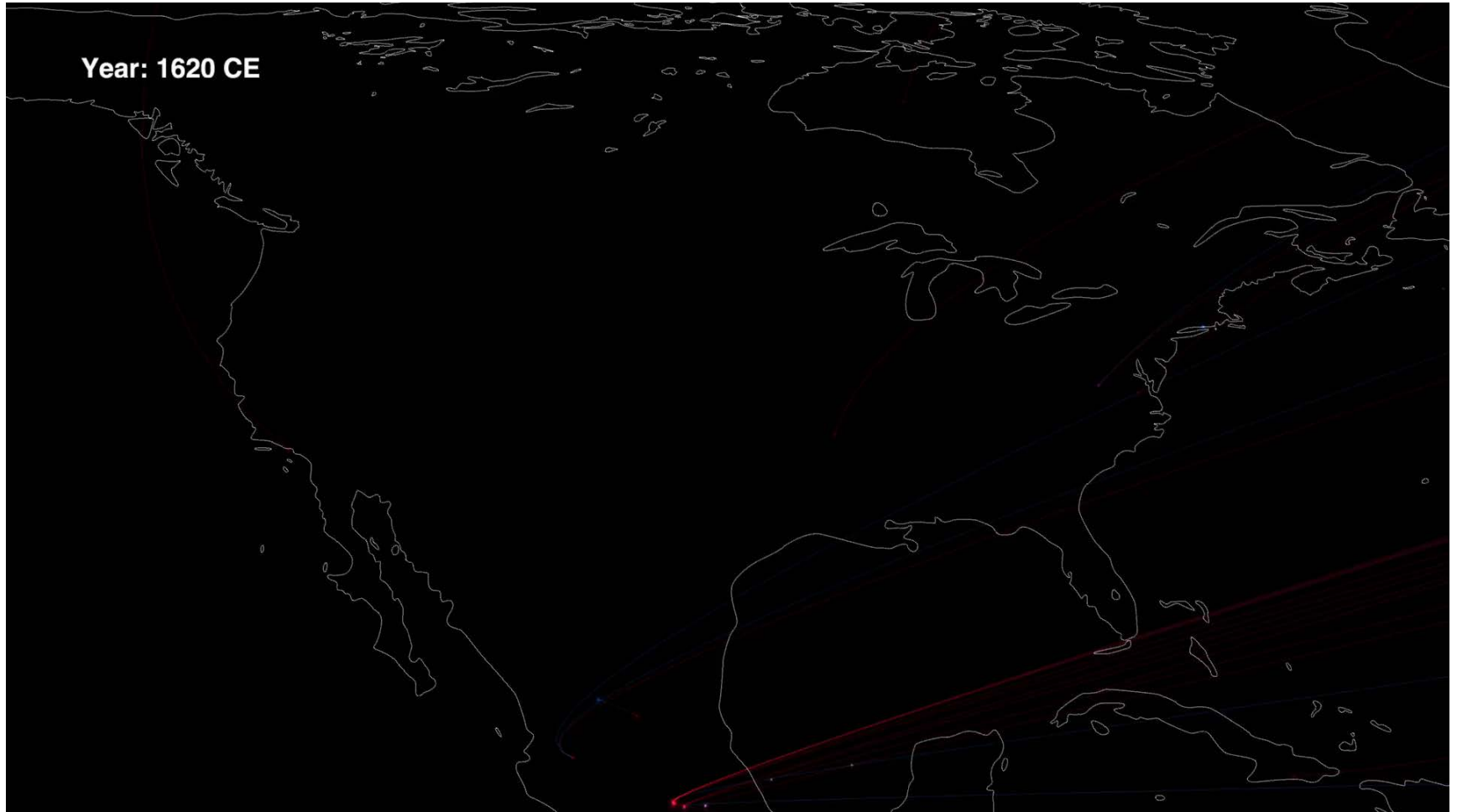


Regularities vs. Specifics



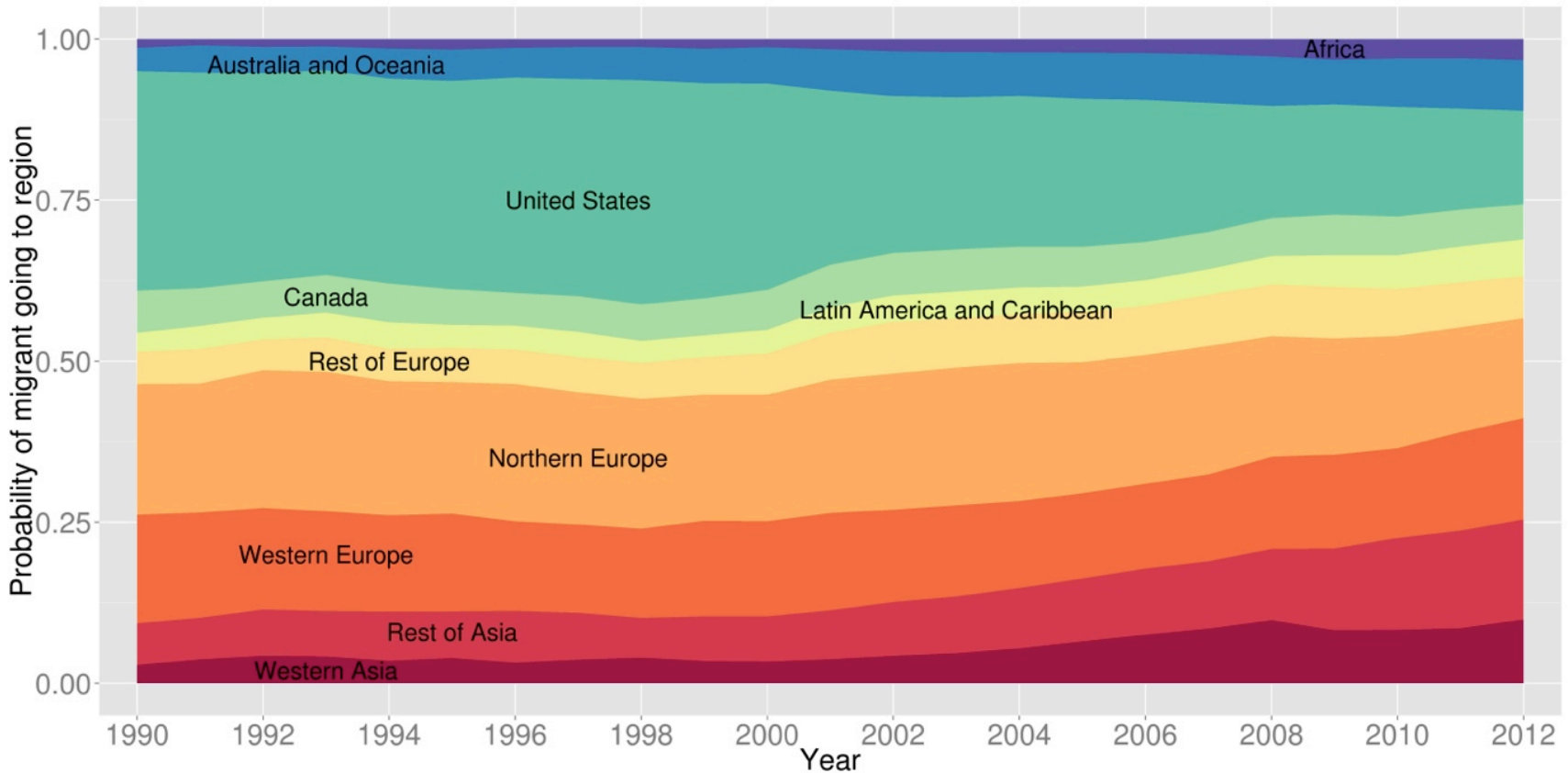
M. Schich, C. Song, Y.-Y. Ahn, A. Mirsky, M. Martino, A.L. Barabasi, DH, submitted (2013)

„Braindrain of Artists“ in the US



M. Schich, C. Song, Y.-Y. Ahn, A. Mirsky, M. Martino, A.L. Barabasi, DH, submitted (2013)

Global Migration Reflects the Development of a Multi-Polar World



B. State, M. Rodriguez, DH, E. Zagheni, submitted (2013)



Techno-Social Systems: Creating an Innovation Accelerator

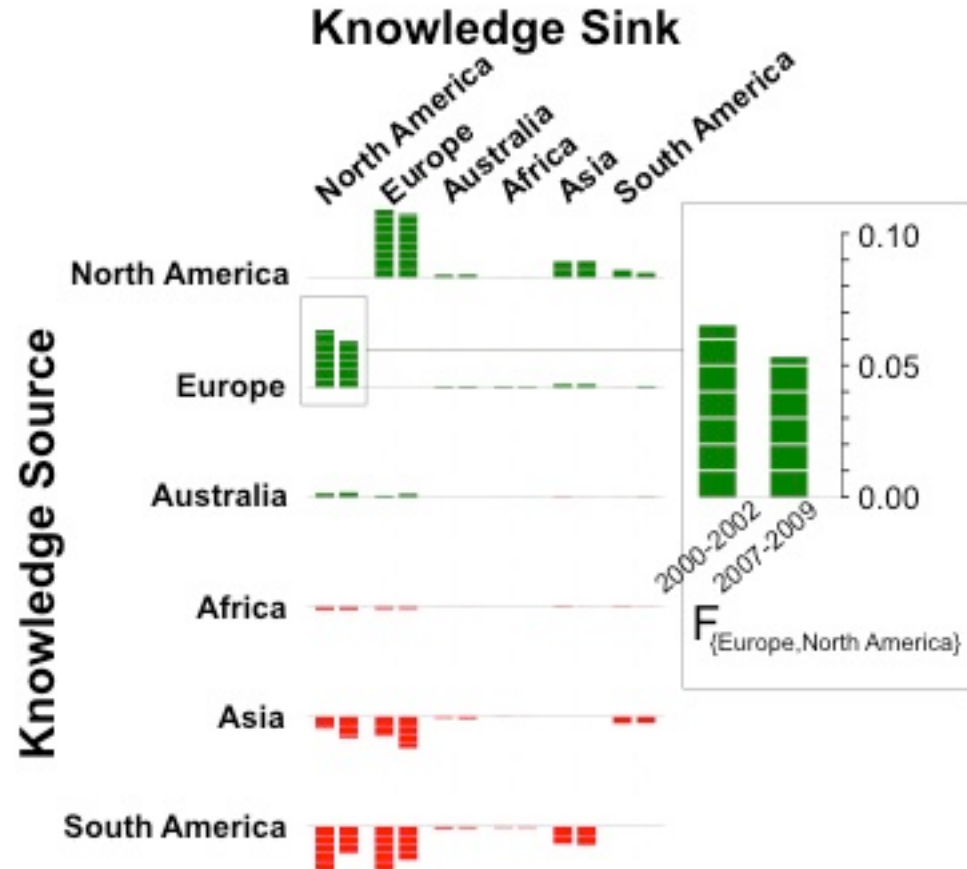
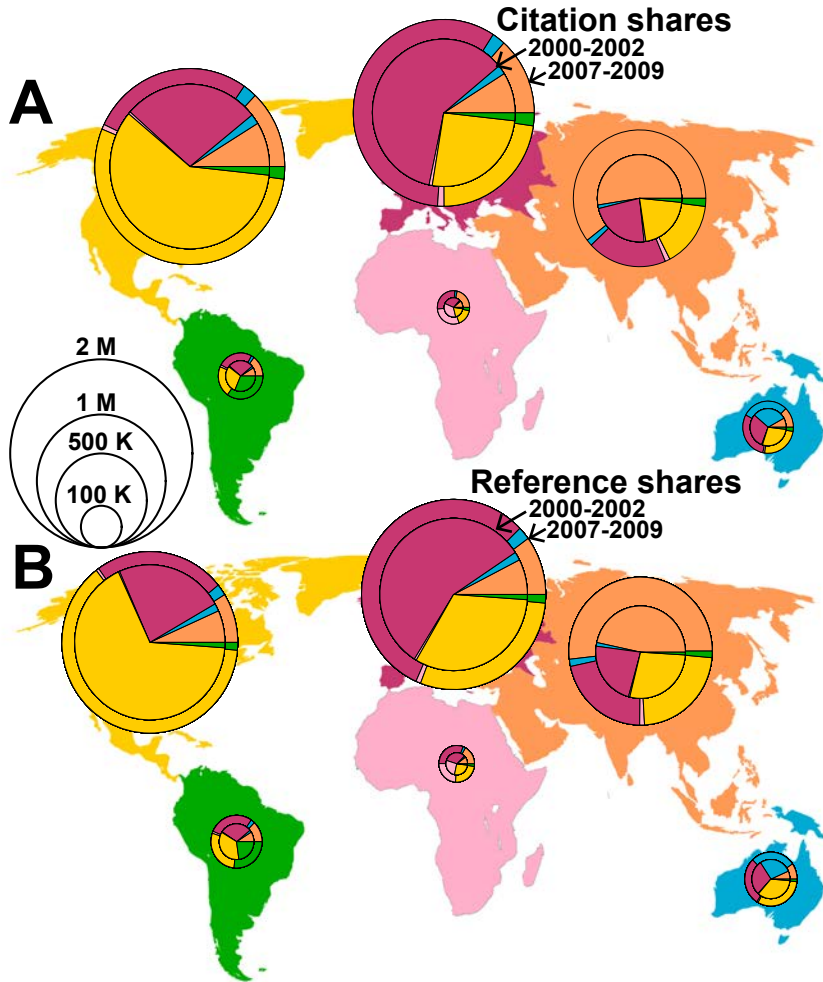
Dirk Helbing

with Stefano Balietti, Tobias Kuhn,

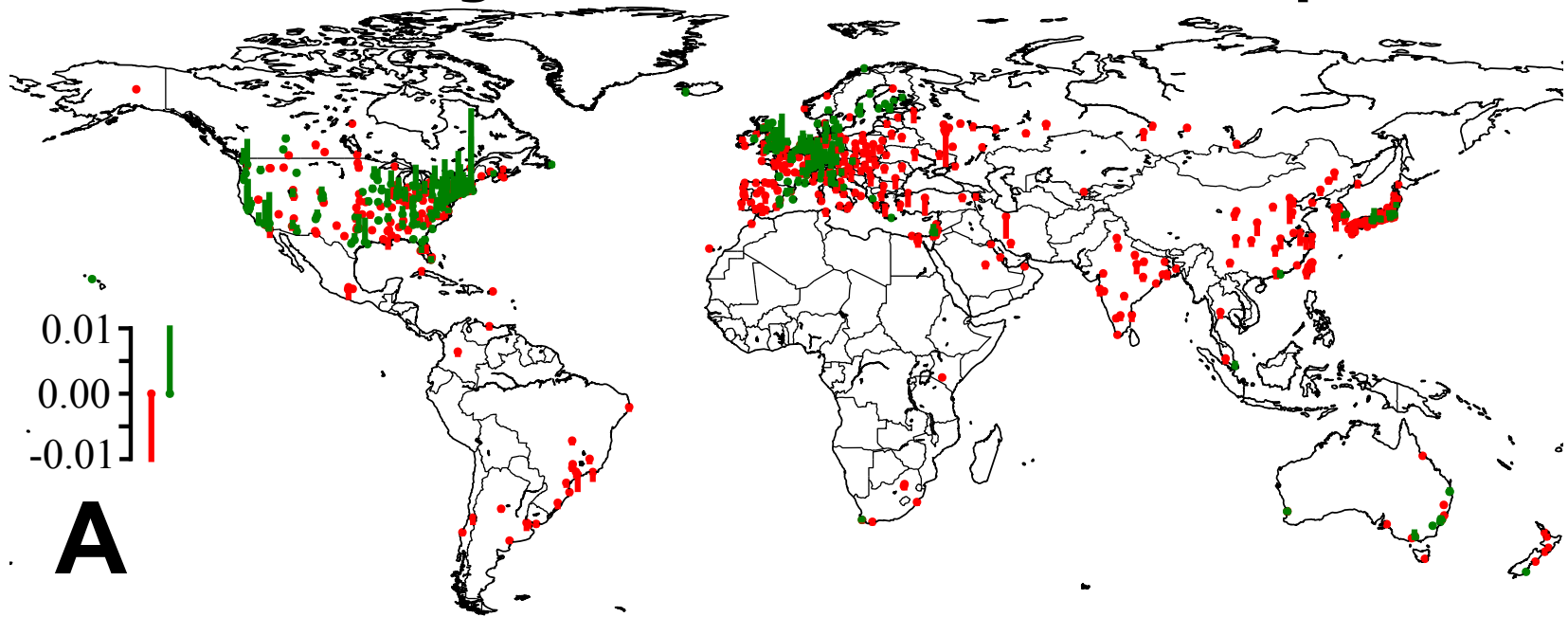
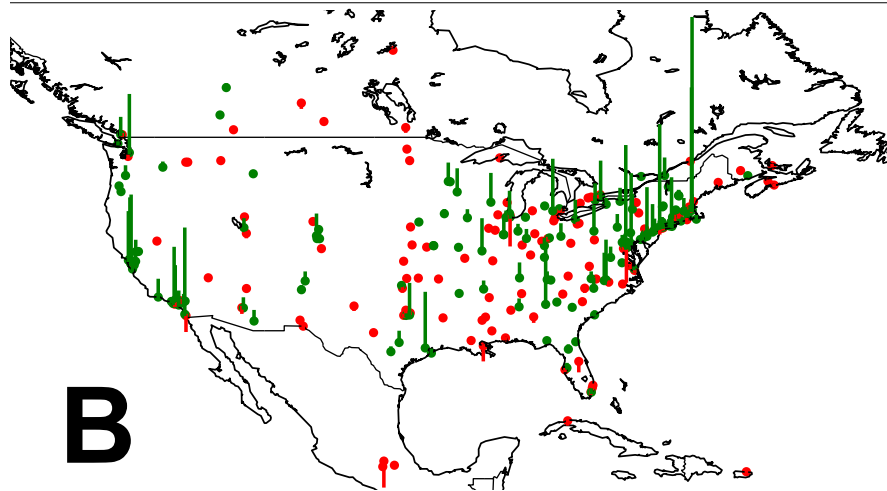
Amin Mazloumian, Christian Schulz, Rob Goldstone,

and others

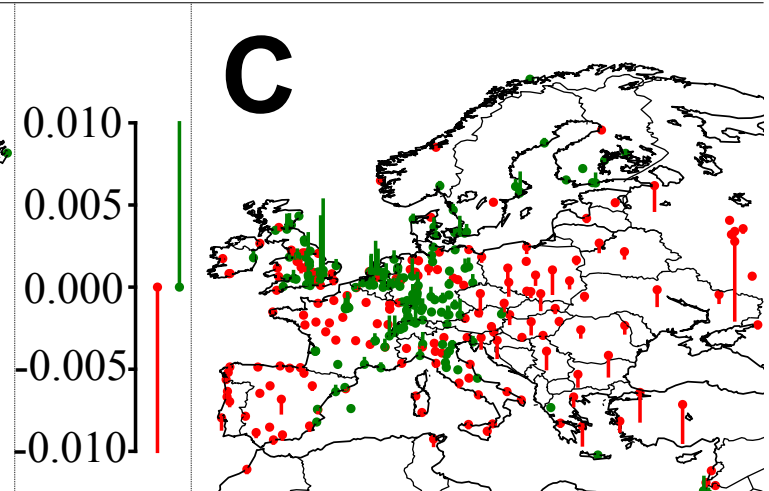
Scientific Productiveness, Impact, and Flow of Ideas



Global Knowledge Production and Consumption

**A****B**

D GESS

**C**

Living Archive

Search engine for open scientific datasets

<http://livingarchive.inn.ac>

The screenshot shows the Living Archive website interface. At the top, there is a navigation bar with the logo "LIVINGARCHIVE" and "Lectives" (with a colorful bar below it). To the right of the logo is a search input field, and further right are links for "Login" and "Register". Below the navigation bar are links for "HOME", "DATASETS", "VISUALISATIONS", and "FEEDBACK". The main header features a large image of a globe with a search bar overlaid, and the text "LIVING ARCHIVE A SEARCH ENGINE FOR OPEN DATA". Below the header is a section titled "RECENT DATASETS" with a green background. This section lists several datasets with their titles, descriptions, and last accessed dates. To the right of the "RECENT DATASETS" section, there is a "43569 and counting" badge, a "Lectives" logo with the text "Featured Datasets from QLectives", and a video player showing a green globe.

LIVINGARCHIVE
Lectives

search Login Register

HOME DATASETS VISUALISATIONS FEEDBACK

LIVING ARCHIVE
A SEARCH ENGINE FOR OPEN DATA

RECENT DATASETS

Find din arbejdsmiljørådgiver
Oversigt over autoriserede arbejdsmiljørådgivere.
Data findes på <http://www.at.dk/sw13545.asp>
...
Last accessed Thu Mar 21 2013 07:51:42 GMT-0100 • 0 files

consulta-giustizia-europea
Testi ### Diritti sul database Nessuna indicazione...
Last accessed Thu Mar 21 2013 07:51:32 GMT-0100 • 0 files

Jobnet
Jobcentrenes fælles database over ledige stillinger. Jobsøgere kan søge efter arbejde og oprette cv og Arbejdsgivere kan søge efter arbejdskraft og oprette jobannoncer
Data findes på Last accessed Thu Mar 21 2013 07:51:06 GMT-0100 • 0 files

Liste des jardins partagés
Jeu de données listant l'ensemble des jardins partagés de Paris...
Last accessed Thu Mar 21 2013 07:51:01 GMT-0100 • 1 files

The Courts
Statistics of The Courts from [www.statcentral.ie](http://www.statcentral.ie/ "statcentral.ie") under the theme People and Society - Crime and Justice from the The Courts Service Classifications: ...
Last accessed Thu Mar 21 2013 07:50:56 GMT-0100 • 0 files

43569 and counting

Lectives
Featured Datasets from QLectives

More

Virtual Journal (ViJo)

Create your own search filters and recommender system

<http://vijo.inn.ac>

The screenshot displays the Virtual Journal (ViJo) website interface. The top navigation bar is orange and contains the 'vijo' logo, user icons, and the name 'SAM SULAIMANOV' with links for 'FEEDBACK' and 'LOGOUT'. The main content area is titled 'Related To My Papers' and features a list of papers. On the left, there are two filter sections: 'MY FILTERS' and 'POPULAR FILTERS'. The 'MY FILTERS' section includes 'Related To My Papers', 'he tried', 'particlepapers', and 'New Filter'. The 'POPULAR FILTERS' section includes 'Physics', 'Maths', 'Astronomy', and 'more...'. Below these filters is a 'Share with a vijo user' input field and a 'Share' button. At the bottom left, there is an orange button labeled 'invite a fellow Scientist'. The paper list on the right includes:

- Published 2005-09-20** FOUND ON ARXIV
Axions 05
BY Farhan Feroz
SIMILAR TO Dynamic Effects Increasing Network Vulnerability to Cascading Failures
KEYWORDS \$3
- Published 1995-03-06** FOUND ON ARXIV
Complex-Temperature Properties of the Ising Model on 2D Heteropolygonal Lattices
BY J. Adamek, Antonio Pereyra
SIMILAR TO Dynamic Effects Increasing Network Vulnerability to Cascading Failures
KEYWORDS \$3
- Published 2006-06-01** FOUND ON ARXIV
The Search for Dark Matter Axions
BY Farhan Feroz
SIMILAR TO Dynamic Effects Increasing Network Vulnerability to Cascading Failures
KEYWORDS \$3
- Published 1992-06-16** FOUND ON ARXIV

Take Home Messages

The Chair of Sociology, in particular of Modeling and Simulation has:

- developed and published various **models of social behavior** (pedestrian crowds, opinion formation, social coordination, cooperation, norms, and conflicts),
- performed **lab and web experiments** to test our models,
- developed models to better **understand contagious spreading processes and human activity patterns on a global scale**, and
- created **platforms to support researchers** in their daily work.

The multi-disciplinary work enjoys **high scientific impact** and public visibility. Some of it helps to **save lives of people**.