

# Physics of socio-economic systems

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## Exploring parking strategies

April 26, 2022

Aleksėjus Kontrimaitis

#Interactive models

#Agent-based models

#Traffic

Traffic problems are ones we all face every day and we can explore using Physics of Risk tools such as agent-based models. Here we will take a look at a couple simple parking strategies from [1, 2].

### Problem setup

Let us assume that cars arrive one at a time at rate  $\lambda$  and park in a long one dimensional parking lot. The drivers are clueless on the location of the best available parking spots, they can see just the first car parked ahead of them (and number of free spots in between them).

One can easily imagine three natural strategies [1]:

- Meek. Park at the first available spot. Just behind the last car in the parking lot. In our setup, if the last spot is taken, then the driver looks for the first gap.
- Prudent. Find the first gap and park at the left end of that gap. If there are no gaps, then you'll have to backtrack.
- Optimistic. Go all the way to the end (destination) and then backtrack until you find available spot.

These parking strategies are illustrated in the figure below. The figure and the respective caption was copied from the original article [1].

Figure 2. Illustration of different parking strategies for the same state of the parking lot: (a) meek, (b) prudent, and (c) optimistic. The red square denotes the newly parked car.

Physics of risk, complexity and socio-economic systems.

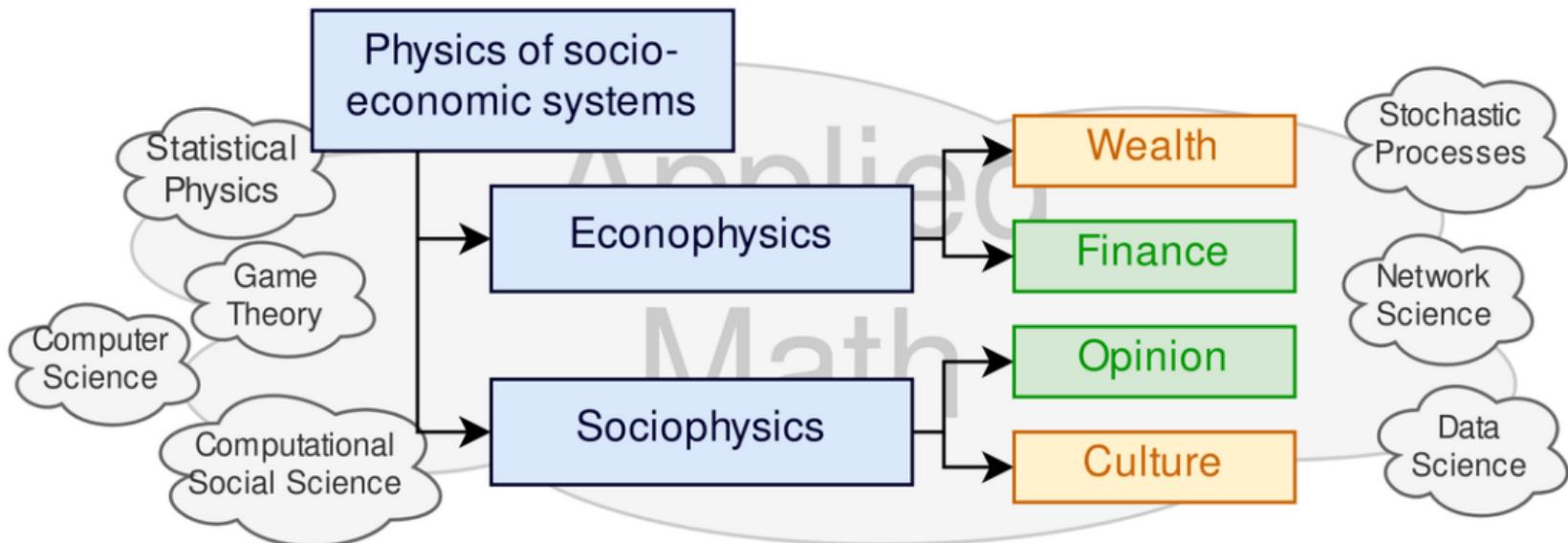
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- Institute of Theoretical Physics and Astronomy
- COST P10 meeting in Vilnius (2006)
- DPG Physics of Socio-Economic Systems Division
- Econophysics Network
- European Centre for Living Technology
- PPS Physics in Economy and

Website: <https://rf.mokslasplius.lt>

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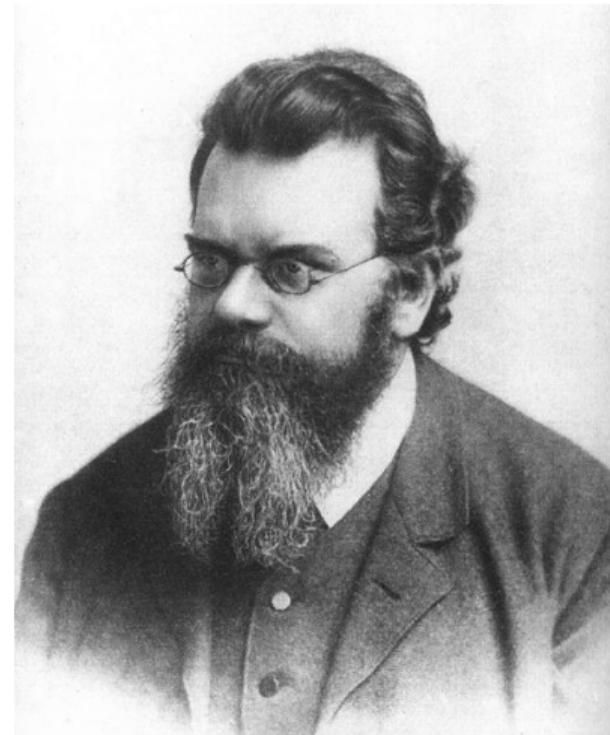
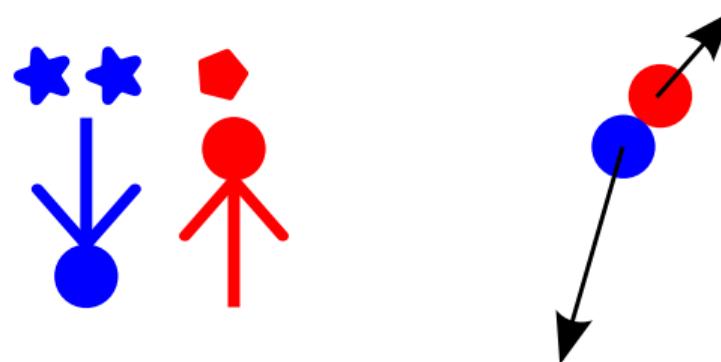
# What this talk is about?



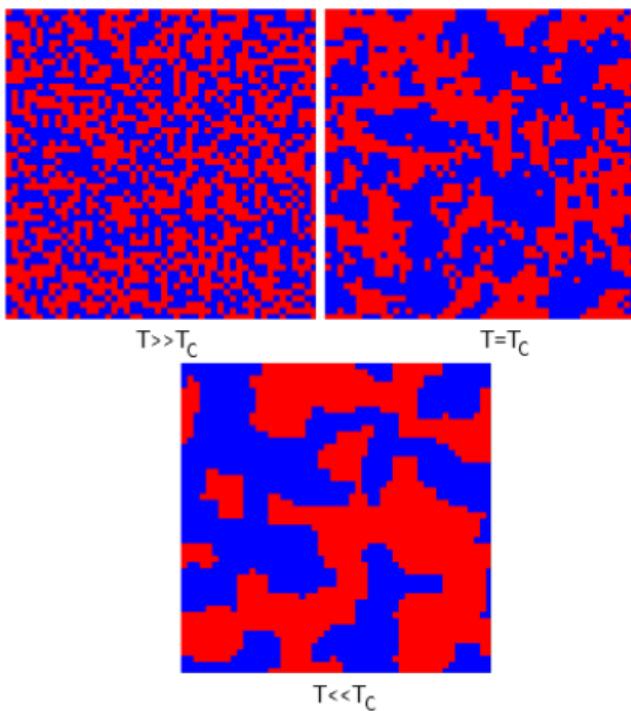
## Historical context

# XIX century: birth of Statistical Mechanics

**"The molecules are like so many individuals,  
having the most various states of motion, ..."**  
(L. Boltzmann)

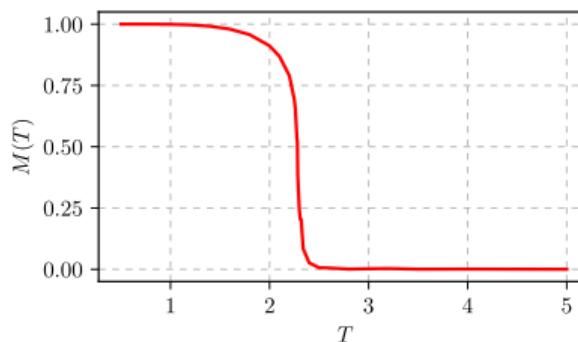


# $\sim$ 1920s: Ising model



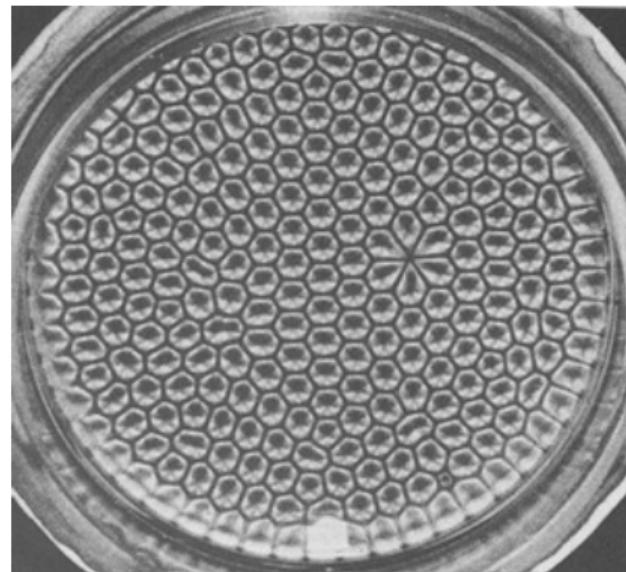
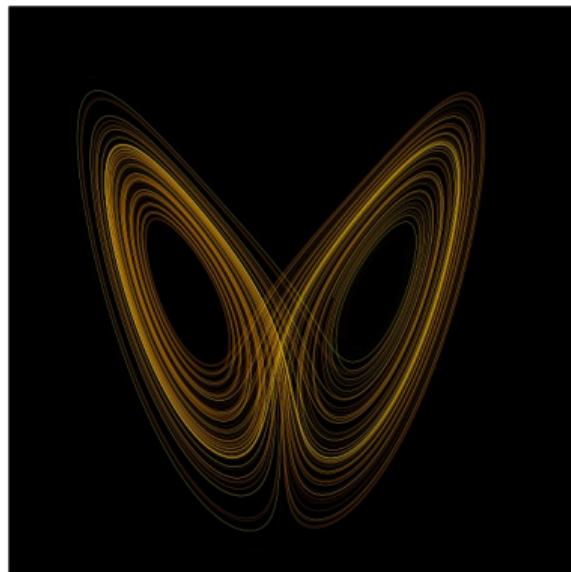
Magnetic spins align with their neighbors to minimize energy:

$$\mathcal{H} = -\frac{1}{2} \sum_{\langle i,j \rangle} J_{i,j} \vec{s}_i \vec{s}_j - \vec{H} \sum_i \vec{s}_i,$$



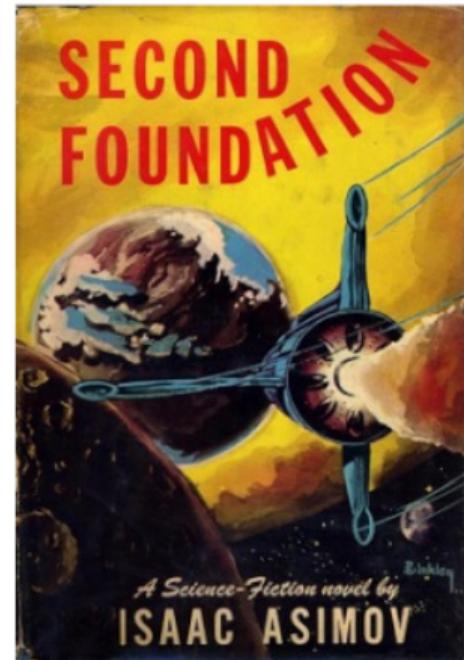
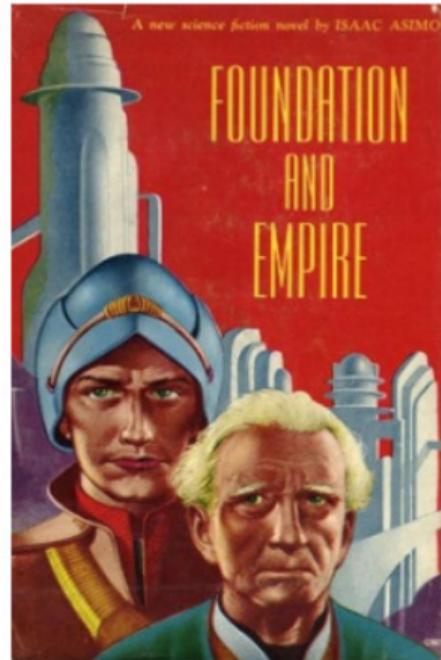
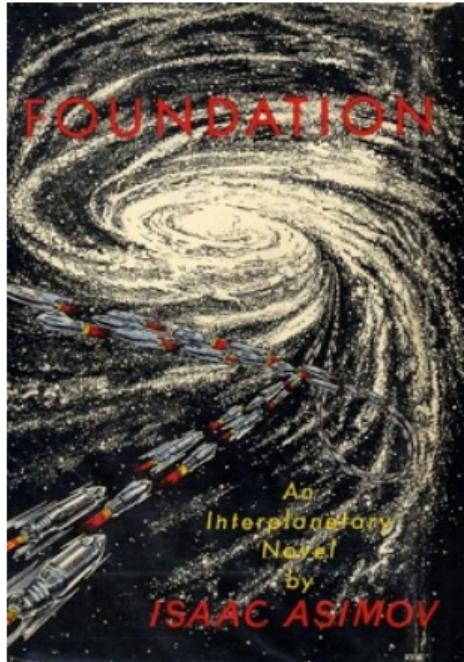
# ~ 1950s: Open and non-equilibrium systems

Macroscopic dynamics of certain systems sometimes is **nor sum nor average of the trajectories of its constituent parts.**



Figs.: [Wikimol](#), [idea.tion.to](#)

# ~ 1950s: Asimov's Foundation series



Figs.: Wikipedia [1, 2, 3]

# 1960s – 1970s: Self-similarity



“Clouds are not spheres, mountains are not cones, coastlines are not circles, and bark is not smooth, nor does lightning travel in a straight line...” (B. Mandelbrot)

Fig.: [Jacopo Wertherl](#)

1980s – 1990s: availability of socio-economic data

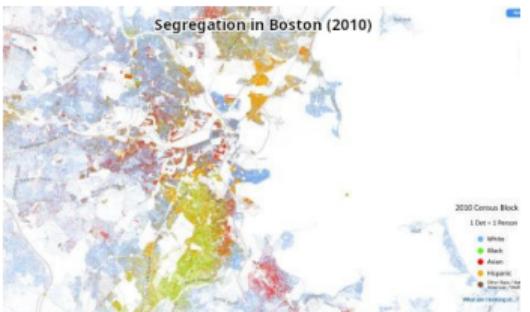
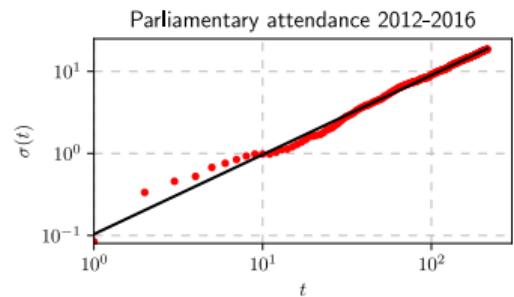
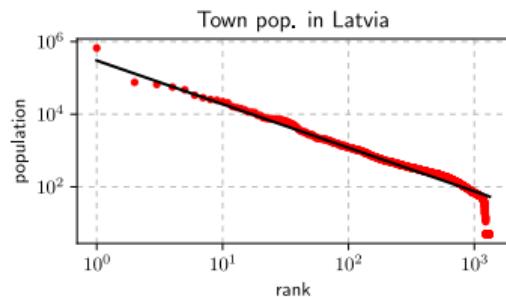
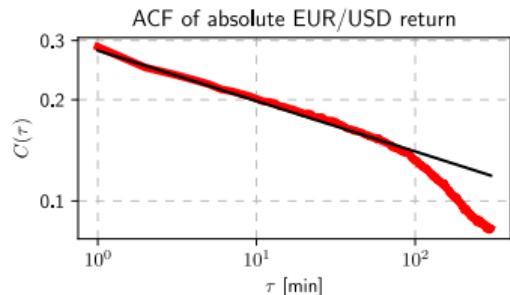
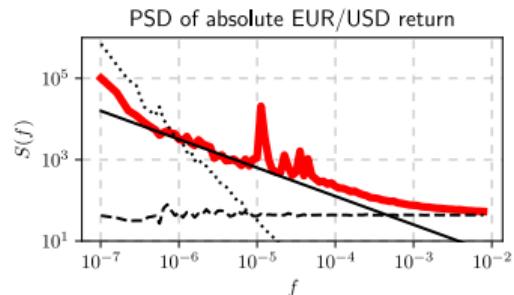
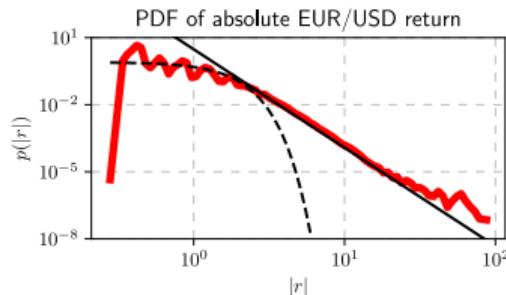


Discontent with financial policy making encourages exploration of economics from physical point of view:

“Econophysics is a little like Biophysics or Geophysics or Astrophysics which tells you that people involved in these fields are interested in Biology or Geology or Astronomy, which they connect from a Physics point of view.”  
(H. E. Stanley, 1995)

Fig.: KAL (Baltimore Sun)

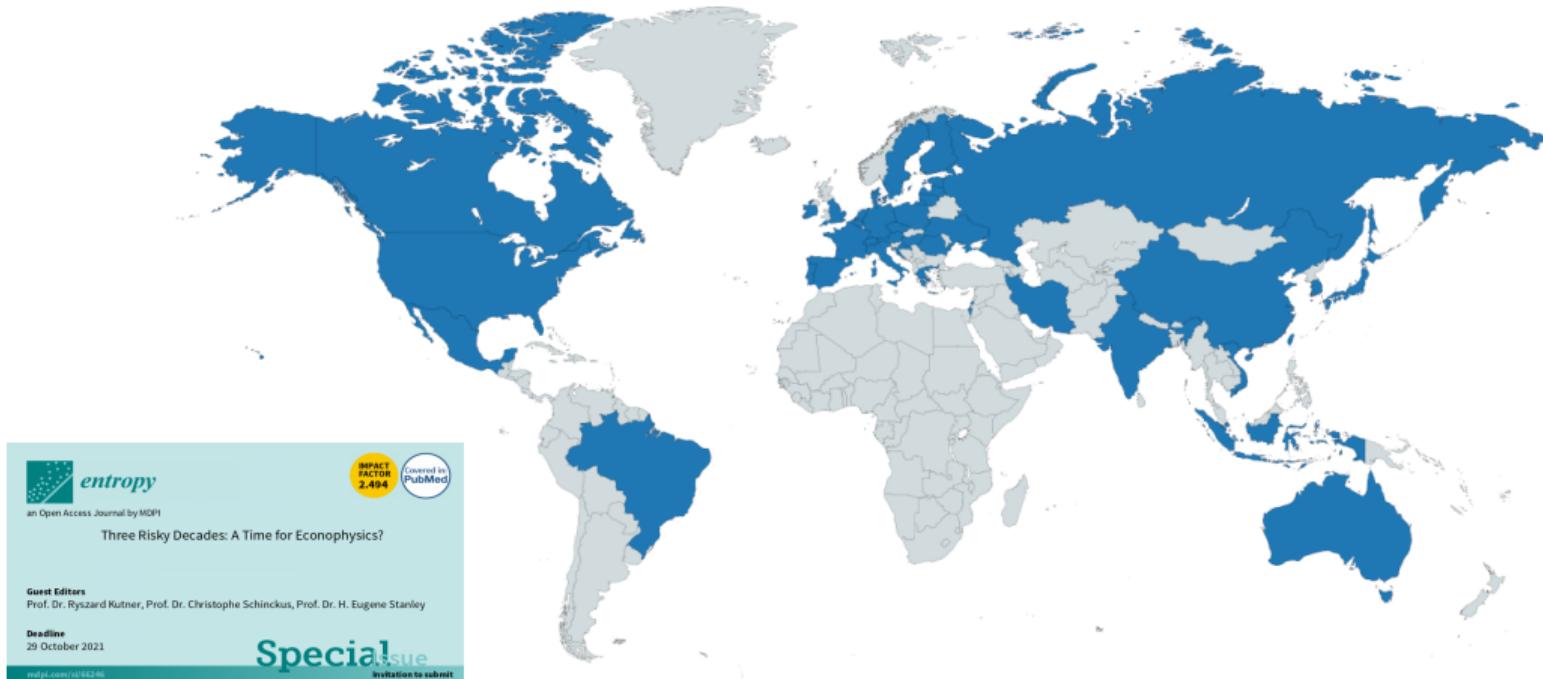
# Self-similarity in financial and other social data



All black solid lines are  $f(x) = x^s$ . Power-laws are self-similar:  $f(a \cdot x) = a^s f(x)$ .

Data: [histdata.com](http://histdata.com) (Forex EUR/USD), [data.stat.gov.lv](http://data.stat.gov.lv) (town pop. in Latvia), [irs.lt](http://irs.lt) (attendance), [demographics.coopercenter.org](http://demographics.coopercenter.org) (segregation).

# 2020s: Researchers world-wide



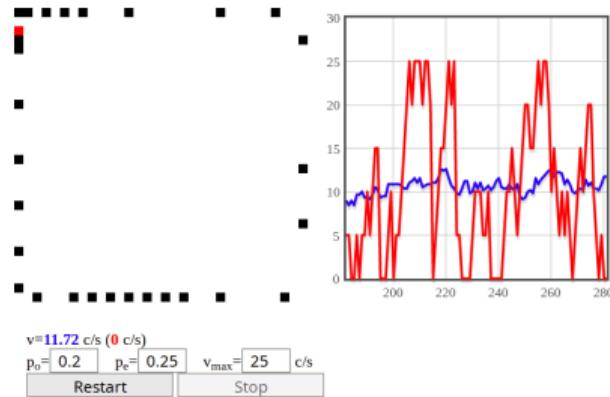
Generated using [mapchart.net](#) based on Econophysics Colloquim 2021, Entropy SI, FuturICT 2.0 and personal connections. Latvia: Riga Technical University.

## Selected problems and models

# Why do the traffic jams occur?

N-S model:

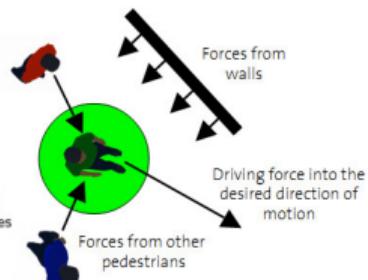
- ① Cars accelerate one step up to  $v_{max}$ .
- ② Slow down if collision imminent.
- ③ Slow down due to (random) error.



[Helbing & Molnar, 1995]

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

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



Interactive model: Nagel–Schreckenberg model. Bottom: [Helbing "Pedestrians, Crowds, Disasters, and the Role of Self–Organization" (2010)].

# Power-law distribution of wealth

- ① Pick two agents  $i$  and  $j$ .
- ② Assume transfer of wealth  $\Delta w$  from  $i$  to  $j$ :

$$\Delta w = (1 - \varepsilon) w_i - \varepsilon w_j.$$

- ③ Adjust agents' wealth:

$$w_i := w_i - \Delta w,$$

$$w_j := w_j + \Delta w.$$

What if fraction of wealth is saved?

$$\Delta w = (1 - \varepsilon)(1 - \kappa_i) w_i - \varepsilon(1 - \kappa_j) w_j.$$

Fig.: [Patriarca & Chakraborti (2013)]; Interactive model: [Kinetic model with heterogeneous saving](#).

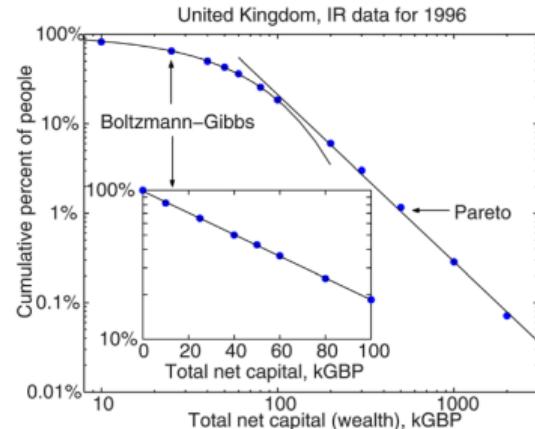
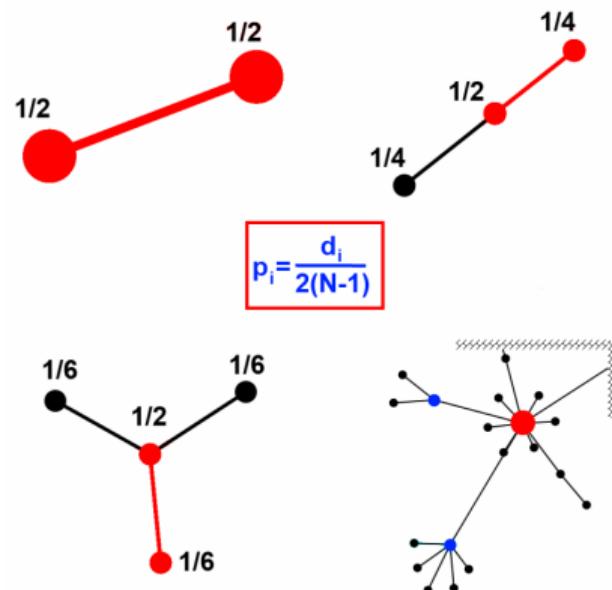


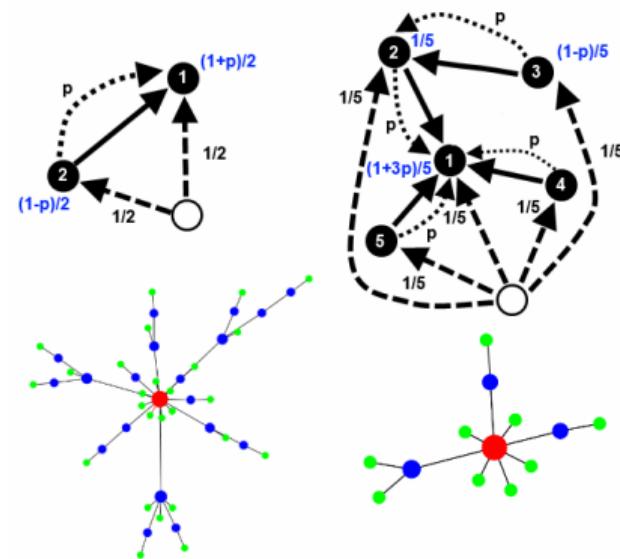
Fig. 1. Cumulative probability distribution of the net wealth, composed of assets (including cash, stocks, property, and household goods) and liabilities (including mortgages and other debts) in the United Kingdom shown on log-log (main panel) and log-linear (inset) scales. Points represent the data from the Inland Revenue, and solid lines are fits to the Boltzmann-Gibbs (exponential) and Pareto (power) distributions (Ref. 15).

# Why are some papers extremely well cited?

Barabasi–Albert model



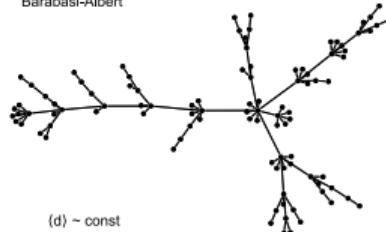
Edge redirection model



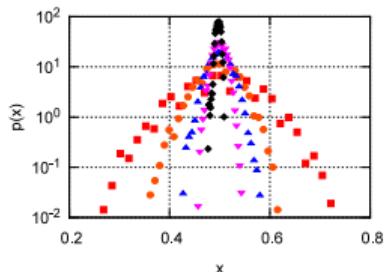
Interactive models: Barabasi–Albert model, Edge redirection model

# How do the networks impact dynamics?

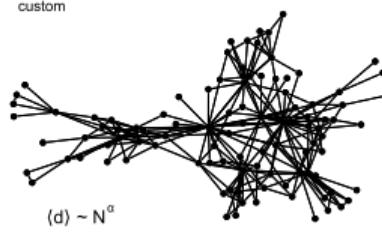
Barabasi-Albert



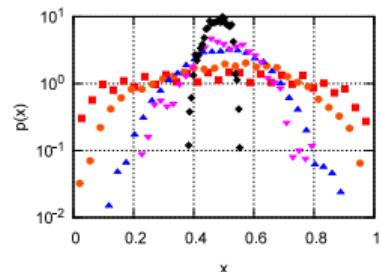
$(d) \sim \text{const}$



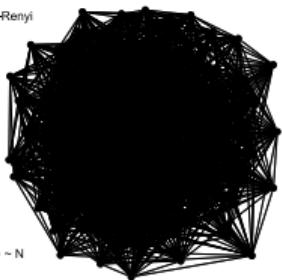
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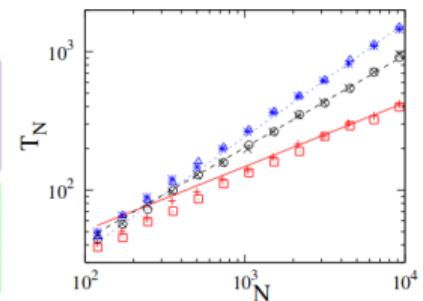
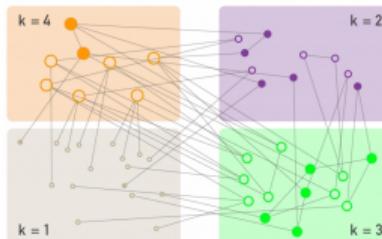
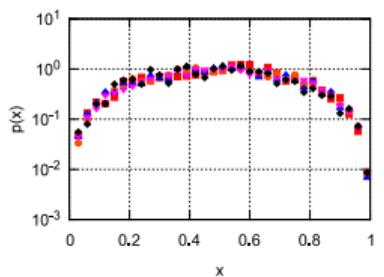
$(d) \sim N^\alpha$



Erdos-Renyi



$(d) \sim N$



Figs.: [Kononovicius & Ruseckas (2014)], [Barabasi "Network Science"], [Sood & Redner (2005)].

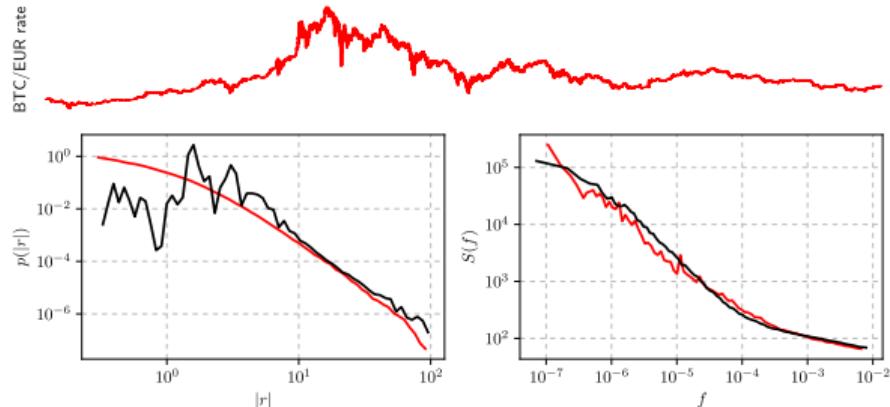
# Madness of the financial markets

**Homo economicus** is:

- informed
- rational
- self–interested



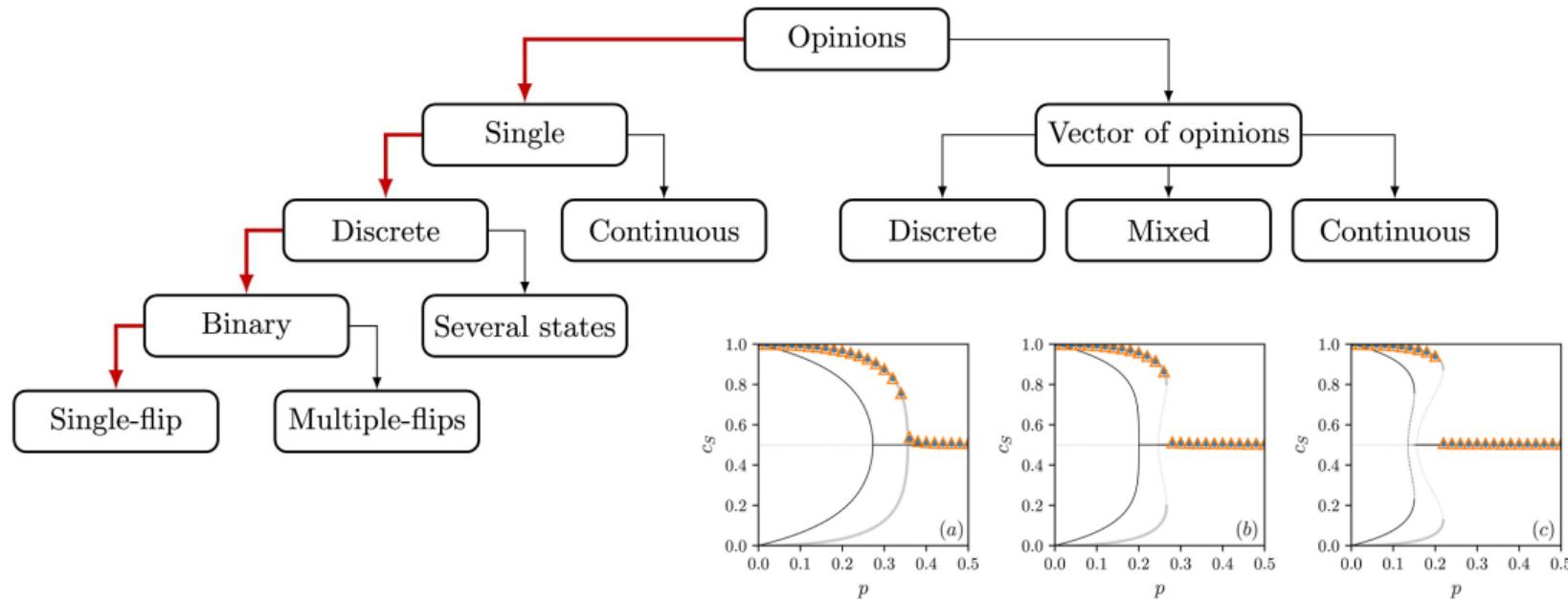
Fig.: Jeff Parker (caglecartoons). Related: [Kononovicius *et al.*(2012), (2019)], [Cristelli *et al.*(2012)], [Kanazawa & Sornette (2021)].



- **Noise trader** trades based on the market mood.
- **Fundamental trader** trades based on the fundamental price.

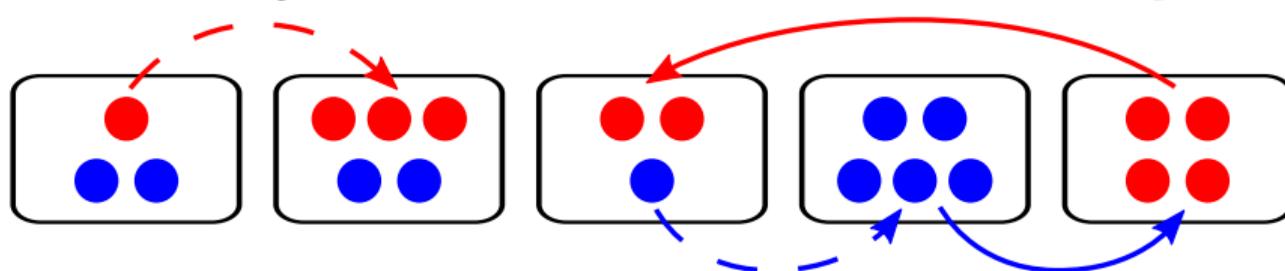
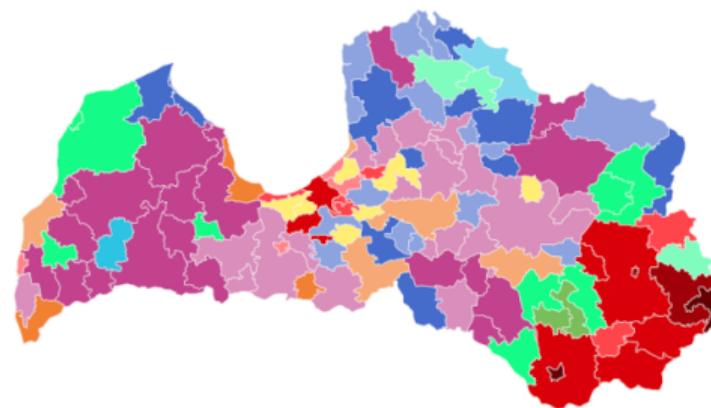
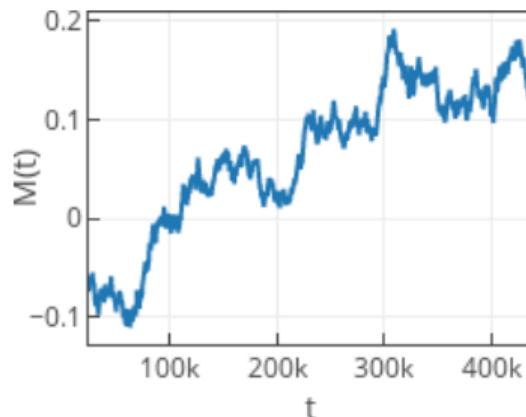
Interactive models: #financial-markets.

# Idealized opinion dynamics



Figs.: [Jedrzejewski *et al.*(2018), (2019)]. Related: [Castellano *et al.*(2009)], [Peralta *et al.*(2023)]. Interactive models: #opinion-dynamics.

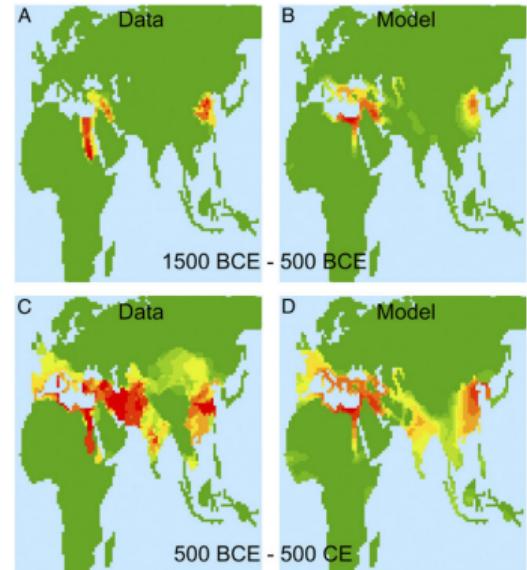
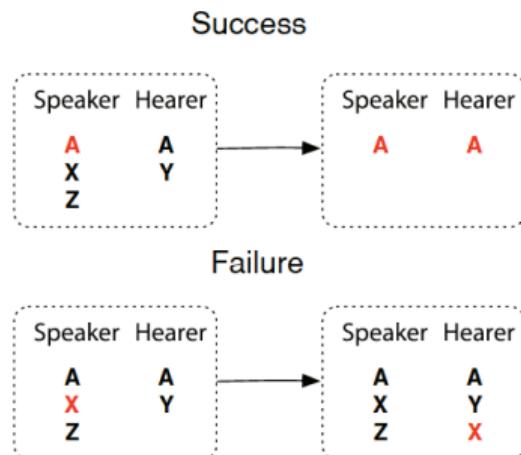
# Opinion dynamics and data



Figs.: q-Voter model, Gajmar@Wikipedia, Compartmental voter model. Related: [Kononovicius (2017), (2019)], [Peralta *et al.*(2023)].

# Other problems

- Economic complexity
- Group formation
- Language dynamics
- History
- Corruption
- Military conflict
- Epidemiology
- Attention dynamics



Figs: [Baronchelli (2011)], [Turchin *et al.*(2013)]. Related: [Cristelli *et al.*(2015)], [Villamil *et al.*(2022)], [Aruka *et al.*(2022)], [Lee *et al.*(2020)].

# Summary

# Key points

- Highly varied field
- Universality
- Interactions over components
- Emergent behavior



Fig.: Internet + spinons from papers by Sznajd-Weron group

# Thank you!

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