Interdependent Evolution of Non-Spectral Opinions and Social Networks

Fabian Russmann and Stefan Rustler
"Social State Physicists"

Zurich, December 18 2012

Overview

BACKGROUND AND MOTIVATION

- Opinion Formation (e.g. voter models) is a common and very fundamental problem in the social sciences
- Goal: Modelling the *co*evolution of both opinions and the underlying social network
- **Does our social network shape the opinion we hold or does our opinion determine who is part of our network?**
- Preview: Analogies to statistical physics, e.g. *phase transitions* can be identified

- ”Opinion” must be mutually exclusive and ”non-spectral”, e.g. brand preference, religious views...

INITIAL SETUP

- Random graph with N nodes (opinion holder) and M edges (social connection)
- Random opinion $g_i \in G$ assigned to node i
- Nodes exchange information (opinion) via undirected edges
- Externally set parameters:
  - N - number of nodes
  - $\gamma = \frac{N}{G}$ - average number of nodes per opinion
  - $k_{avg} = \frac{2M}{N}$ - average degree
  - Φ - reconnection probability

TIME EVOLUTION ALGORITHM

1. Pick a random node i with opinion g_i.
2. (**a**) With probability Φ select at random one of the nodes j that i is connected to.
   - If $g_i = g_j$, start over at step 1.
   - Otherwise, reconnect to a randomly chosen j' of same opinion, i.e. $g_{j'} = g_i$.
3. (**b**) Otherwise, with probability $1 - \Phi$ randomly select one of the neighboring vertices j and change g_i to g_j.
4. Repeat until *consensus state* is achieved.

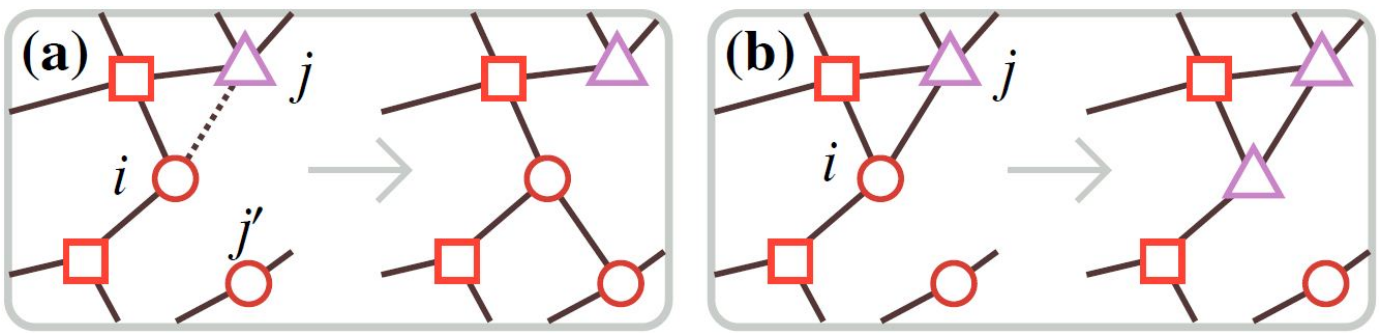
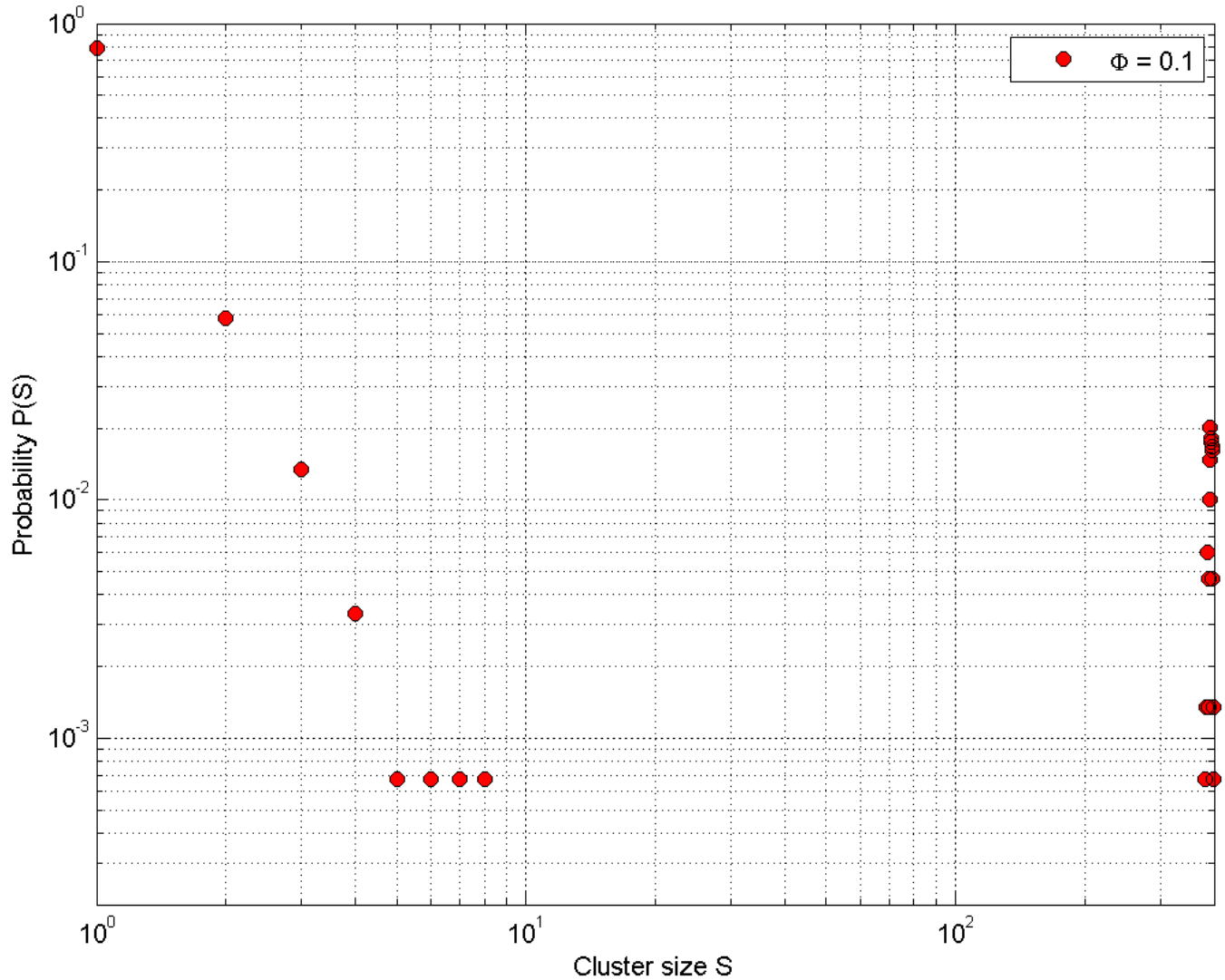
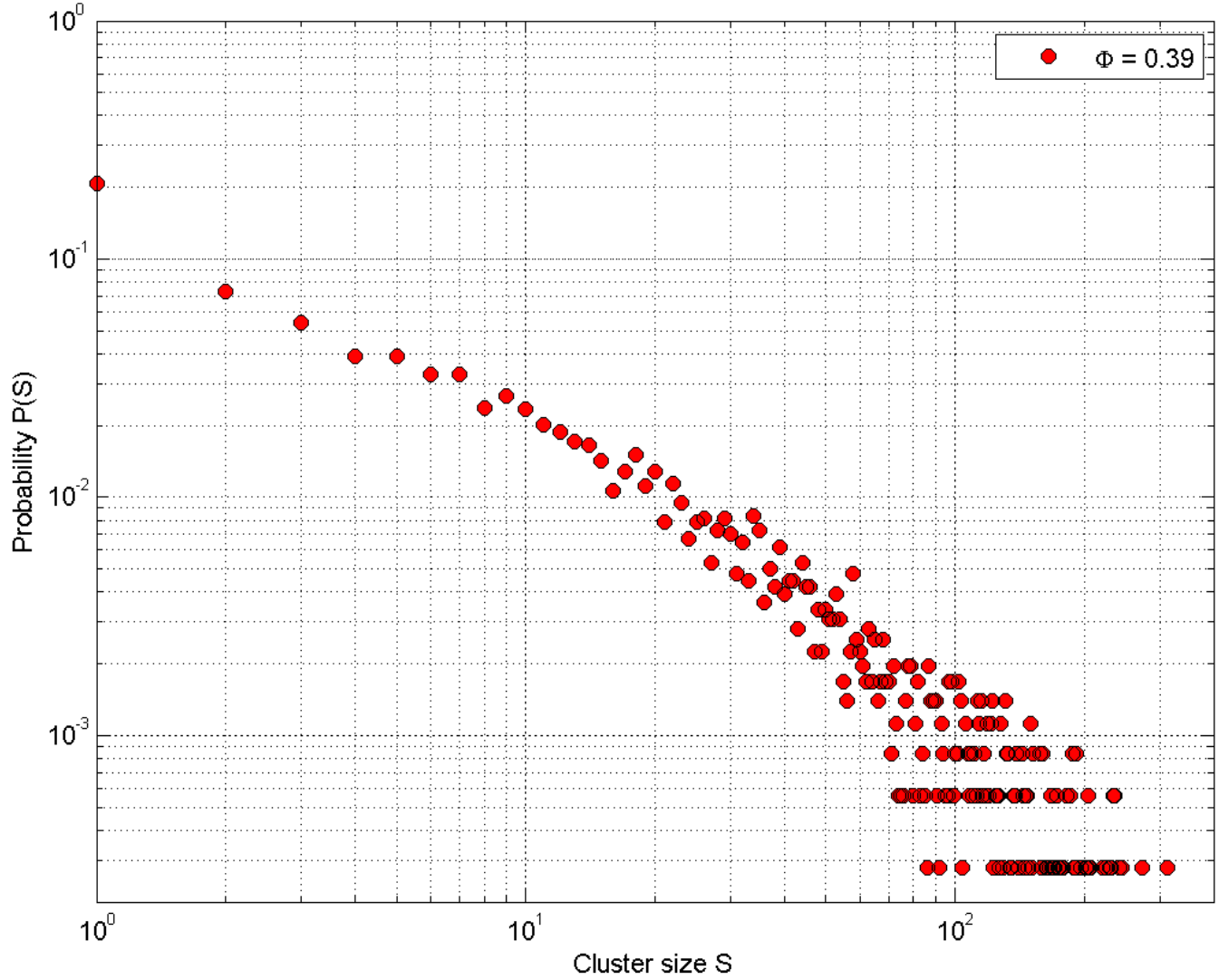


Figure: Holme and Newman, 2006 [5]

CLUSTER SIZE DISTRIBUTION



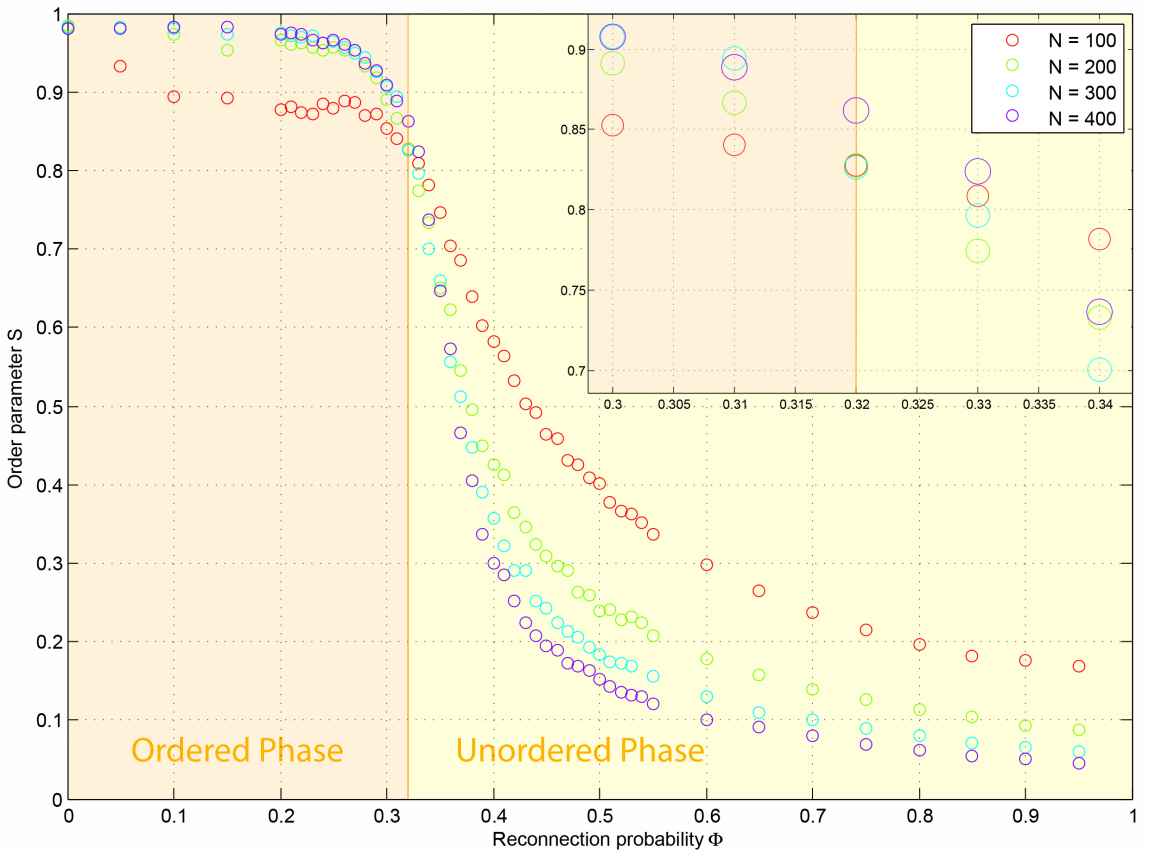
CONTINUOUS PHASE TRANSITION?



CLUSTER SIZE DISTRIBUTION

- Ordered phase
  - Low Φ, i.e. tendency to change opinion
  - Small clusters follow power law distribution
  - Existence of giant cluster
- Unordered phase
  - High Φ, i.e. tendency to keep opinion
  - Clusters follow Poisson-like distribution
  - No giant cluster!
- Phase transition
  - First guess: $\Phi_c = 0.35 \pm 0.05$
  - Power law behavior over the whole s-range

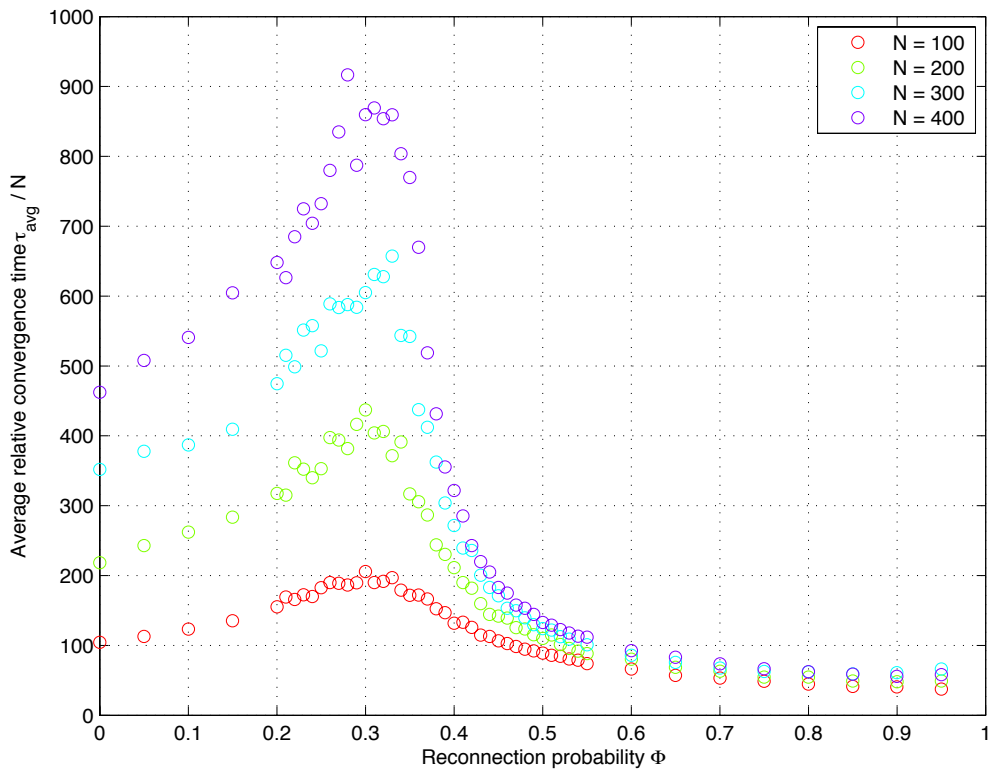
PHASE TRANSITION & CRITICAL POINT



- Really continuous phase transition
- Bigger $N \rightarrow$ more dramatic transition
- $\Phi_c = 0.32 \pm 0.02$ independent of system size N
- Weak agreement with $\Phi_c = 0.39 \pm 0.05$

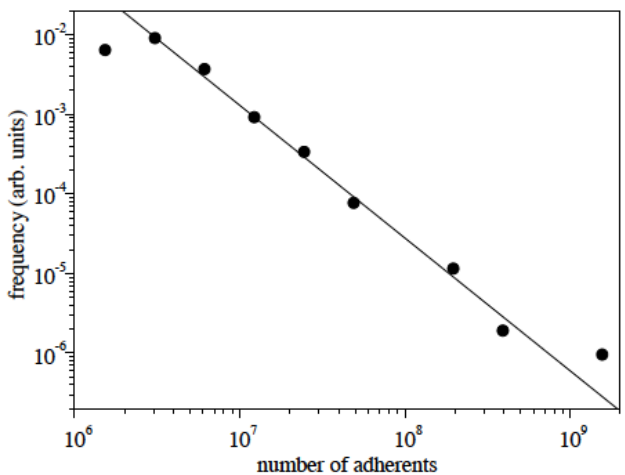
CONVERGENCE TIME

- Iterations per node to reach consensus as function of Φ:
- "Divergence" at some Φ_c for different N
- Similar to divergent response functions in physics
- Supporting phase transition interpretation, but difficult to find direct analogy to τ_{avg}



COMPARISONS TO EMPIRICAL DATA

- Idea: Compare distributions of some ”opinion” in real world to the model → identify and interpret corresponding Φ
- **Religion:**
- Worldwide distribution of religions follows power law: Neither adaptation nor reconnection dominate in the formation?

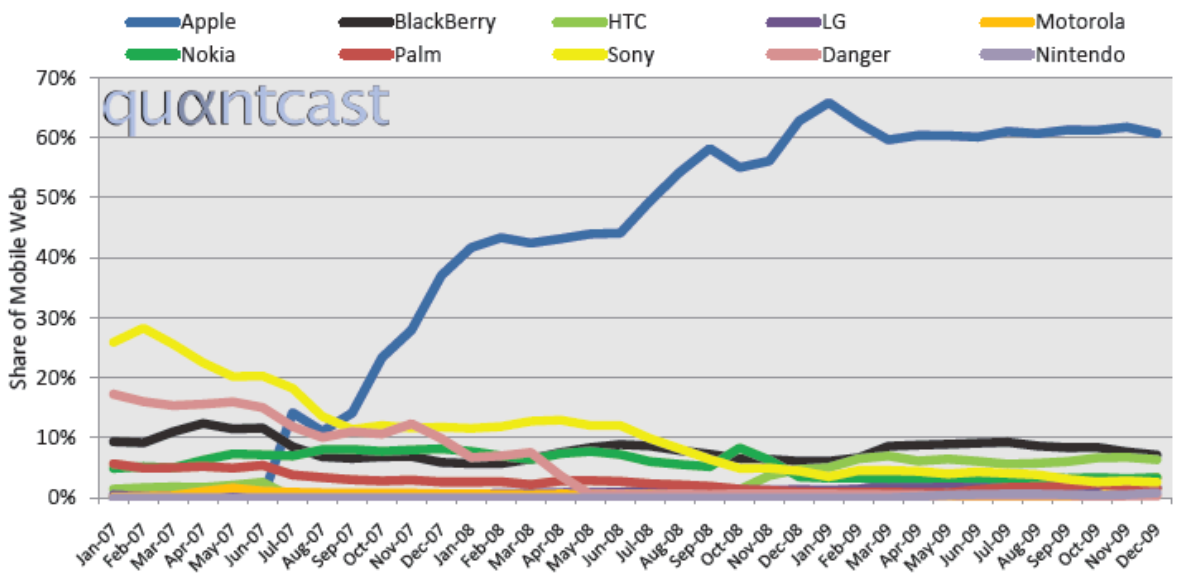


- Interpret Φ as an ”intolerance indicator”?

Zanette and Manrubia, 2000 [9]

COMPARISONS TO EMPIRICAL DATA

- **Mobile Web Browsers:**
- An example for opinion = brand preference
- Contrast between giant cluster and ”softer” distribution
- Note: Plot is not a cluster size histogram!



- Interpret Φ as a ”brand loyalty indicator”?

Quantcast Review, 2009 [7]

SUMMARY

- Interdependent evolution of opinions and networks, combining two mechanisms of adaption and reconnection determined by Φ
- Holme's and Newman's [5] work could be reproduced with more realistic assumptions
- Continuous phase transition
  - N-independent critical value $\Phi_c = 0.32 \pm 0.02$
  - Divergent consensus time at Φ_c

Outlook

- Variation of γ (diversity) and k_{avg} (density)
- Include analogue of "magnetic field" in model: *"informed agents"*?
- Make opinions *spectral*
- More detailed comparisons to empirical data

REFERENCES


R. Albert, A.-L. Barabasi. *Statistical mechanics of complex networks*. Rev. Mod. Phys, 74:4798, 2002.


S. Brugger, C. Schwirzer. *Opinion formation by "employed agents" in social networks*. Project Report: Modelling and Simulating Social Systems with MATLAB, ETH Zurich, 2011.


C. Castellano, D. Vilone, and A. Vespignani. *Incomplete ordering of the voter model on small-world networks*. Europhys. Lett., 63:153158, 2003.


P. Erdős, A. Rényi. *On the evolution of random graphs*. Publications of the Mathematical Institute of the Hungarian Academy of Sciences 5: 1761, 1960.


P. Holme, M. E. J. Newman. *Nonequilibrium phase transition in the coevolution of networks and opinions*. Physical Review E, vol. 74, Issue 5, id. 056108, 11/2006.


W. Nolting. *Grundkurs Theoretische Physik 6: Statistische Physik*. Springer Berlin Heidelberg. 5. Aufl, 2004.


Quantcast, *Quantcast Review of 2009 Mobile Web Trends*. "https://www.quantcast.com/inside-quantcast/2010/01/quantcast-review-of-2009-mobile-web-trends-mobile-web-share-up-110-in-north-america-and-148-globally" Accessed December 13, 2012.


V. Sood, S. Redner. *Voter model on heterogeneous graphs*. Phys. Rev. Lett., 94:178701, 2005.


D. H. Zanette,S. C. Manrubia. *Vertical transmission of culture and the distribution of family names*. Physica A, 295:18, 2001.


A. Zheludev. *Advanced solid state physics*. Lecture, ETH Zurich, Fall 2012.