Modeling face-to-face social interaction networks

Romualdo Pastor-Satorras
Dept. Fisica i Enginyería Nuclear
Universitat Politècnica de Catalunya
Spain
http://www.fen.upc.edu/~romu

Work done in collaboration with ...

Michele Starnini

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

Andrea Baronchelli

Northeastern University

Alain Barrat

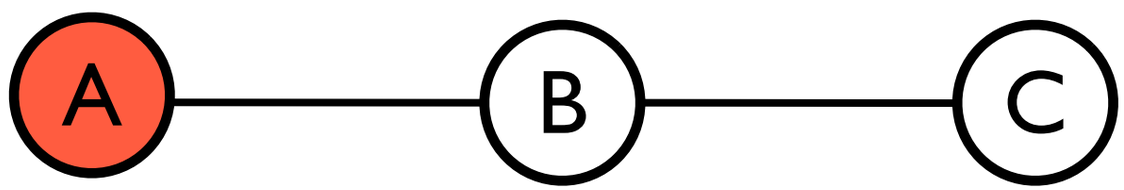
cnrs
dépasser les frontières

Dynamical social networks

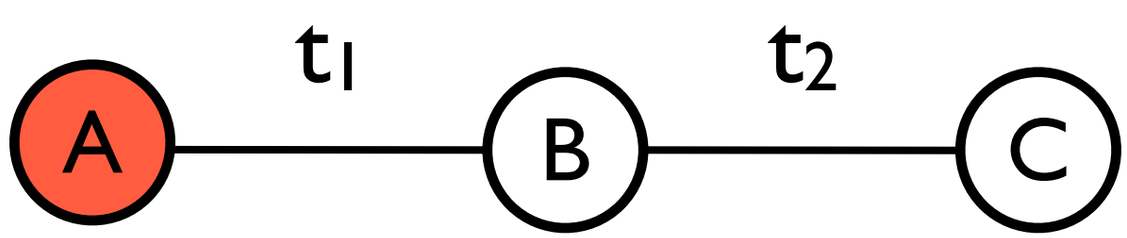
- Networks have been used since long to characterize social systems (1934, J. Moreno)
- Many insights have been obtained, by looking at the topological properties of social networks
  - ➡ Small diameter, long tailed distributions, high clustering, community structure, etc
- Most previous considerations have focused on *static* social networks, in which vertices and edges do not change in time
  - ➡ Approximately correct in certain cases: citation networks
- Social interaction networks are however intrinsically dynamic, edges being a succession of contact or communication events, which are constantly created or terminated between pairs of individuals (actors)
  - ➡ Static networks being an integrated projection of dynamical ones
- The temporal dimension of social networks has important consequences
  - ➡ Epidemic spreading, usually considered on static networks

Effects of network dynamics on epidemics

- Key point: You are not in contact with all your friends simultaneously
- Imagine three individuals: Anne, Bob and Carol
- Anne has a contact with Bob and Bob has a contact with Carol



- In a simple network interpretation, if Ann has a disease, she can pass it to Carol
- Adding a temporal dimension, the timing of the contacts matters



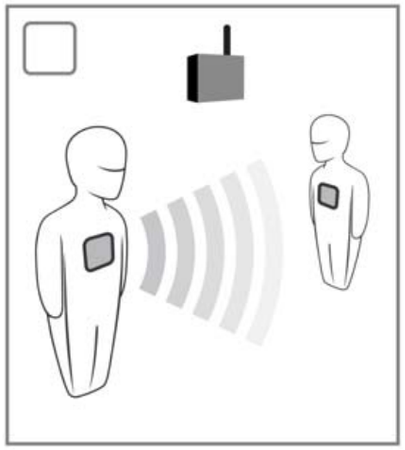
➡ If $t_2 < t_1$, then Carol cannot catch the disease!

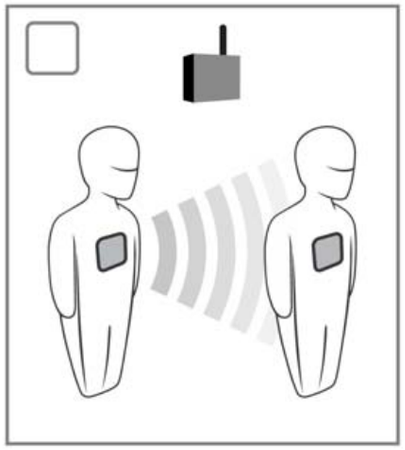
Empirical analysis of dynamical social networks

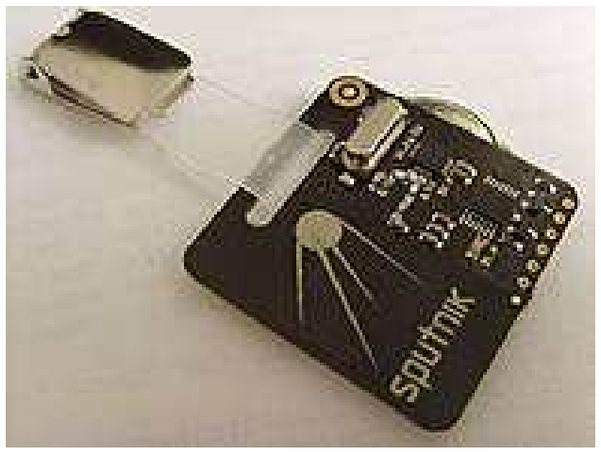
- The empirical measurement of social interactions is a non-trivial task
  - ➡ Classically, it was performed by means of personal interviews and questionnaires
    - ❖ Expensive, time consuming, unreliable
- Recent technological advances have made possible the real-time tracking of social interactions in groups of individuals, at several temporal and spatial scales
  - ➡ E-mail exchanges
  - ➡ Mobile phone communications
- Here we focus on a cheap, largely scalable and high-resolution method:
  - ➡ The SocioPatterns project

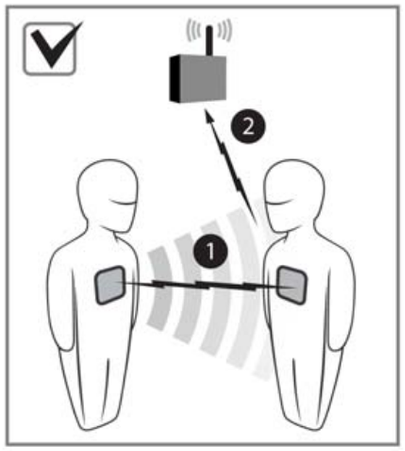
The SocioPatterns Project

- Measure of the contact patterns of a group of interacting individuals in a spatially bounded setting, such as a set of offices or a conference. The participants are asked to carry small RFID tags (beacons). These beacons continuously broadcast small data packets which are received by a number of stations and relayed through a local network to a server
- Tags exchange low power messages in a peer-to-peer fashion to sense their neighborhood and assess directly contacts with nearby tags
- After the beacons detect a contact, they broadcast a report message at a higher power level. These reports are received by the stations and relayed to the monitoring infrastructure. The reports are stored with a time stamp, the id of the relaying station and the id of the tags which participate in the contact event



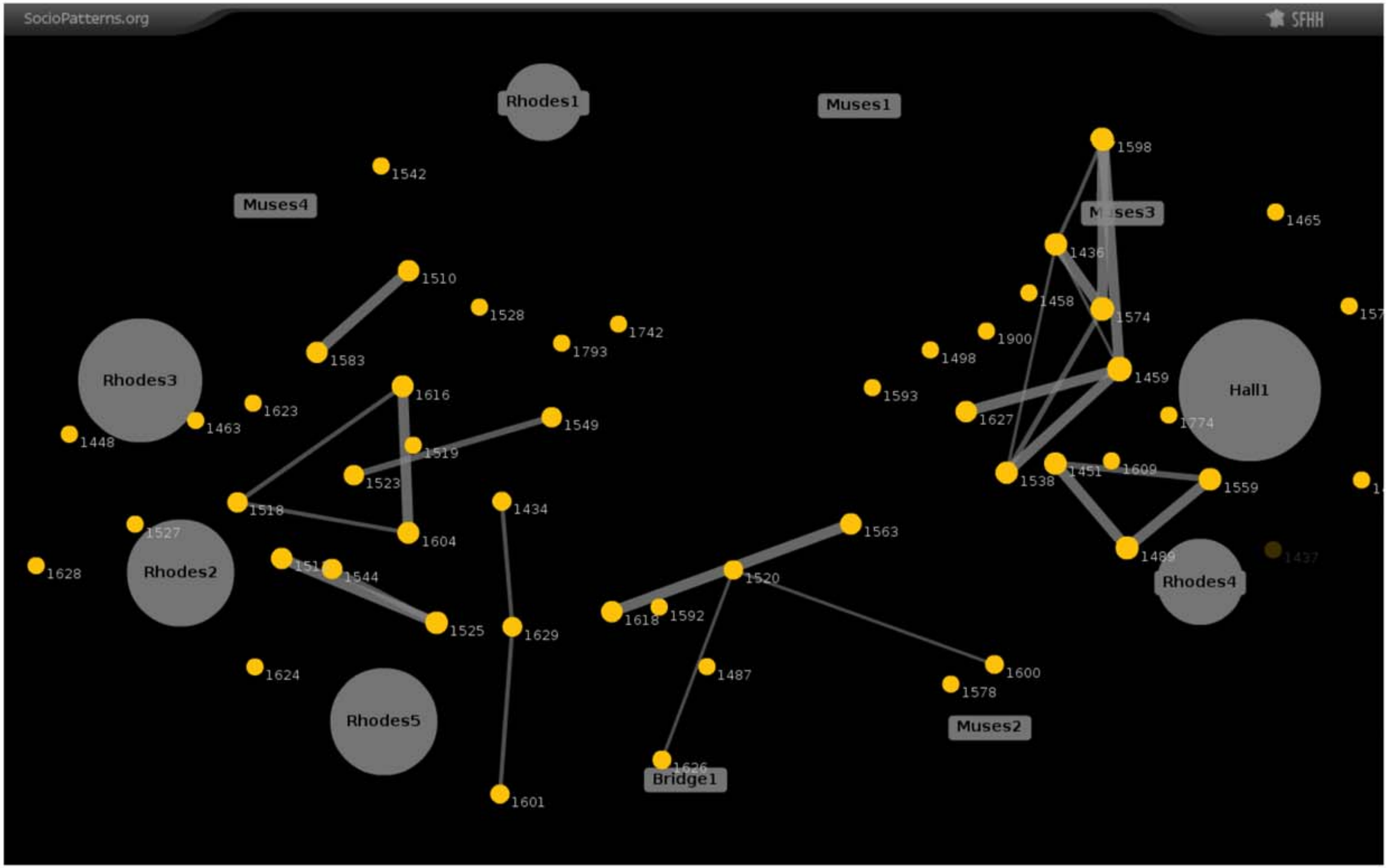






Cattuto et al. PLoS ONE (2010)

Output of SocioPatterns deployments

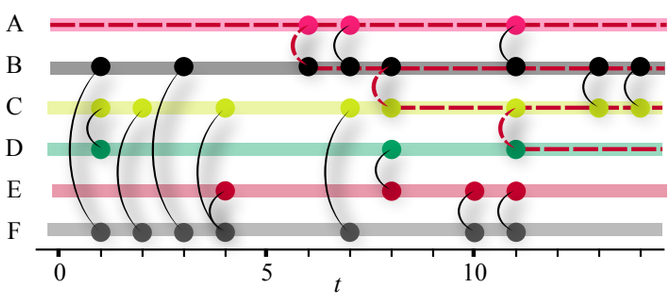


Cattuto et al. PLoS ONE (2010)

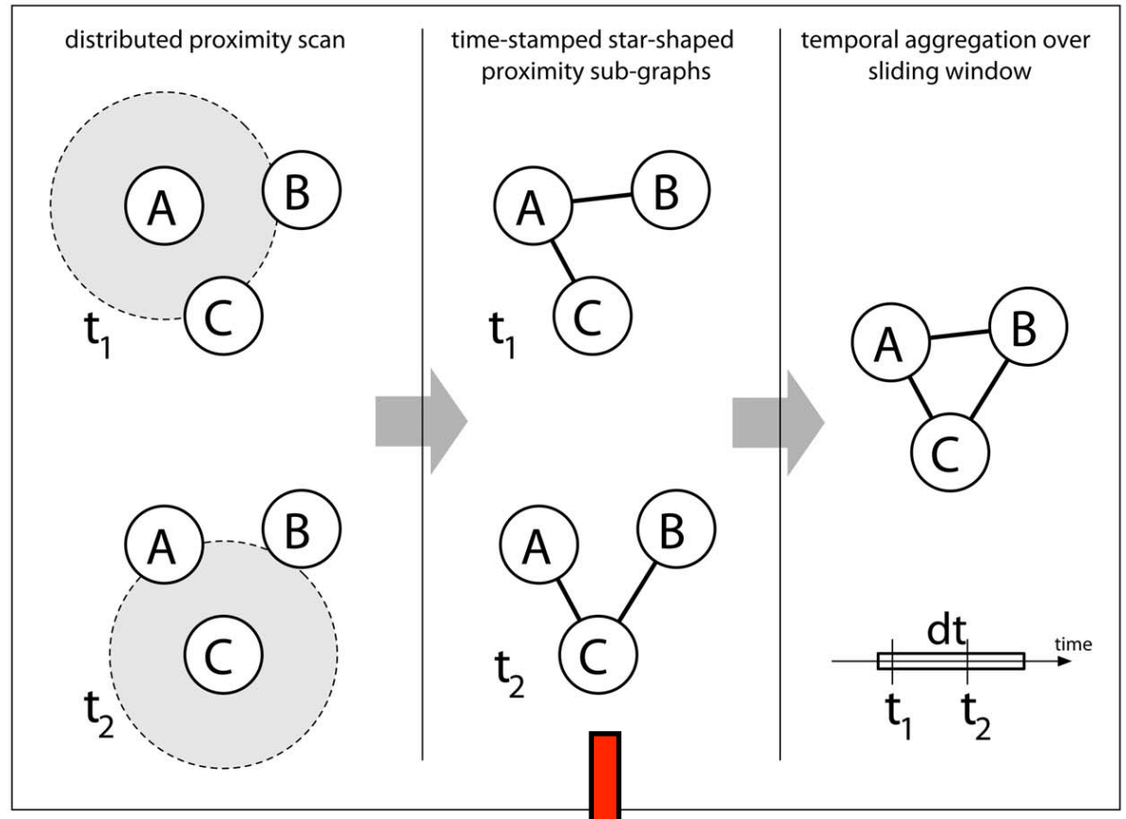
Representation of dynamical network's data

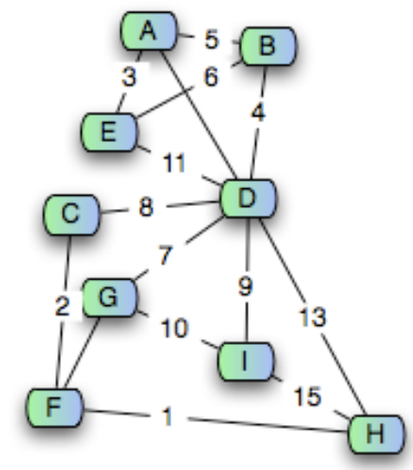
Cattuto et al. PLoS ONE (2010)

Holme et. al, Physics Reports (2011)

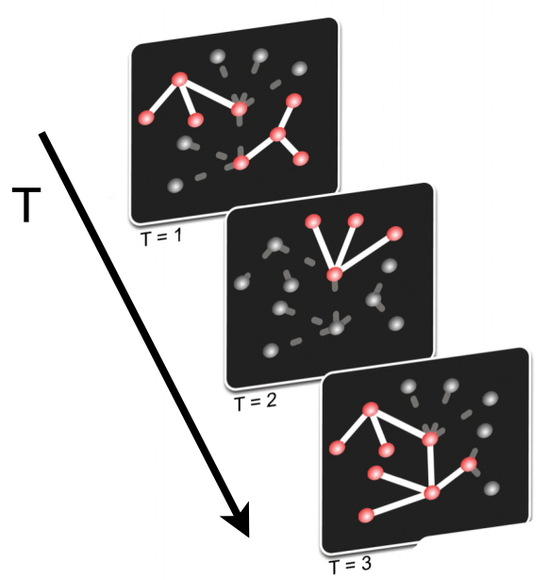


Contact Sequence





Integrated (Weighted) Network



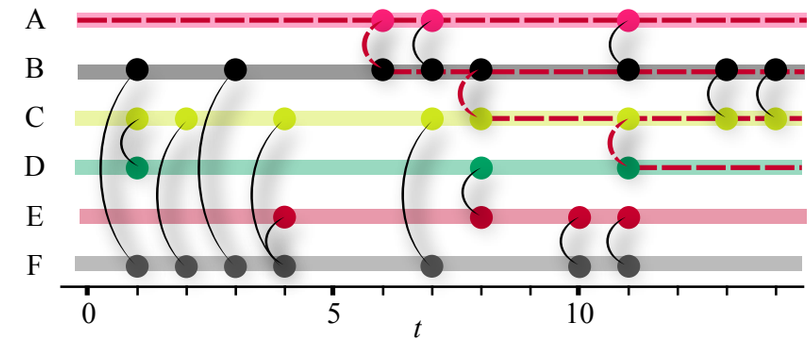
Instantaneous Temporal Networks

Statistical properties of dynamical networks

- Contact sequence:

  ➡ Analysis of the patterns of interactions between agents

  - ❖ Length of conversations Δt
  - ❖ Gap between conversations τ

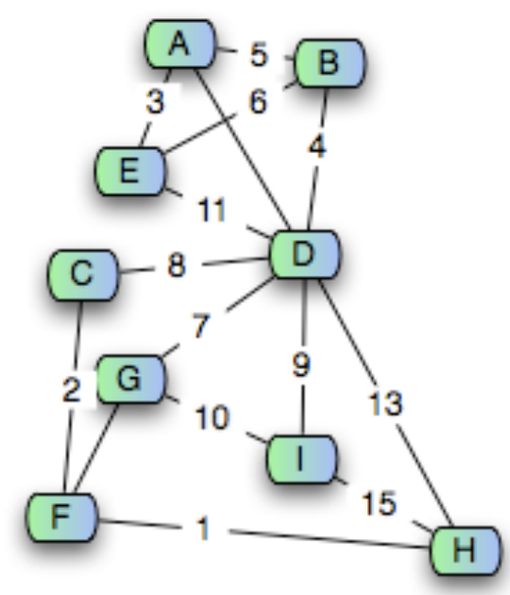


Holme et. al, Physics Reports (2011)

- Weighted integrated network:

  ➡ Topological properties of the weight pattern

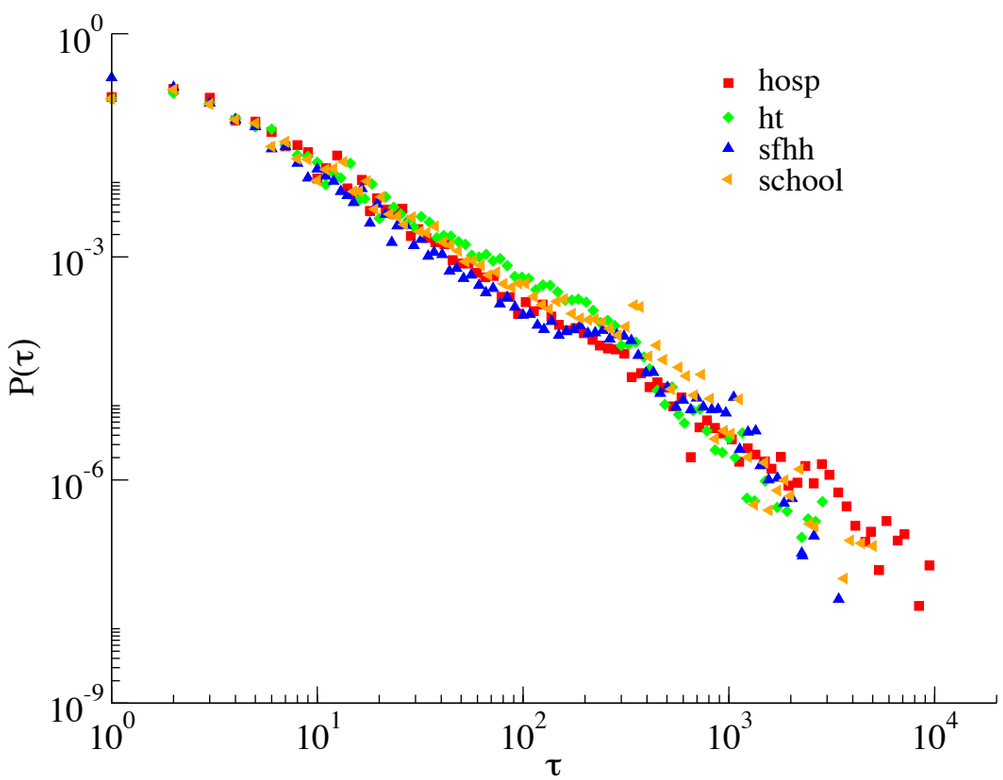
  - ❖ Weight ω of edges (time conversing)
  - ❖ Strength s (total time conversing)

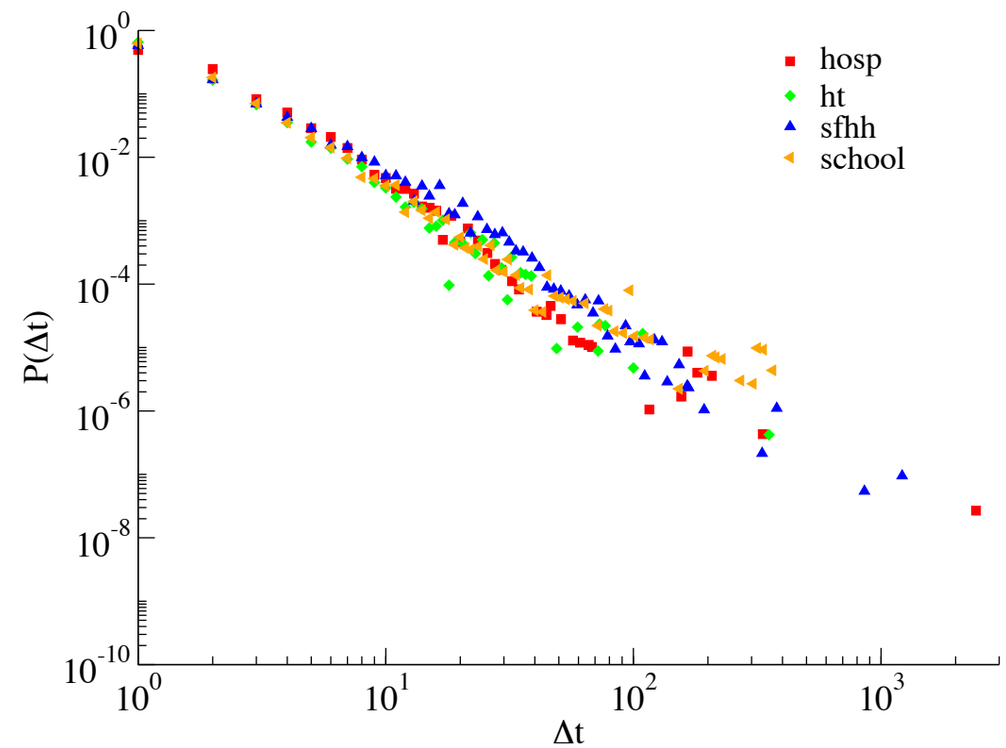


Contact sequence properties of face-to-face contacts

- Long-tailed distribution of conversation length and gaps

Distribution of gap times between consecutive conversations

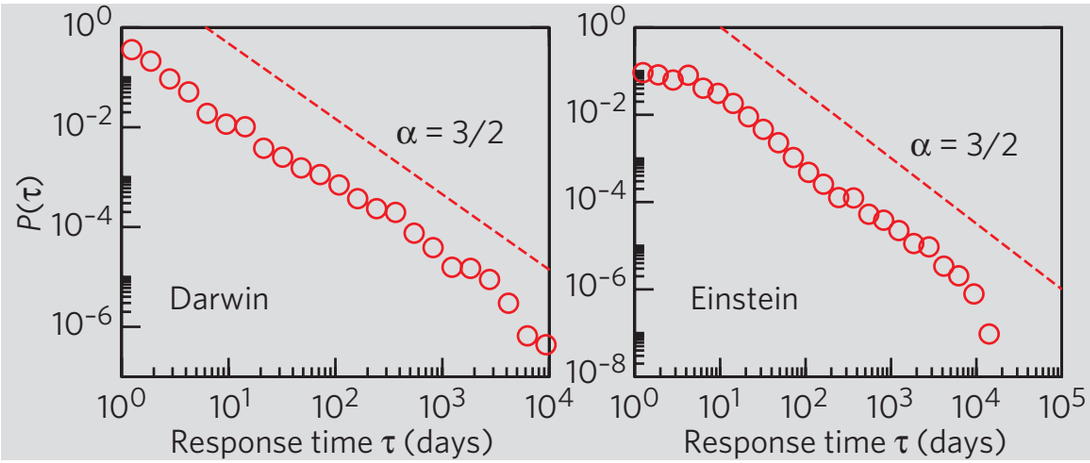




Distribution of the length of conversations

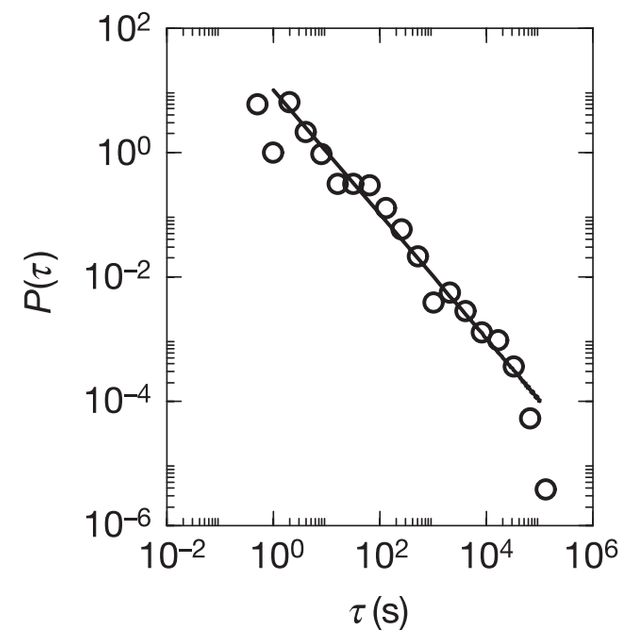
General property: “Burstiness” of human activity

Oliveira et al., Nature (2005)

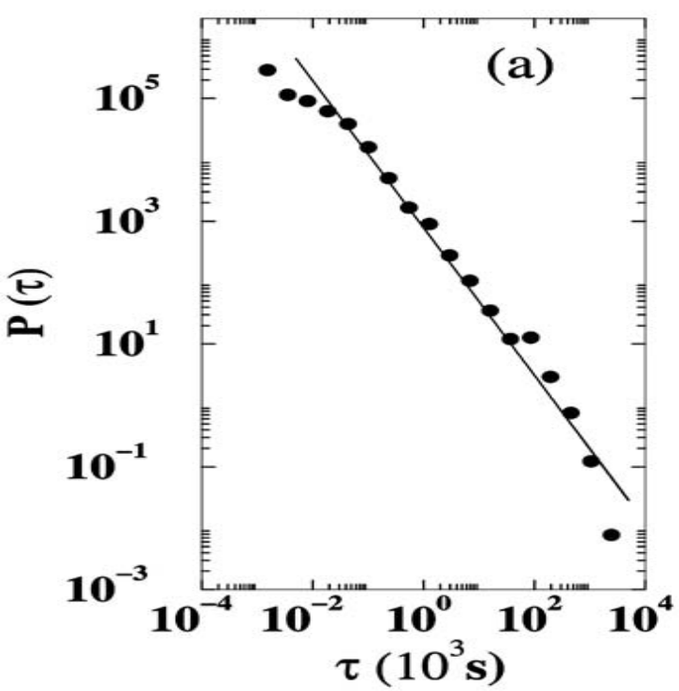


Distribution of response times between receiving a letter and answering it (Darwin-Einstein correspondence)

Barabasi, Nature (2005)



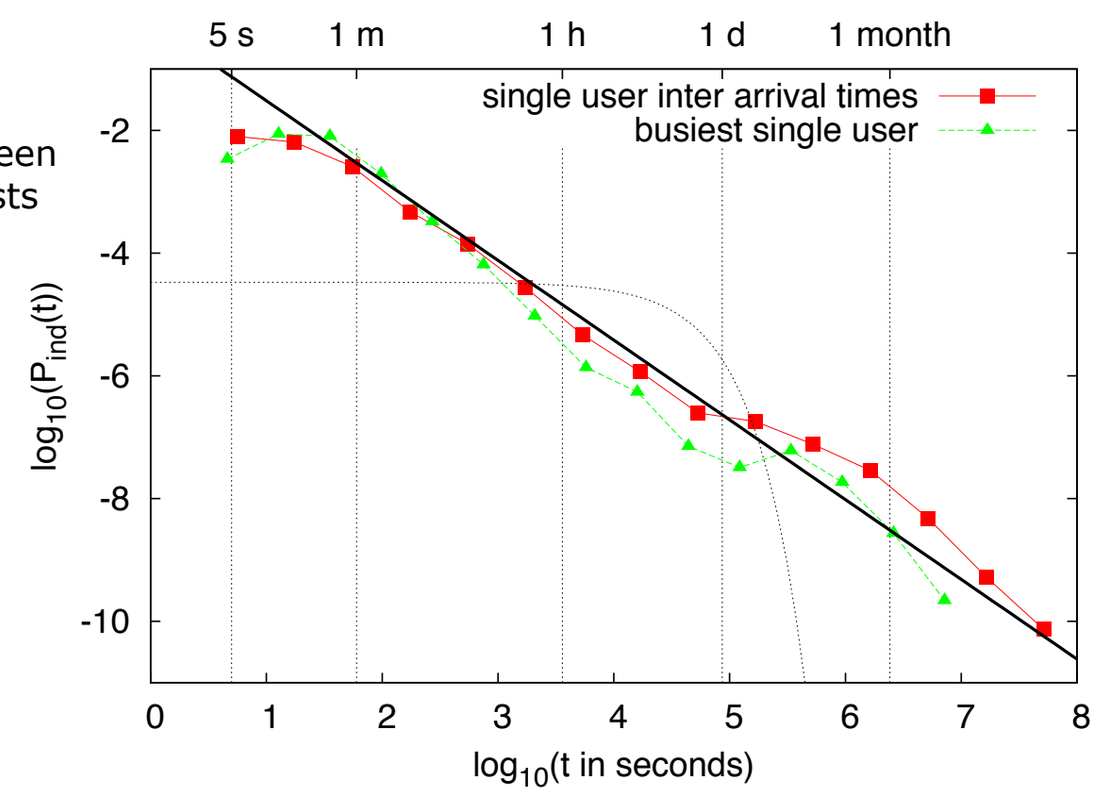
Distribution of time between consecutive e-mails sent



Distribution of times between consecutive HTML requests to the portal by the same user

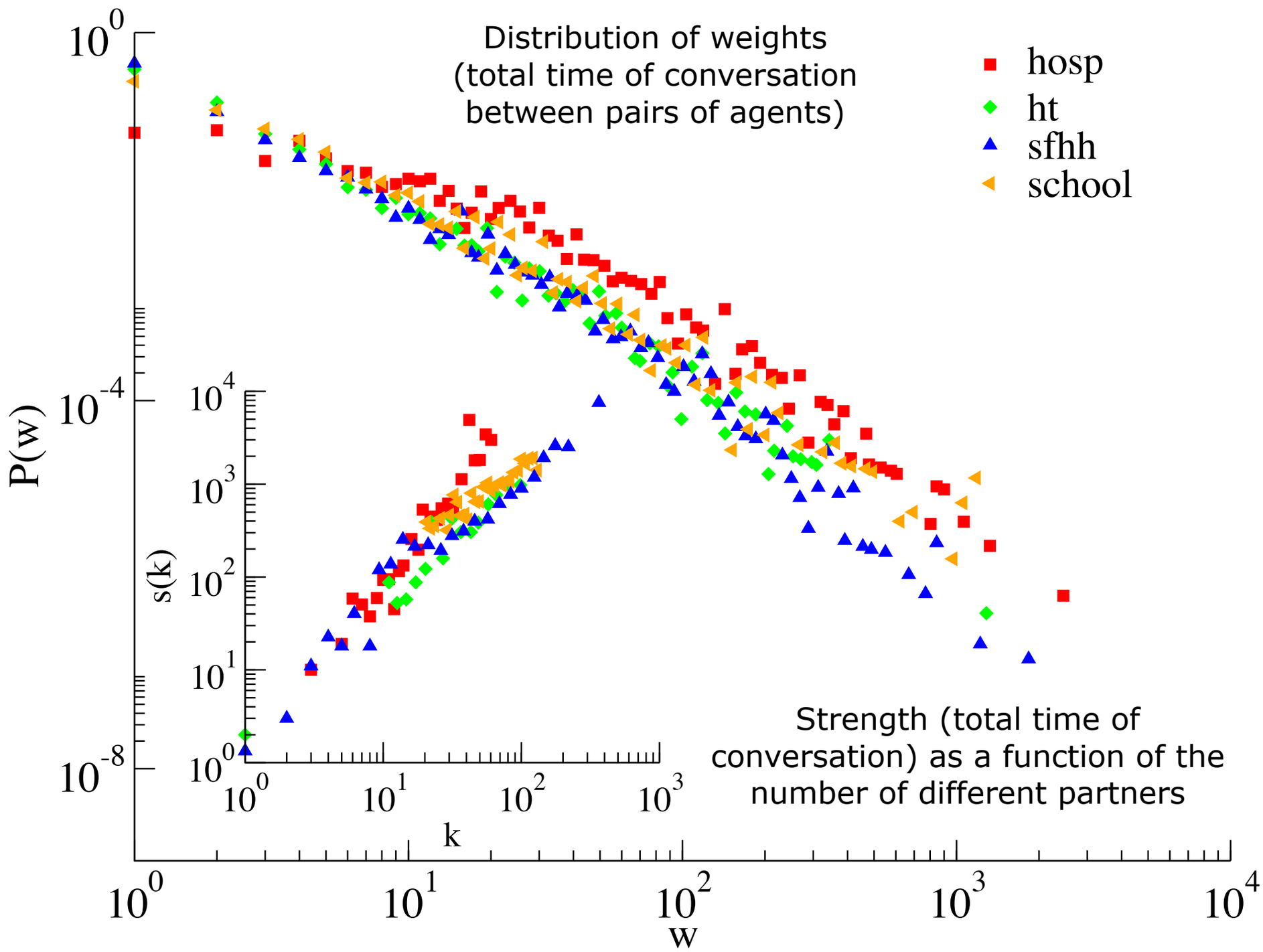
Dezso et al., PRE (2006)

Distribution of time between consecutive print requests



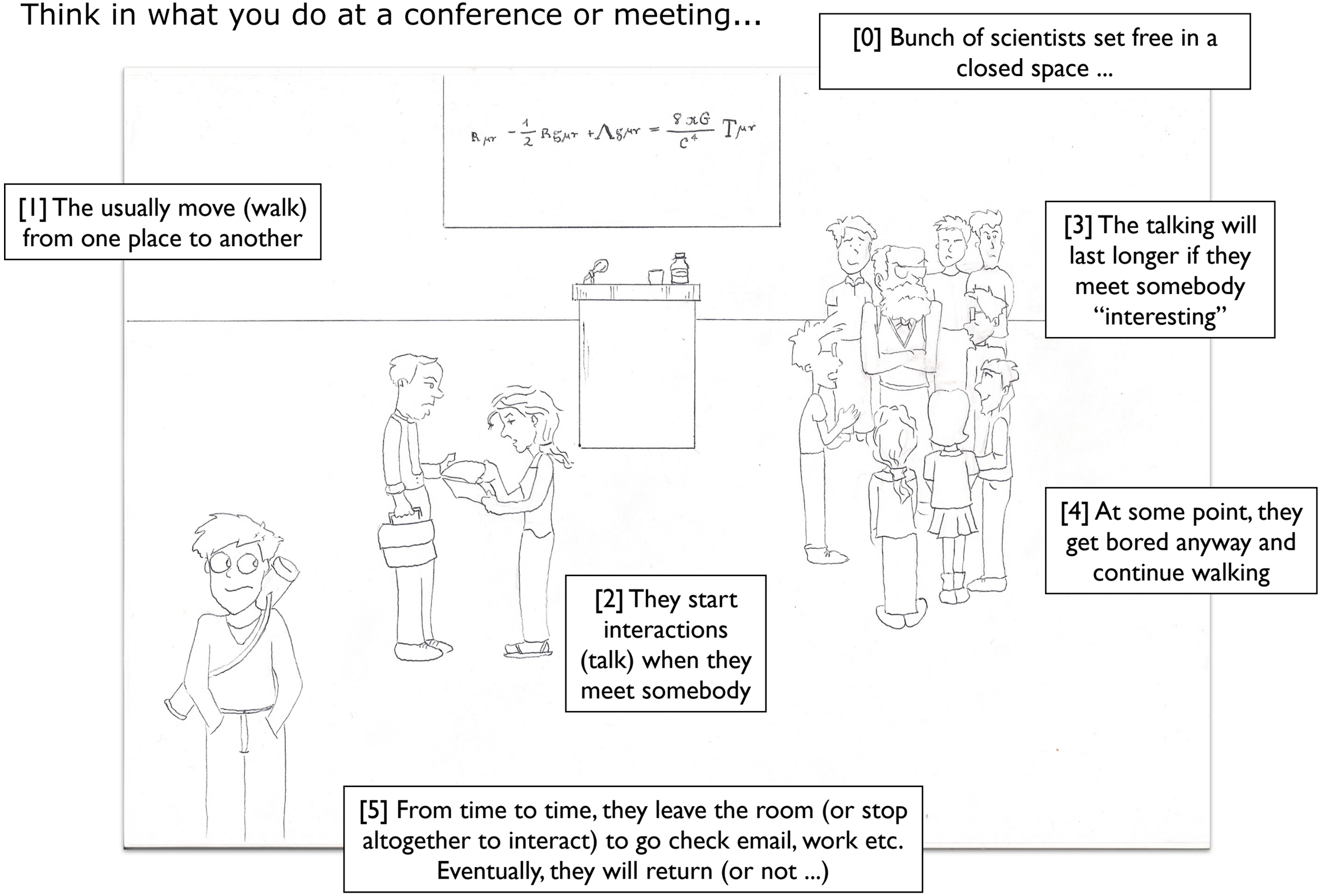
Harder et al., Physica A (2006)

Weighted network topological properties



Modeling social interaction networks

- Think in what you do at a conference or meeting...

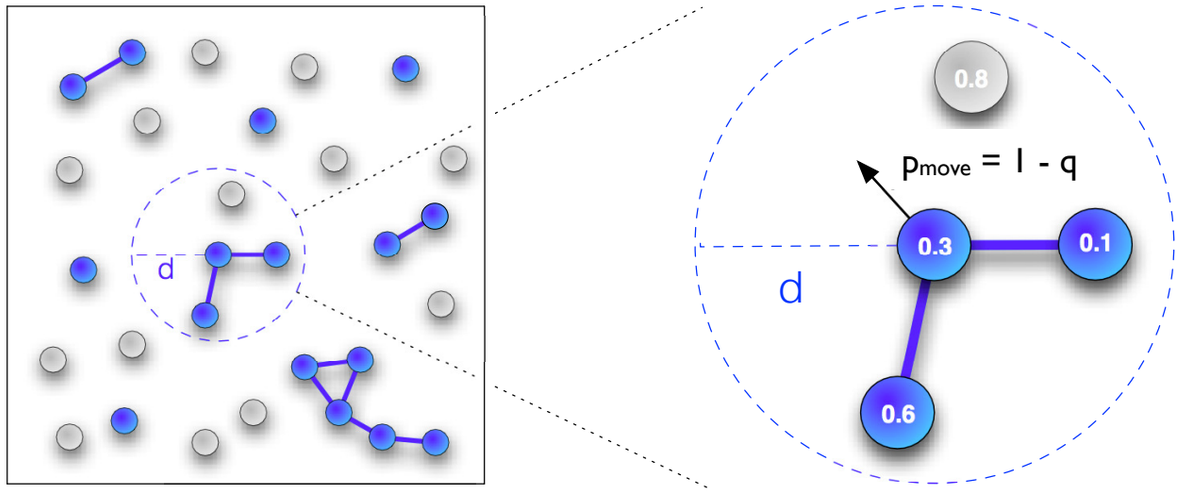


Model definition in mathematical terms

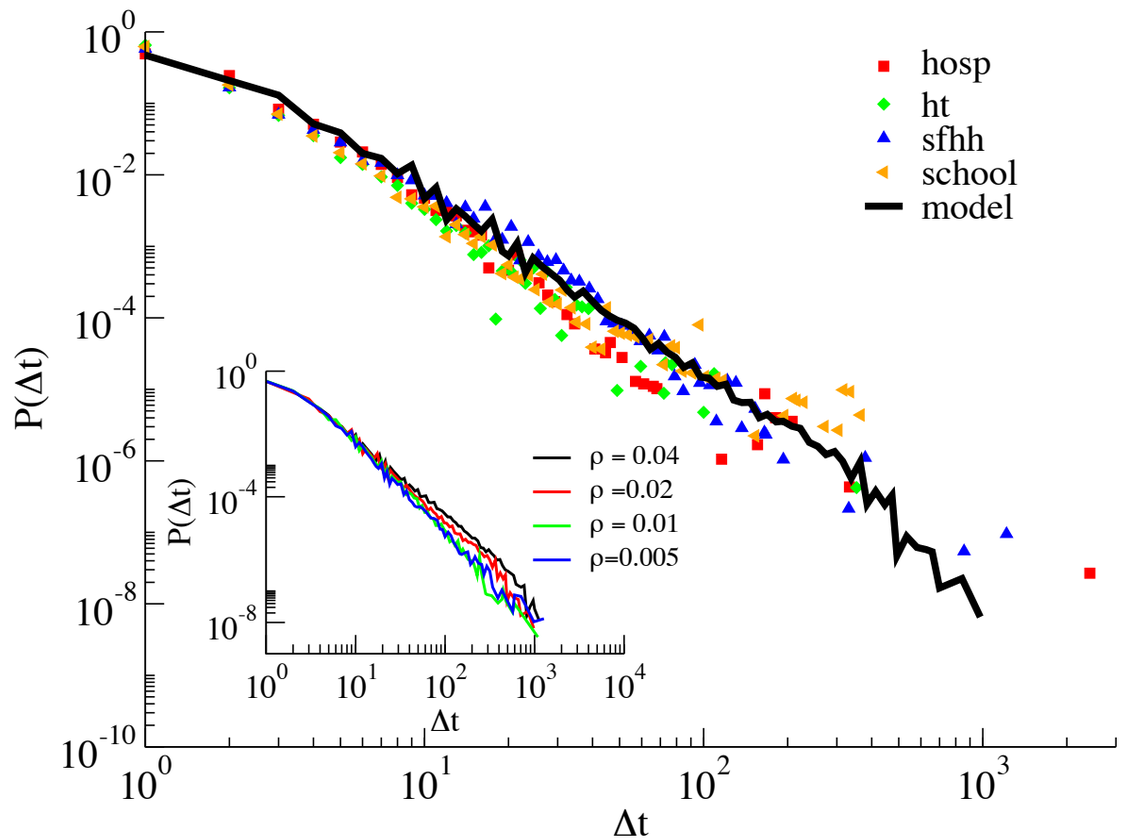
- N agents (individuals) in a square box of size L
- Two individuals at a distance less that d can interact ("talk")
- Agents are characterized by an *attractiveness* a and and *activity* r
  - ➡ a ⇒ "interest" of an agent as seen by others
  - ➡ r ⇒ how active an agent is
    - ❖ Random variables with distributions η(a) and ζ(r)
- Agents perform a biased random walk, depending on its environment:
- At time t, agent i stays in place with probability

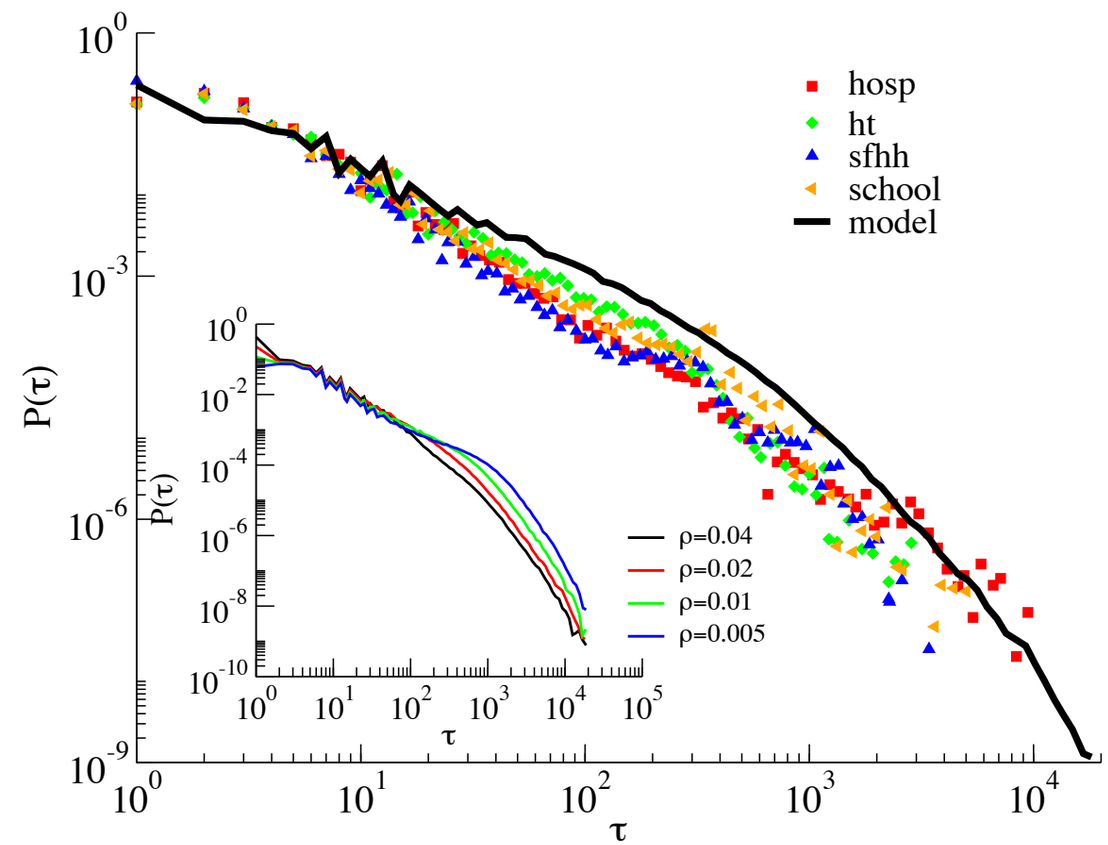
$$q_i(t) = \max_{j \in \mathcal{N}_i(t)} \{a_j\},$$

- Otherwise, performs a step in a random direction
- With probability 1-r, the agent becomes inactive, and stops interacting
- If inactive, with probability r becomes active and interacts again



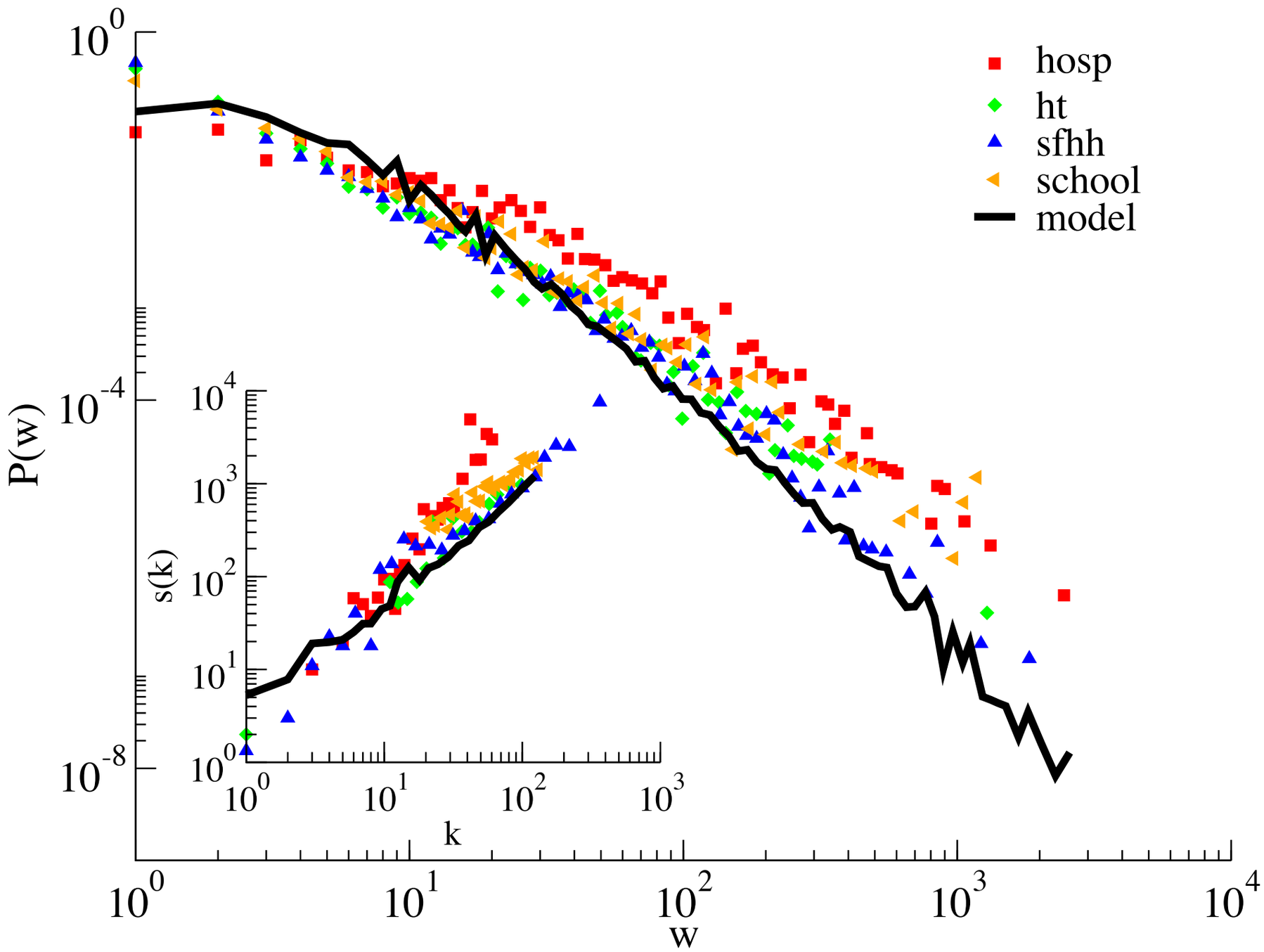
Model Results: Statistics of contacts





η(a) and ζ(r) uniform distributions

Model Results: Topology of the weighted connected network



Conclusions

- Social networks are better characterized with an additional temporal dimension
- Recent advances allow the easy and cheap gathering of large-scale data on dynamical social networks
  - ➡ The SocioPatterns projects
- The statistical analysis of SocioPatterns data allows to obtain novel information about human behavior
  - ➡ Long-tailed interaction distributions, burstiness, etc
- We have developed a simple model that can explain the basic features of human social face-to-face interactions as represented by the SocioPatterns data
- Realistically inspired:
  - ➡ People walk and stop to talk
  - ➡ The more interesting the partner, the larger the tendency to keep talking
- Model with simple simple parameters and no tuning
- Results qualitatively independent of the functional parameters $\eta(a)$ and $\zeta(r)$
- Very good fitting between model results and empirical data
- Opens the door to a better understanding of social behavior and social interactions

Thanks for your attention...

... and see you at the poster session !!