Studying human mobility in a social petri dish

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Why study human mobility?

- Spread of epidemics
- Urban planning, traffic management
- Crowd dynamics
- Geomarketing
- Spread of computer viruses

Barthelemy, Phys Rep 499, 1-101 (2010)
Castellano et al, Rev Mod Phys 81, 591-646 (2009)
Pastor-Satorras and Vespignani, PRL 86, 3200-3203 (2001)
Wang et al, Science 324, 1071-1075 (2009)
Helbing et al, PRE 75, 046109 (2007)

Measuring mobility

Large-scale datasets: mobile phones, dollar bills, subway

- Topology often a spatial network
- Predictability
- Diffusion

"Universal theory of human mobility"?

Brockmann et al, Nature 439, 462-465 (2006)
González et al, Nature 453, 779-782 (2008)
Roth et al, PLoS One 6, e15923 (2011)
Song et al, Science 327, 1018-1021 (2010)
Koelbl and Helbing, New J of Phys 5, 48 (2003)

Data problems

Problems:
- No raw data, but reconstructed positions
- Limited to specific human activity
- Limited spatial/temporal resolution
- No socio-economic contexts
- Different datasets

"Universal theory of human mobility"?

→ Not yet!

Brockmann et al, Nature 439, 462-465 (2006)
González et al, Nature 453, 779-782 (2008)
Roth et al, PLoS One 6, e15923 (2011)
Song et al, Science 327, 1018-1021 (2010)
Koelbl and Helbing, New J of Phys 5, 48 (2003)

Our contribution

1) Uncover socio-economic constraints on mobility using complete information on a human society

2) Unveil mechanism of mobility: Time-order

Establishing a socio-economic laboratory

www.pardus.at

400,000 participants live an alternative life,
in an online society interacting with others

- trading
- socializing
- conflicts

since 7 years

PARDUS

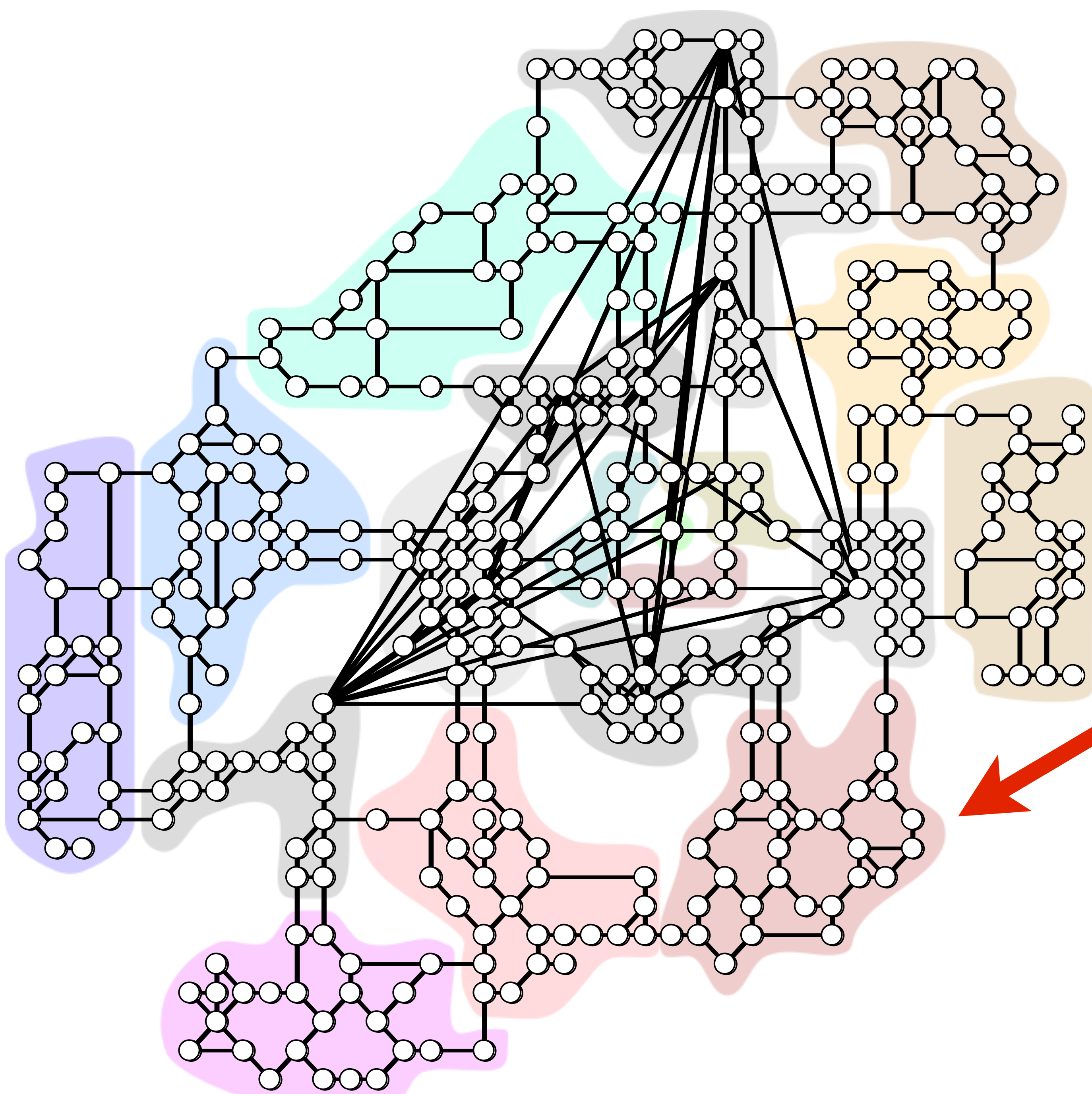
Complete data on human society!

Here: use to study mobility

Bainbridge, Science 317, 472 (2007)
Szell and Thurner, Social Networks 32, 313-329 (2010)
Szell et al, PNAS 107, 1363-13641 (2010)

The universe of the game

Network

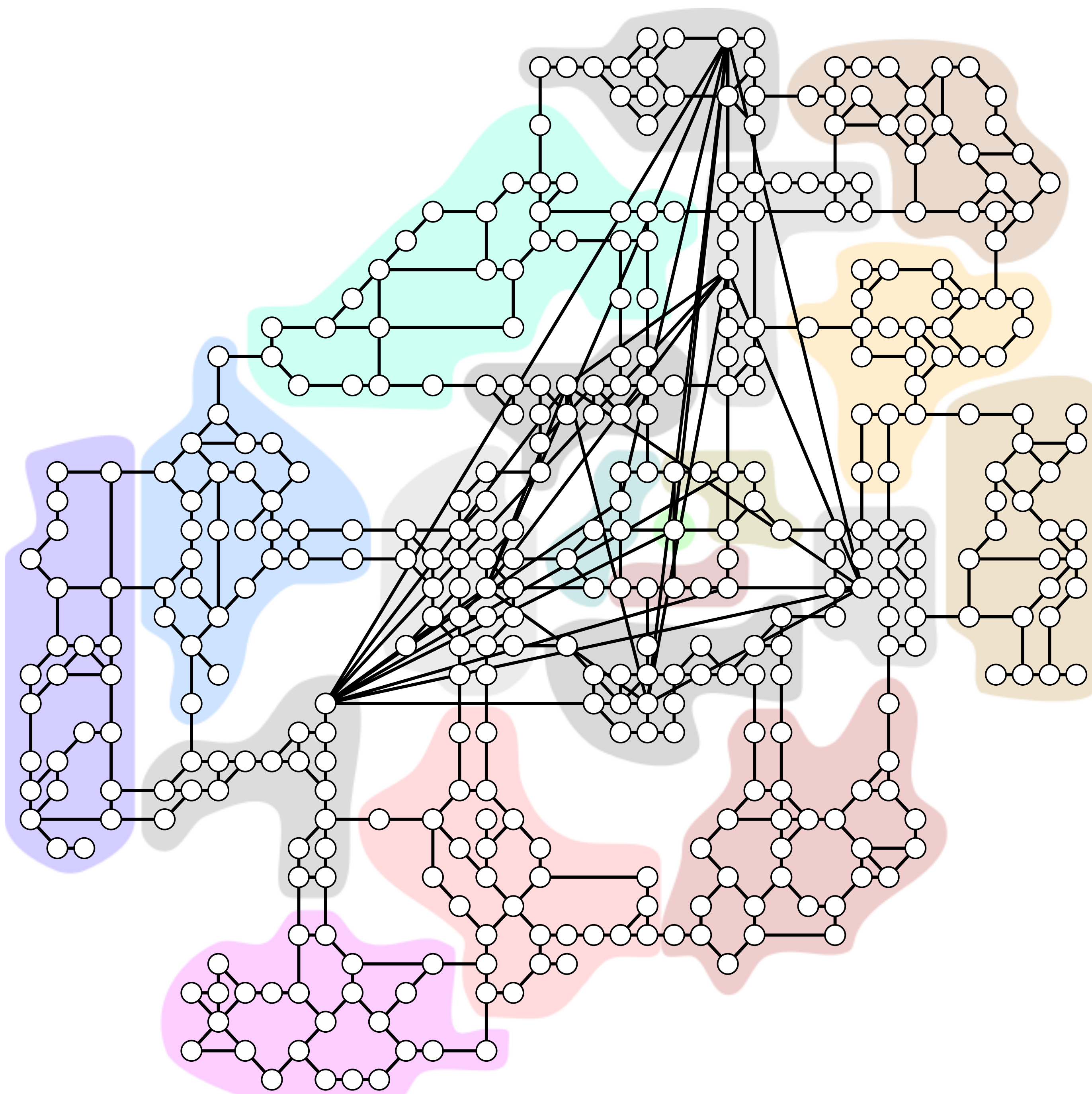


- 400 Nodes, “Cities”
- Diameter = 27
- Lattice-like

20 Clusters
“Countries”

Mobility on a network

Day-to-day mobility of active players over 1000 days



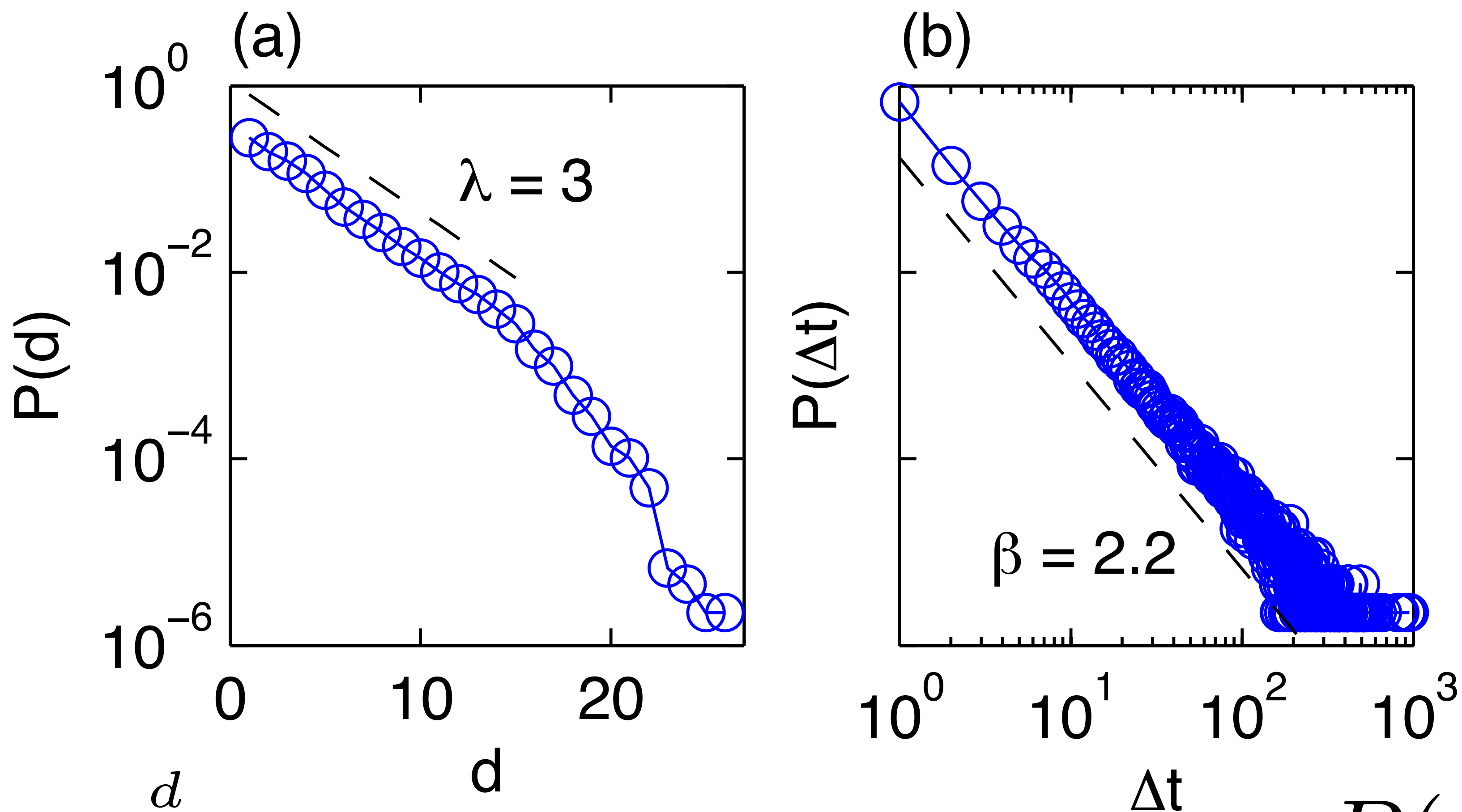
One mode of transportation

Move along links

Basic features of motion

Trip lengths
exponential

Waiting times
power

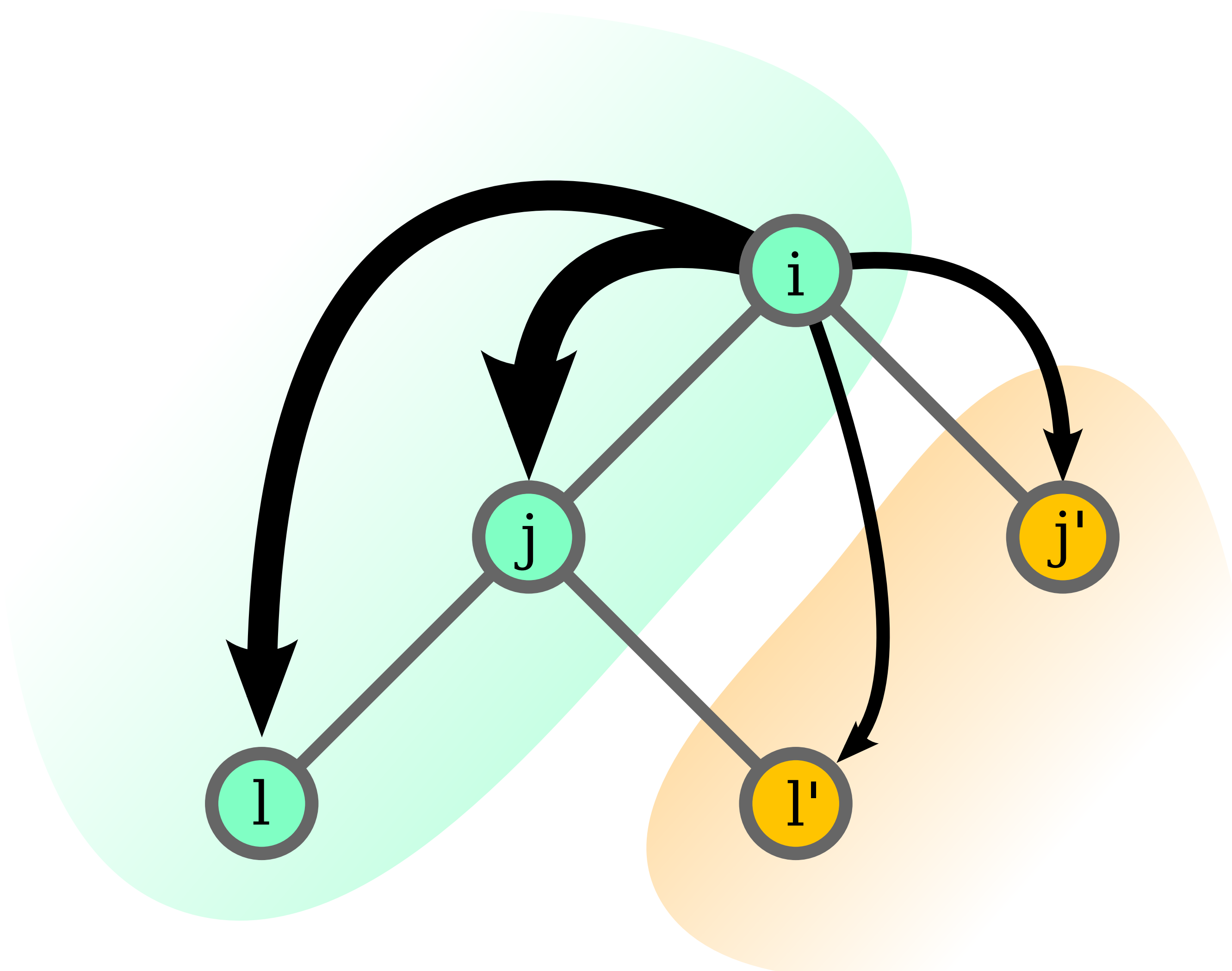


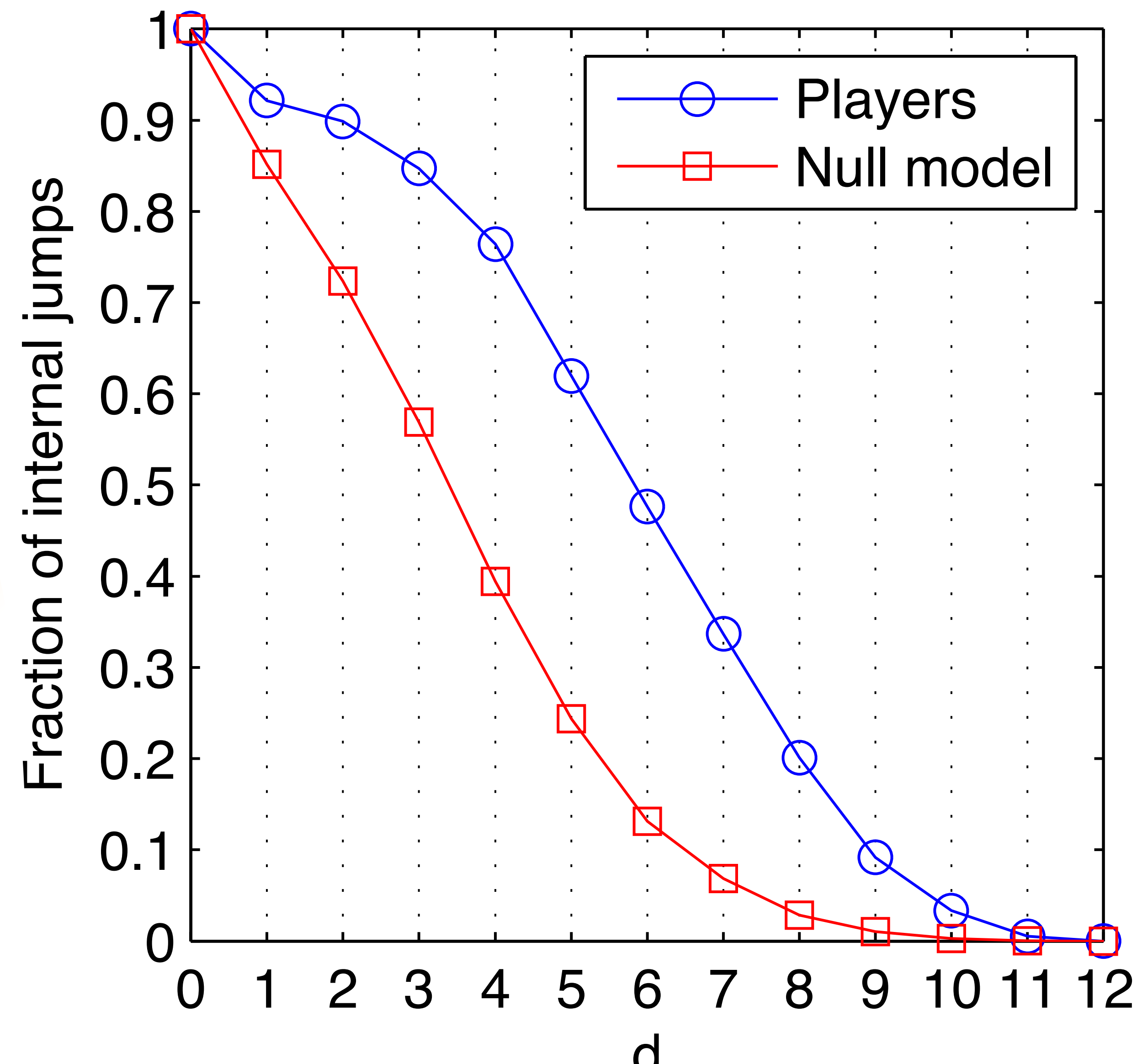
$$P(d) \sim e^{-\frac{d}{\lambda}}$$

$$P(\Delta t) \sim \Delta t^{-\beta}$$

Brockmann et al, Nature 439, 462-465 (2006)
Bazzani et al, J Stat, P05001 (2010)
Roth et al, PLoS One 6, e15923 (2011)
Song et al, Nature Physics 6, 818-823 (2010)
Koelbl and Helbing, New J of Phys 5, 48 (2003)
Han et al, PRE 83, 036117 (2011)

Do clusters influence mobility?



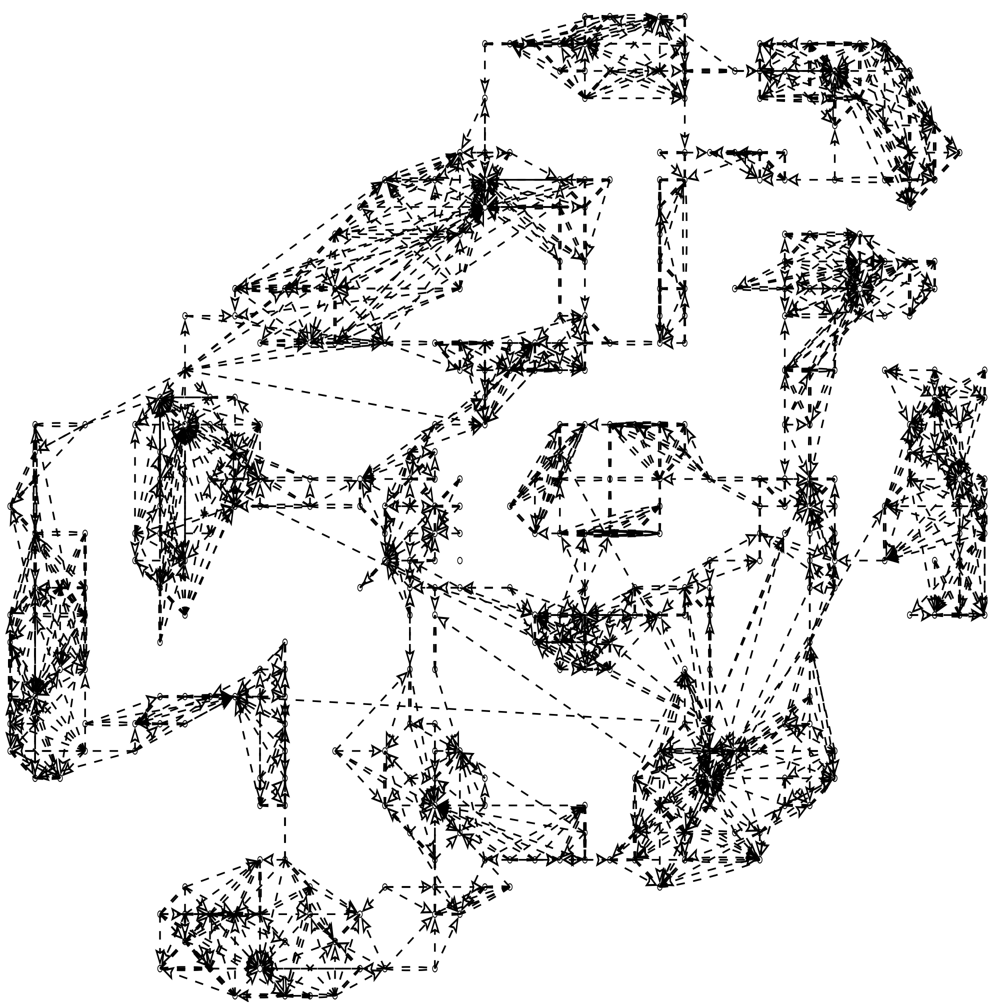


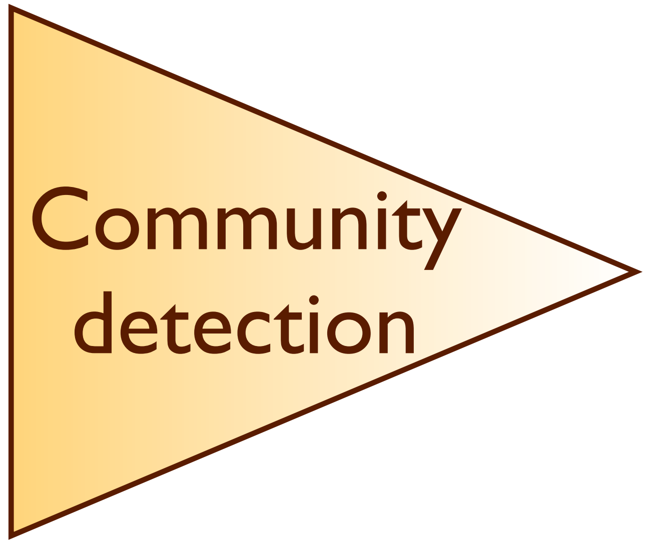
More movements within than between "countries"?

YES

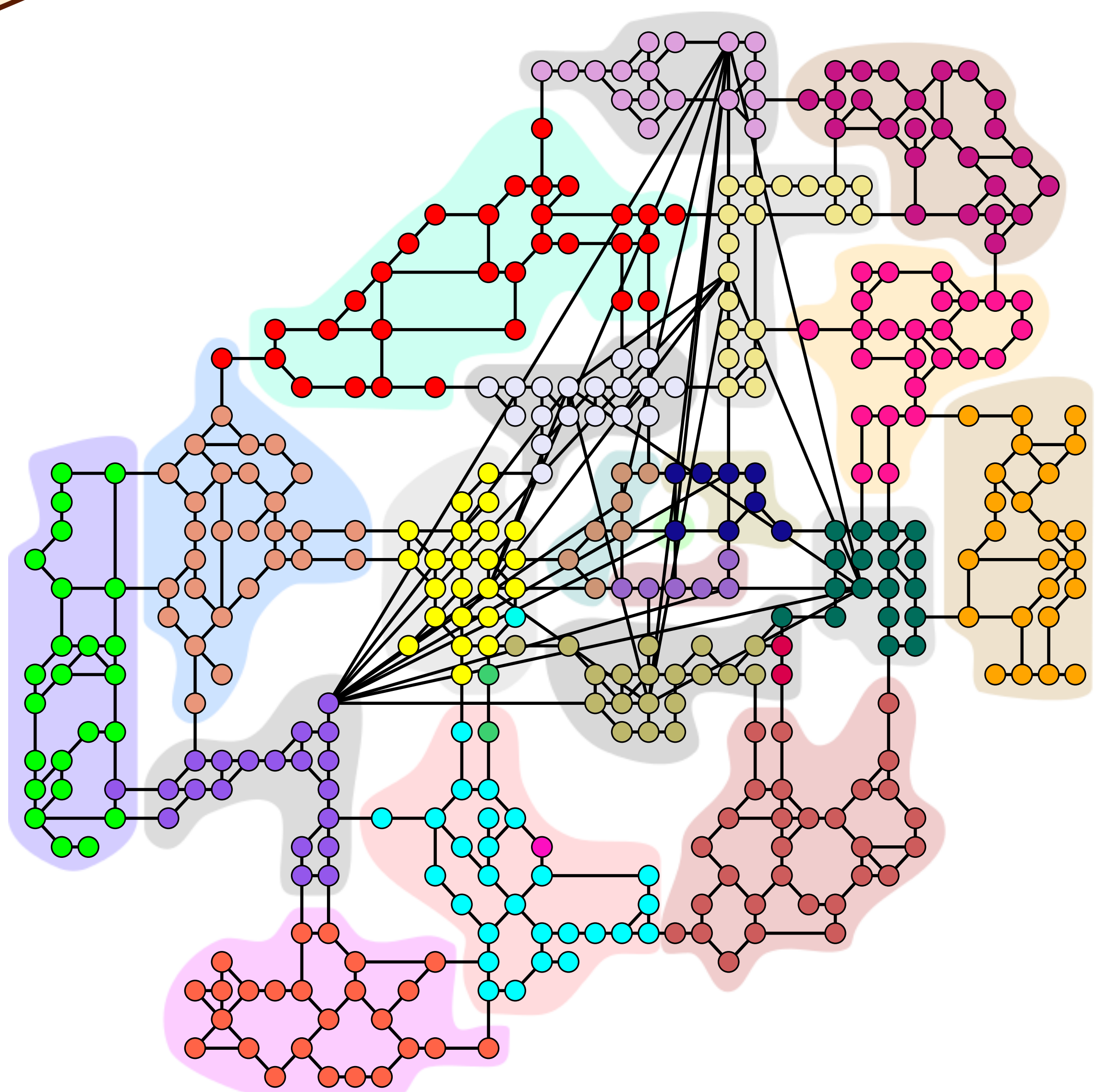
Mobility reveals socio-economic clusters

Movement data





Clusters



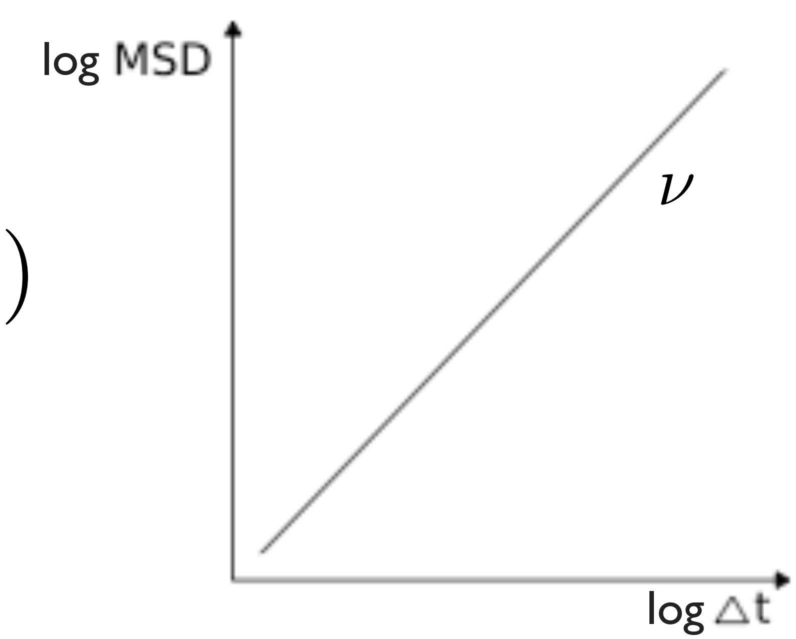
(almost) Perfect match!

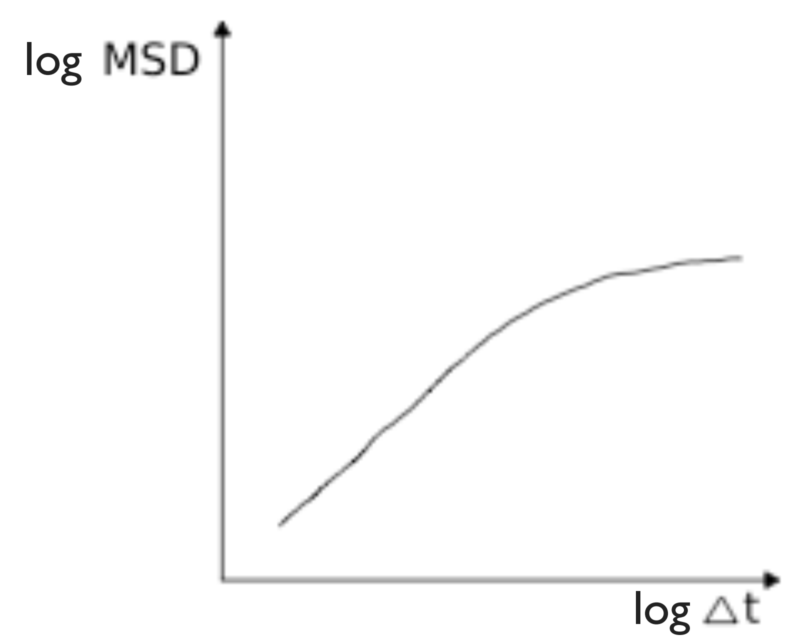
Diffusion and MSD

Mean Square Displacement

finite universe

$$\nu = \lim_{t \to \infty} \frac{d}{dt}(\mathrm{MSD})$$





expect finite size effect

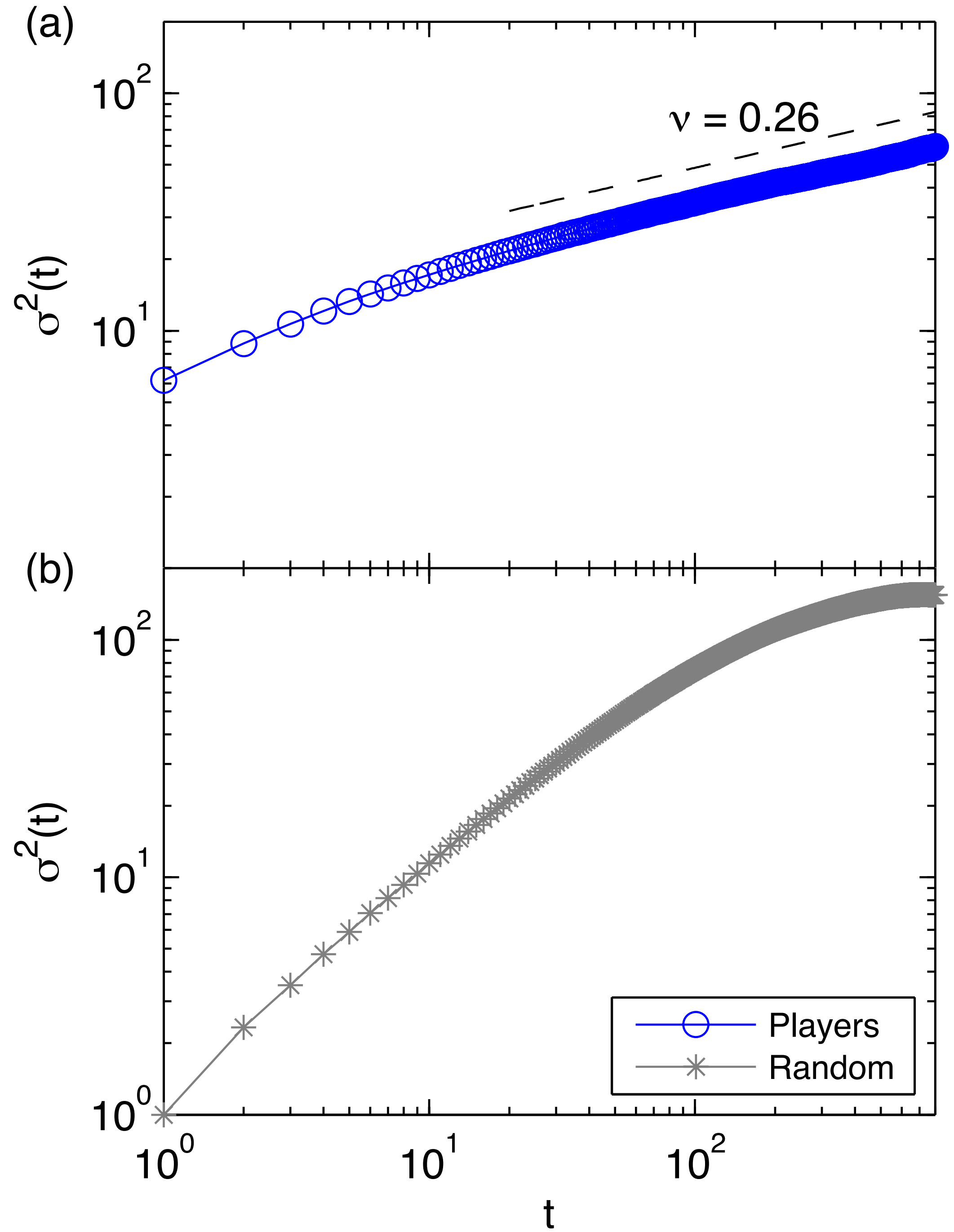
Anomalous diffusion

$\nu = 0.26 < 1$

Subdiffusive

Random walkers

have $\nu = 1$



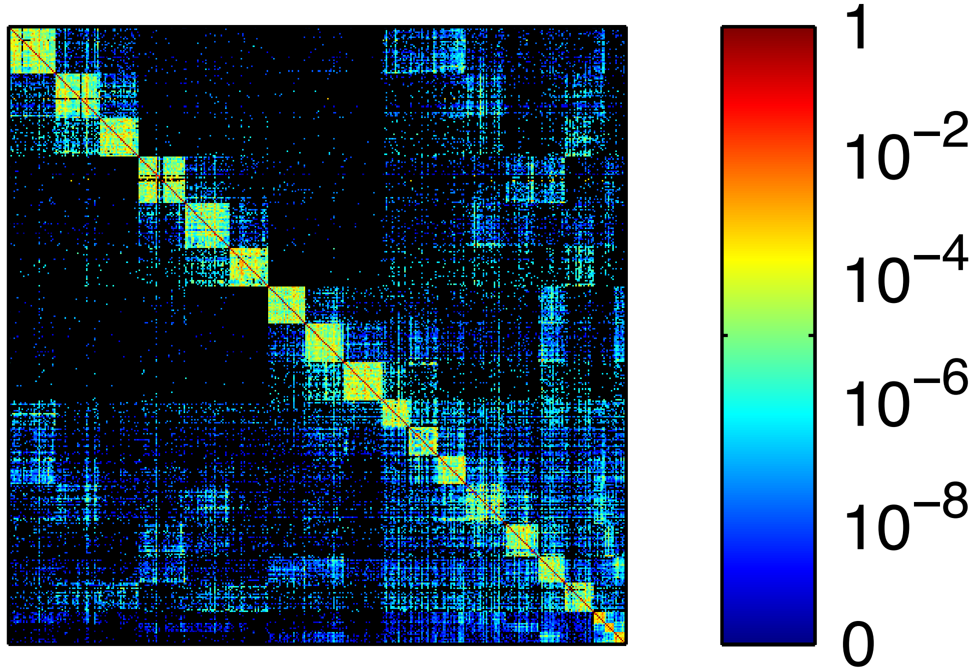
Players

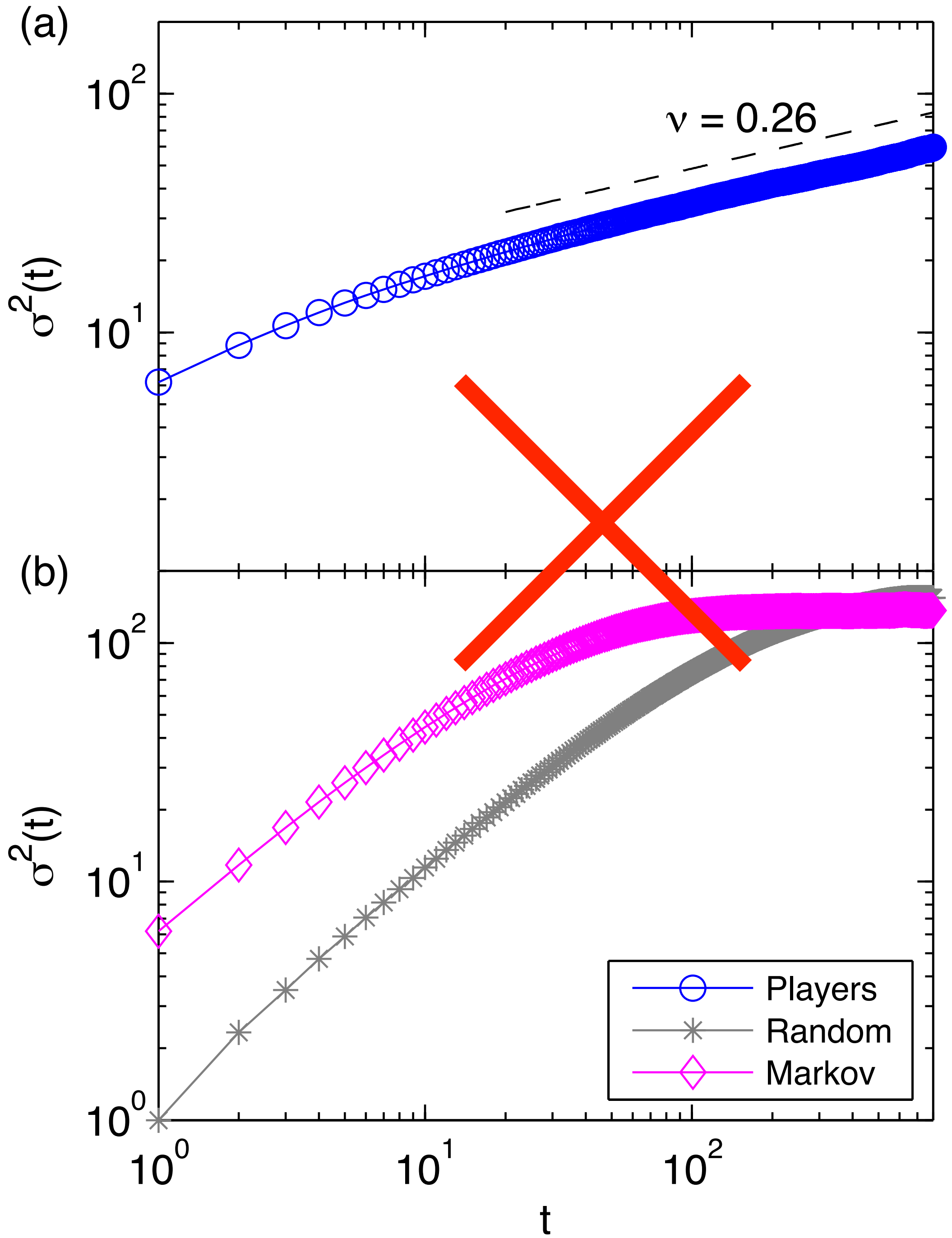
Models

Model I: Markov

- Markov use <u>all</u> day-to-day transitions

Transition P





Players

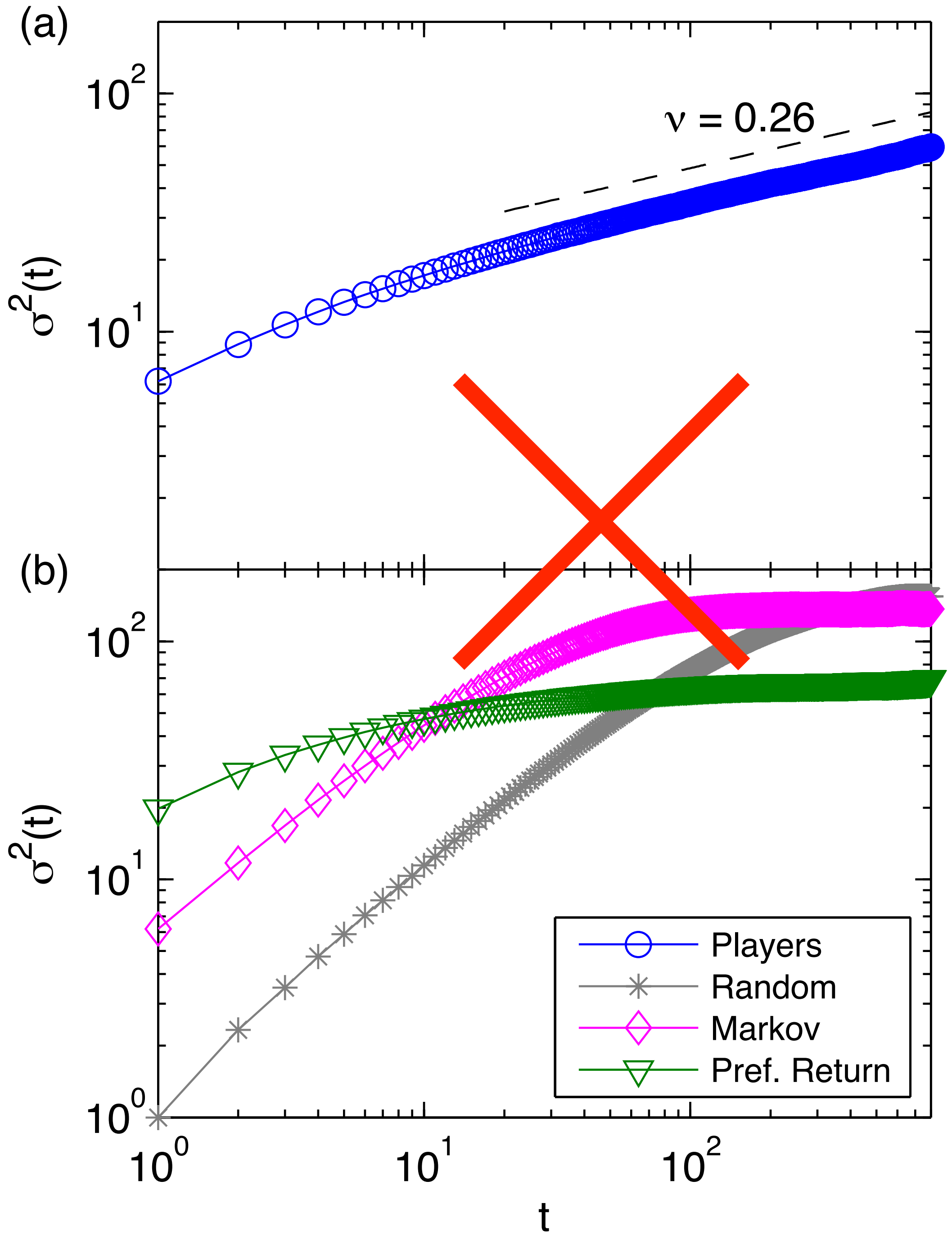
Models

encodes all information,
but no memory

Model II: Preferential return

- Markov use all day-to-day transitions

- Preferential return to <u>often</u> visited places



Players

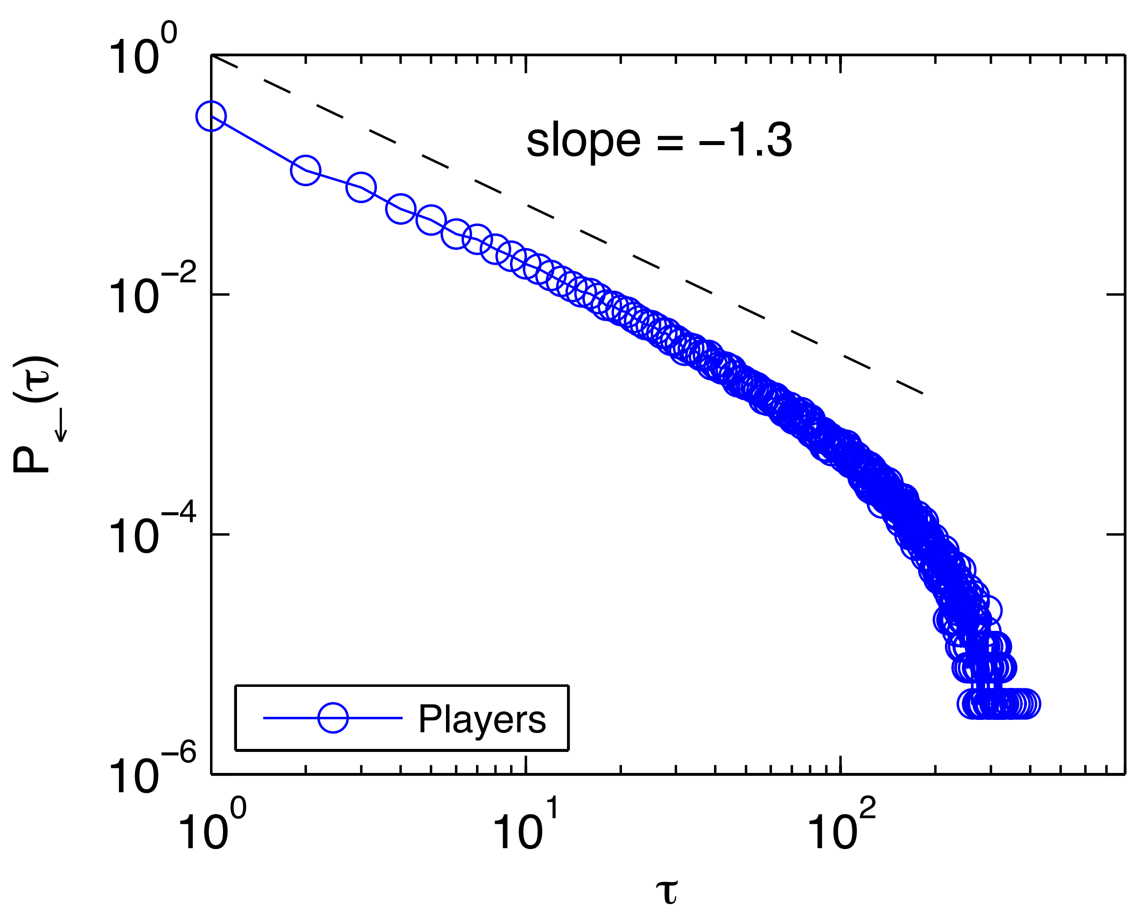
Models

Song et al, Nature Physics 6, 818-823 (2010)

What is the essential ingredient?

Order of visitations!

Time to first return



...A B A B C D B A

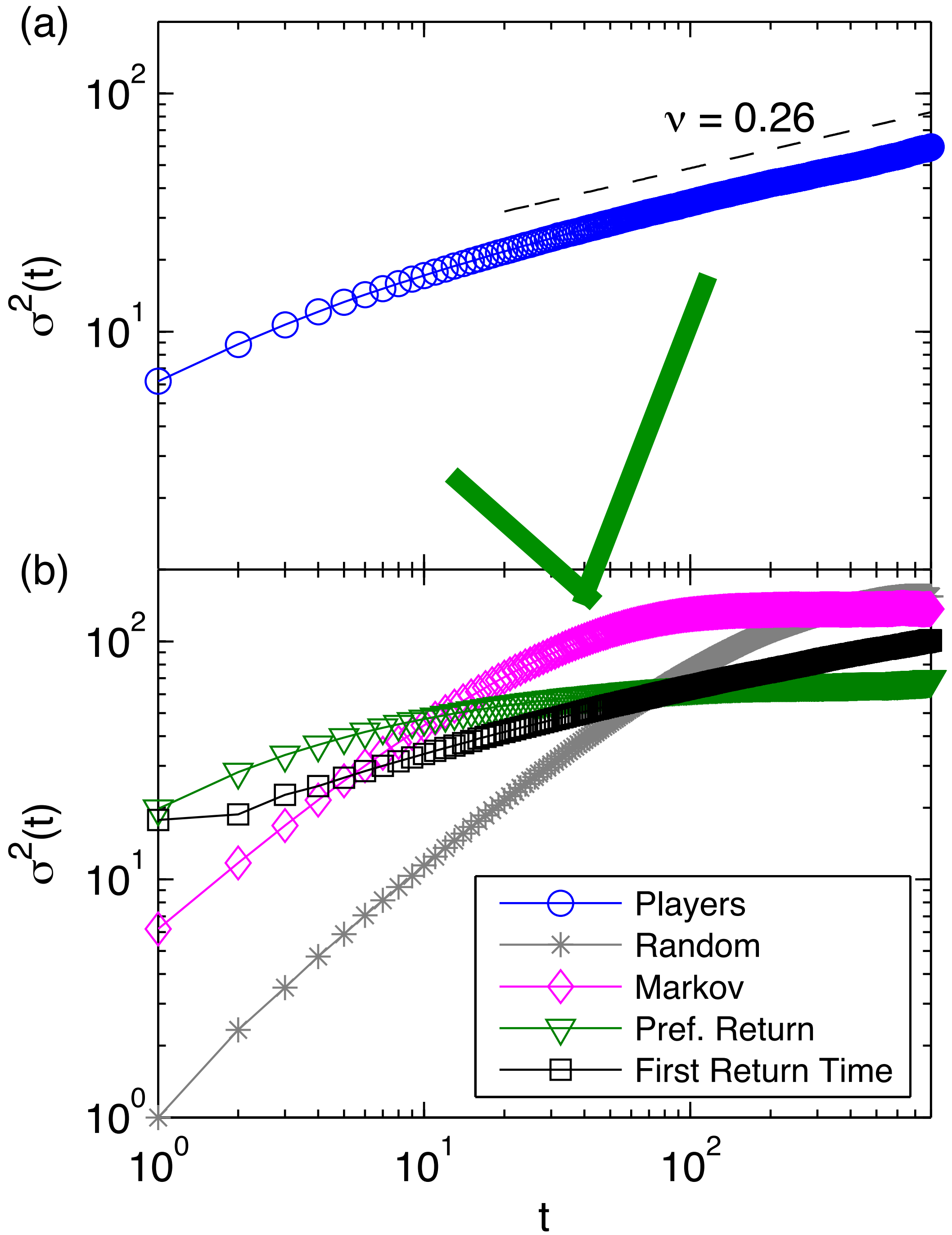
5

Long-time memory

$$P_{\hookleftarrow}(\tau) \sim \tau^{-1.3}$$

Our Model: First return

- Markov use all day-to-day transitions
- Preferential return to often visited places
- First return to <u>recently</u> visited places



Players

Models

Our Model: First return

1) Draw waiting time Δt from $\Delta t^{-\beta}$

2a) With probability ν

Return to visited location with first return time τ from $\tau^{-\alpha}$

2b) With probability $1-\nu$

Explore new location at distance d from $e^{-\frac{d}{\lambda}}$

$\beta = 2.2$

$\nu = 0.9$

$\alpha = 1.3$

$\lambda = 3$

4 measured parameters

Mobility in a socio-economic laboratory

- Socio-economic laboratory with complete information on a human society
- Movements reveal socio-economic constraints
- Driving mechanism: Time-order of visitations, First Return Model

arXiv: available very soon

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