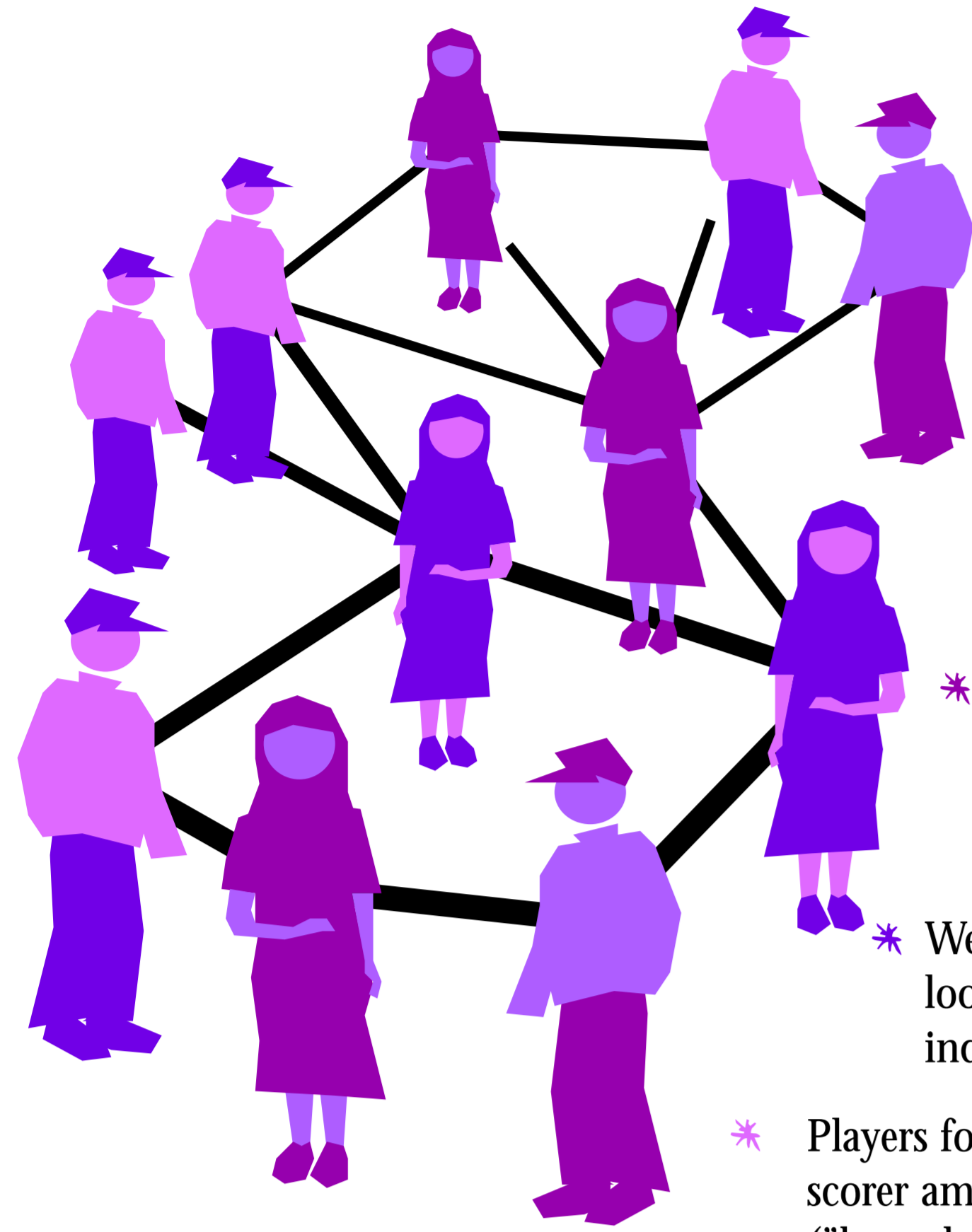


# Prisoners' dilemma in real-world acquaintance networks

by Petter Holme  
with Ala Trusina, Beom Jun Kim, and Petter Minnhagen

## The rules



- \* Two strategies: cooperate  $C$  or defect  $D$
- \* The gain of a player is the sum of the gain over his/her ties
- \* A  $C-C$  encounter gives both players unity gain
- \* A  $D-D$  encounter gives both players zero gain
- \* A  $D-C$  encounter gives the cooperator zero gain and the defector the gain  $b$ ,  $1 < b < 2$
- \* We use synchronous updating, i.e. loop over: 1. Calculation of individual gain. 2. Choice of
- \* Players follows the strategy of the high-scorer among the neighbors and his/herself ("bounded rationality paradigm").

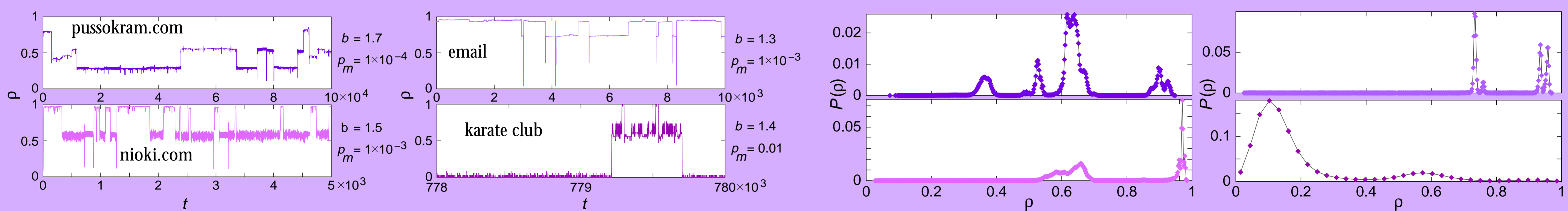
## The reason

The prisoners' dilemma is a metaphor for situations where egoism is profitable in a short perspective but cooperation is best in the long run. Such situations are everywhere in all levels of society . . . from household disputes to global politics. To study the cooperation in social space Nowak & May let embedded the players in a geometry and let them interact only with their local surrounding. The interaction pattern among people is highly complex . . . so we put the prisoners' dilemma dynamics in its most natural setting: in a empirically acquired social network

## The networks

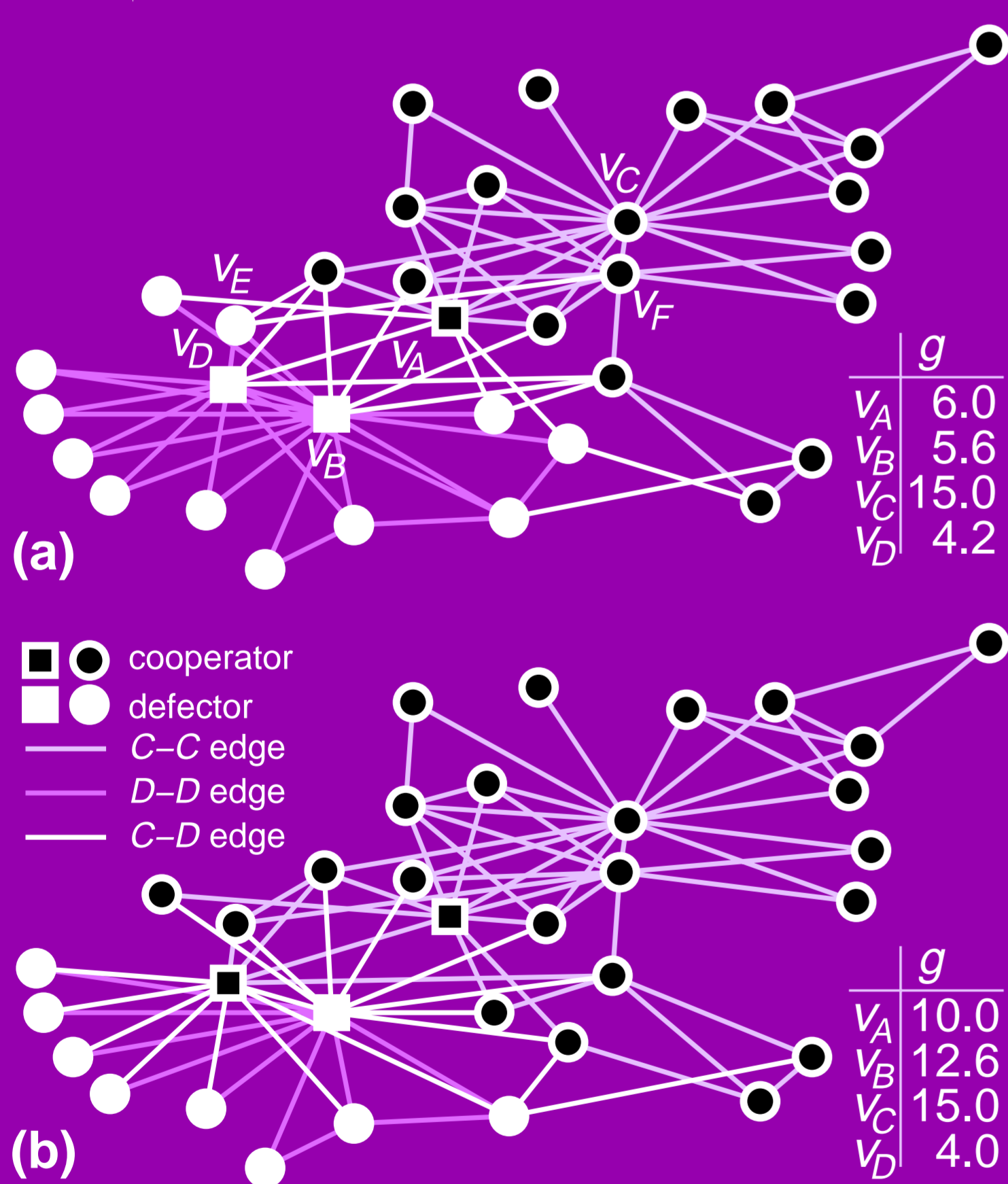
pussokram.com		nioki.com		email	karate club
	pussokram.com is Swedish Internet community intended for romantic interaction $N = 29\,314$ , $M = 115\,684$ P. Holme, C. R. Edling and F. Liljeros, cond-mat/0210514		nioki.com is a French Internet community with a younger audience than pussokram.com $N = 50\,259$ , $M = 239\,452$ R. Smith, cond-mat/0206378		

## Time evolution of cooperator density



- \* Complex time series over a large parameter range
- \* Spikes and transitions between quasi-stable states (and noise + high frequency oscillations, as on regular networks)
- \* The distribution of cooperator density (for a specific  $b$  value) is independent of the mutation rate and forms a fingerprint of the network.

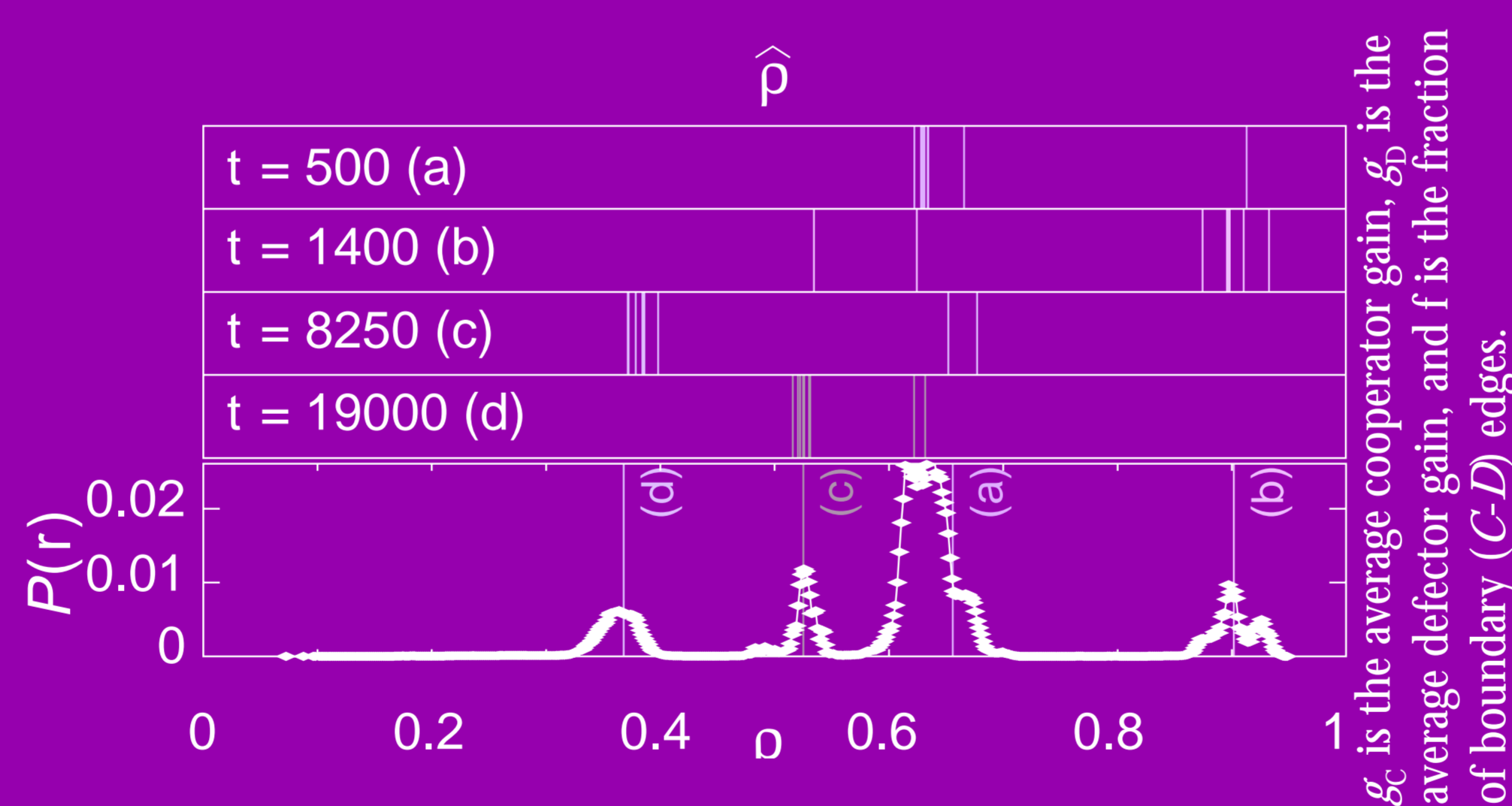
## A quasi-stable state



A cyclic quasi-stable state of the karate club time series above. That  $v_A$  and  $v_B$  is not connected is a crucial feature sustaining the quasi-stable state.

We note that if  $v_E$  is mutated in the (a) configuration the system looses the cyclic behavior. Thus, the quasi-stable levels of the  $\rho$  time series is a collection of quasi-stable states, close in Hamming distance.

## Statistics of the C/D clusters



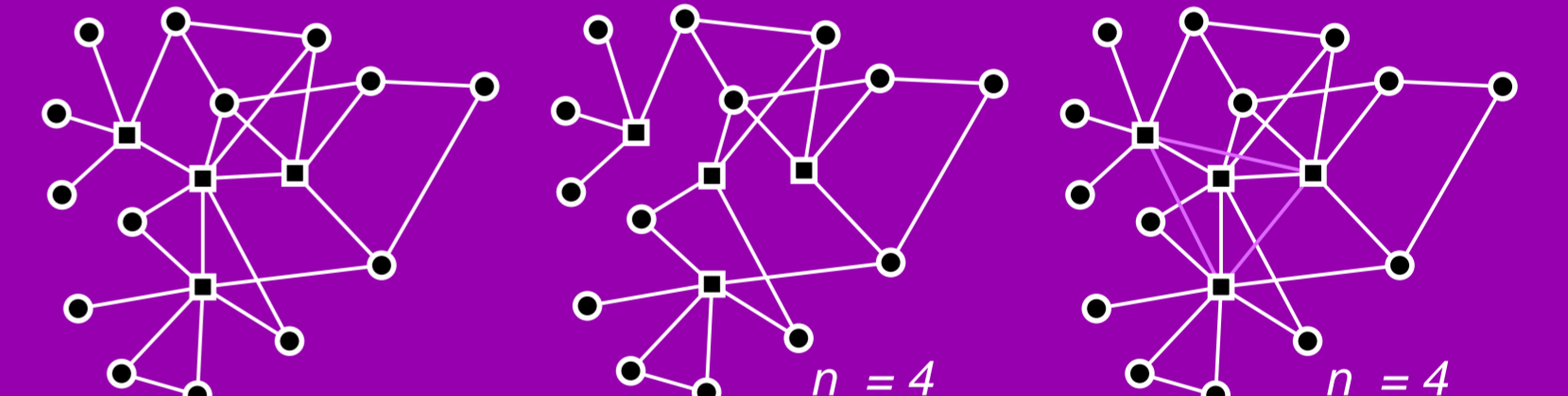
## Correlations within high-degree vertices

We test the correlations within the set of highest degree vertices we measure the average degree within the maximal subgraph of the  $n$  vertices of highest degree,  $k_n$ .

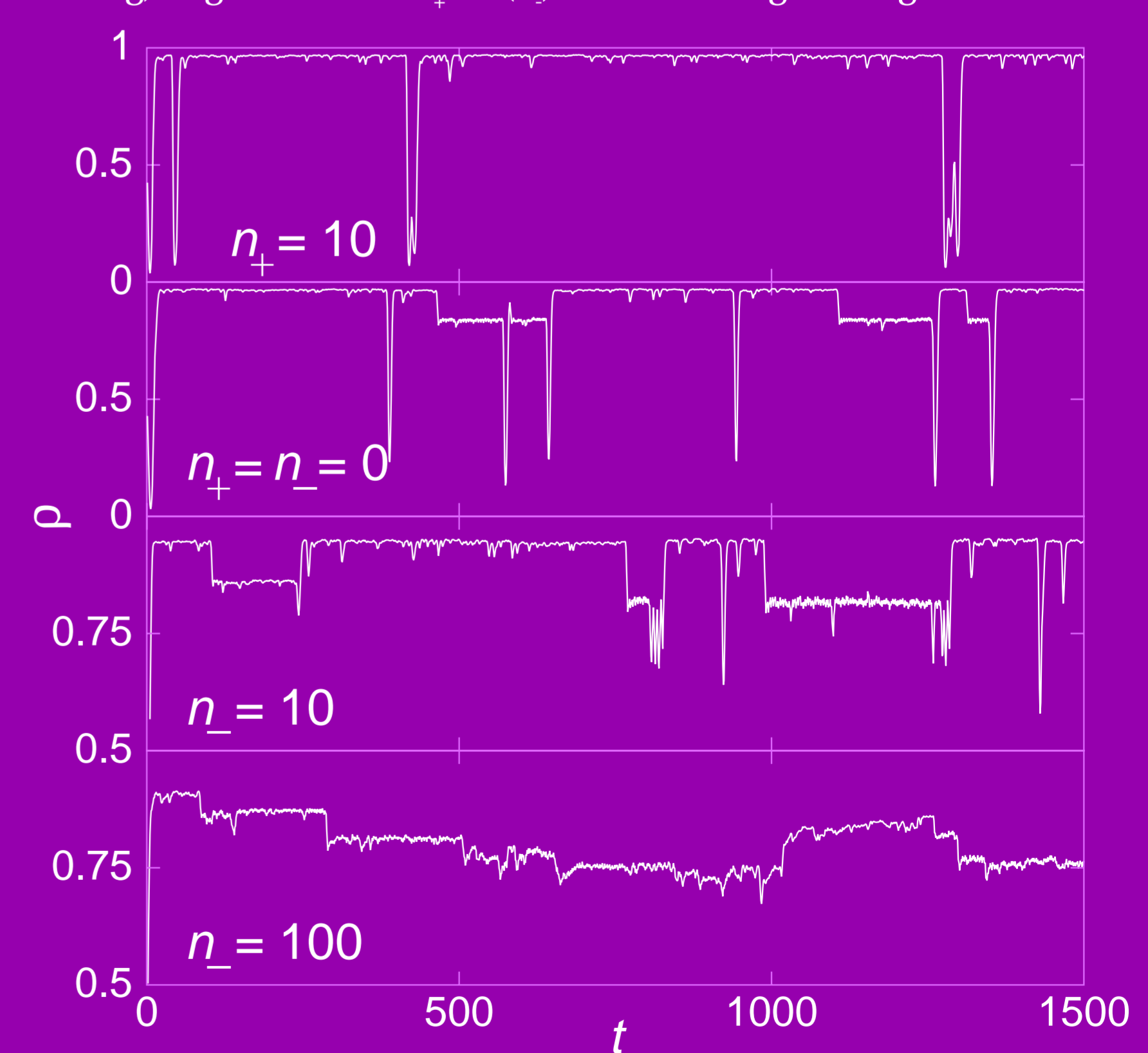
This is compared with the corresponding values of random graphs with the same degree sequence  $K_n$ .

	$k_n$	$K_n$
pussokram.com	1.6	6.0(1)
nioki.com	1.2	1.9(1)
email	1.8	4.9(1)

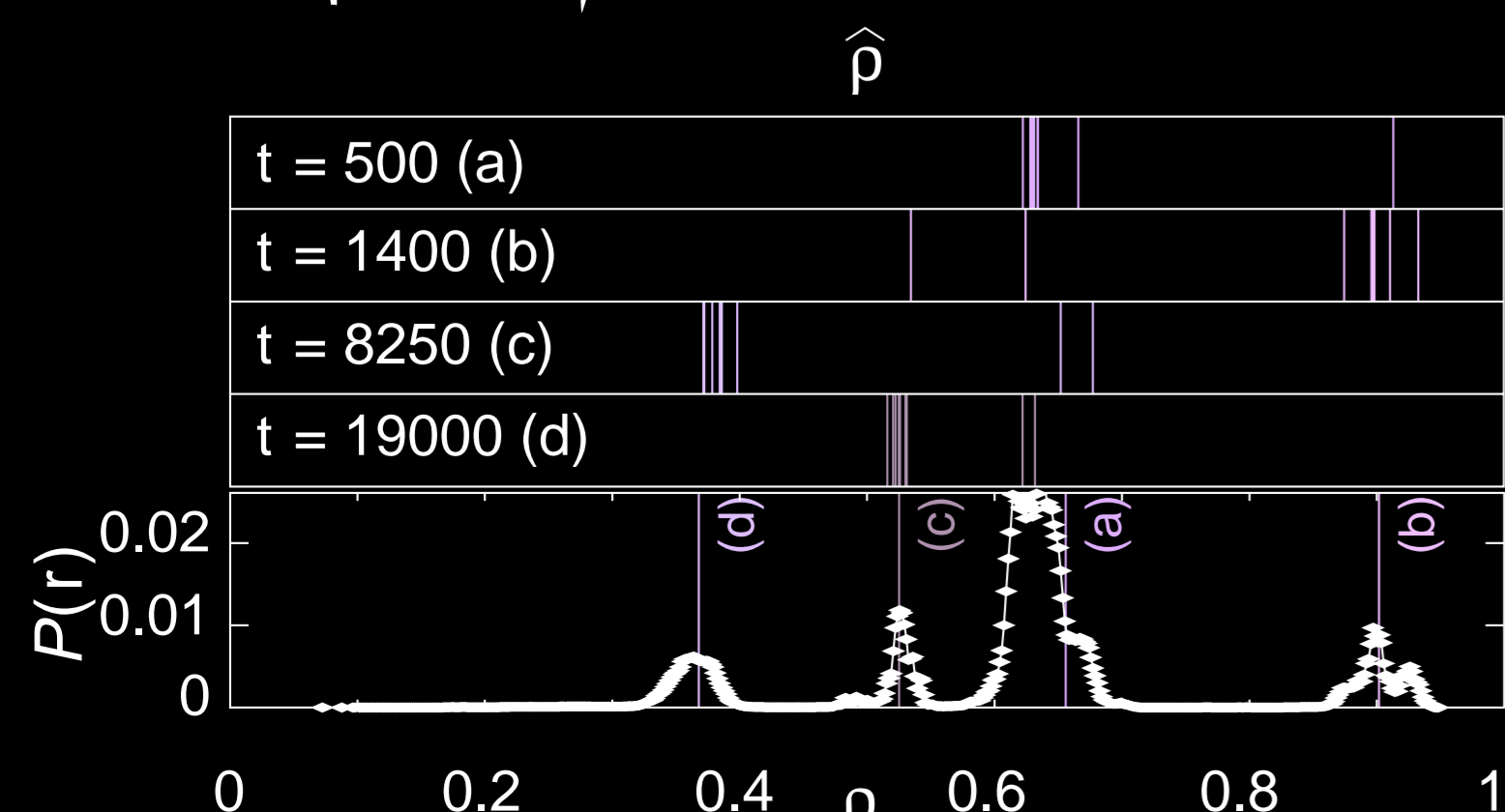
## Model networks



To get a broad degree-distribution we start by creating  $M = 3N$  BA model networks. We tune the number of edges within the highest-degree vertices by adding the missing (or deleting the existing) edges from the  $n_+$  or ( $n_-$ ) vertices of highest degree.



## One player mutation impact



To test how much a single player mutation can affect the system we plot  $\rho$  after a mutation (if we let the system evolves without mutations). The figure shows the ten most different  $\rho$  values for four times.

## Conclusions

- \* We find a complex  $\rho$  behavior with steps & spikes
- \* High- $\rho$  states are characterized by high cooperator gain and small boundaries, low- $\rho$  states vice versa.
- \* The transitions are likely caused by single-player mutations on high degree vertices.
- \* Important ingredients for the emergence and sustention of the quasi-stable states are: 1. A broad degree distribution. 2. That the vertices of highest degree and not mutually well-connected.

Based on: P. Holme, A. Trusina, B. J. Kim, and P. Minnhagen, Nonstationary social stability induced by the structure of acquaintance networks, submitted to Phys. Rev. E (RC).

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