Network of Likes & Dislikes: Conflict and Membership

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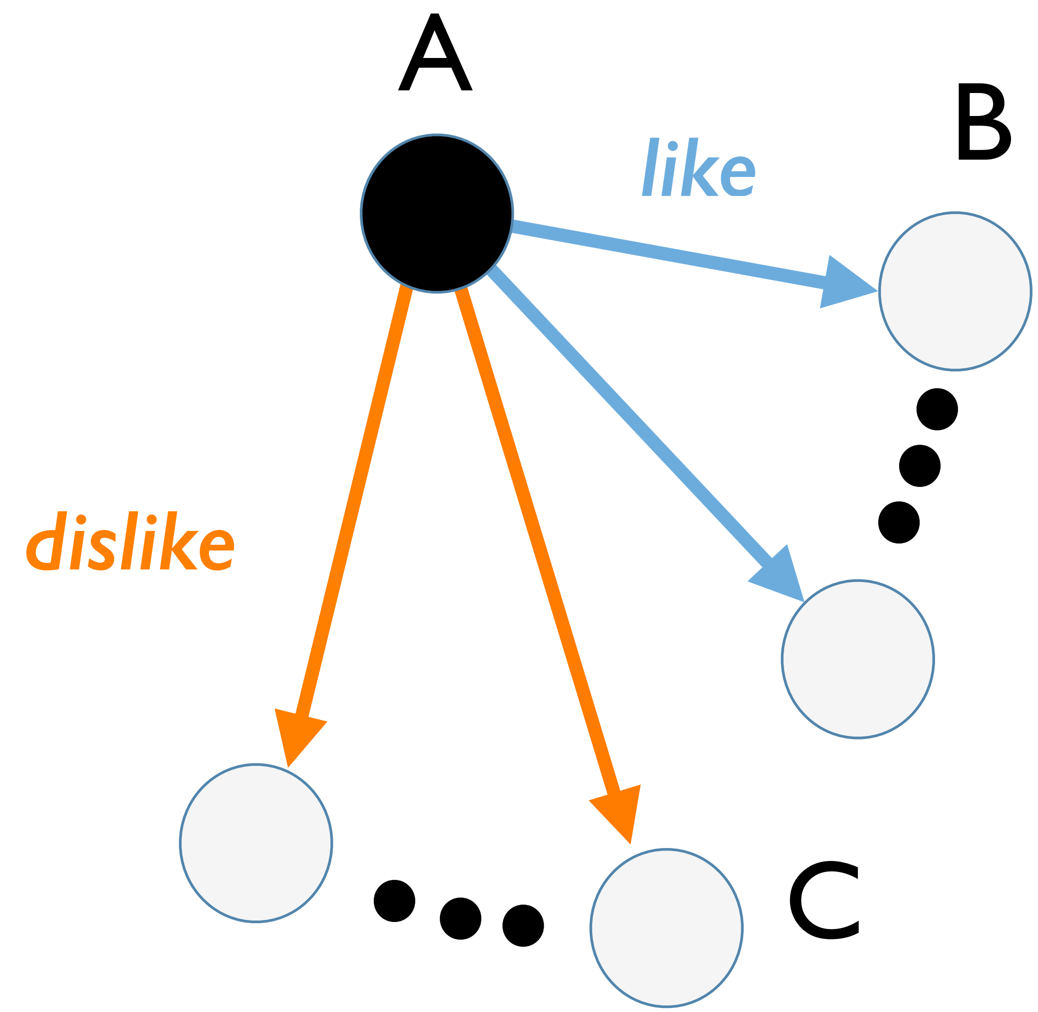
EAJSSP2015

(Oct. 15, 2015)@KIAS

Network Data

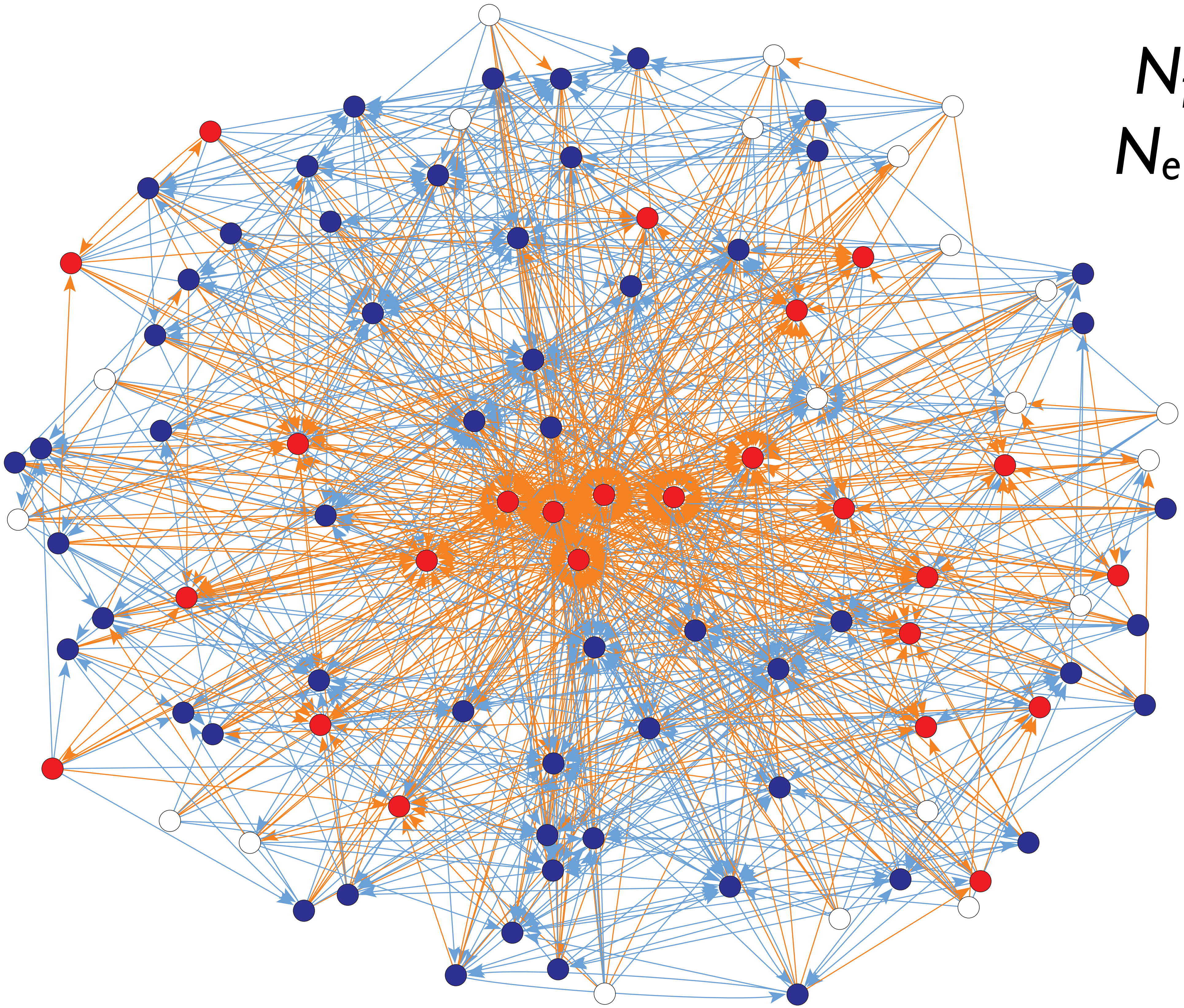
- Surveys at an anonymous organization of N = 103 members in 03' & 06'.
- Everyone is asked to choose 5 members she wants to work with & 5 members she does not want to work with.
  k_{out}(like)= k_{out}(dislike)=5.
- Directed networks with two different link types (like/dislike) at two different times (03' & 06').



A likes B and dislikes C.

03' Network

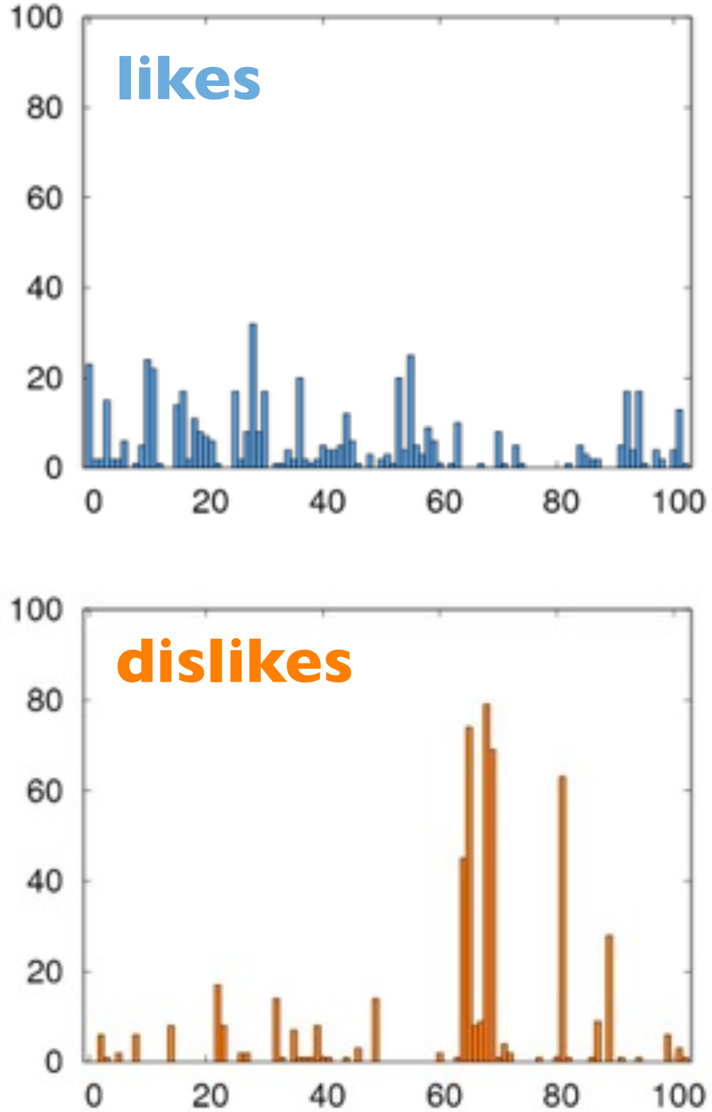
N_f = # of friends
N_e = # of enemies



●: $N_f > N_e$
●: $N_f < N_e$
○: $N_f = N_e$

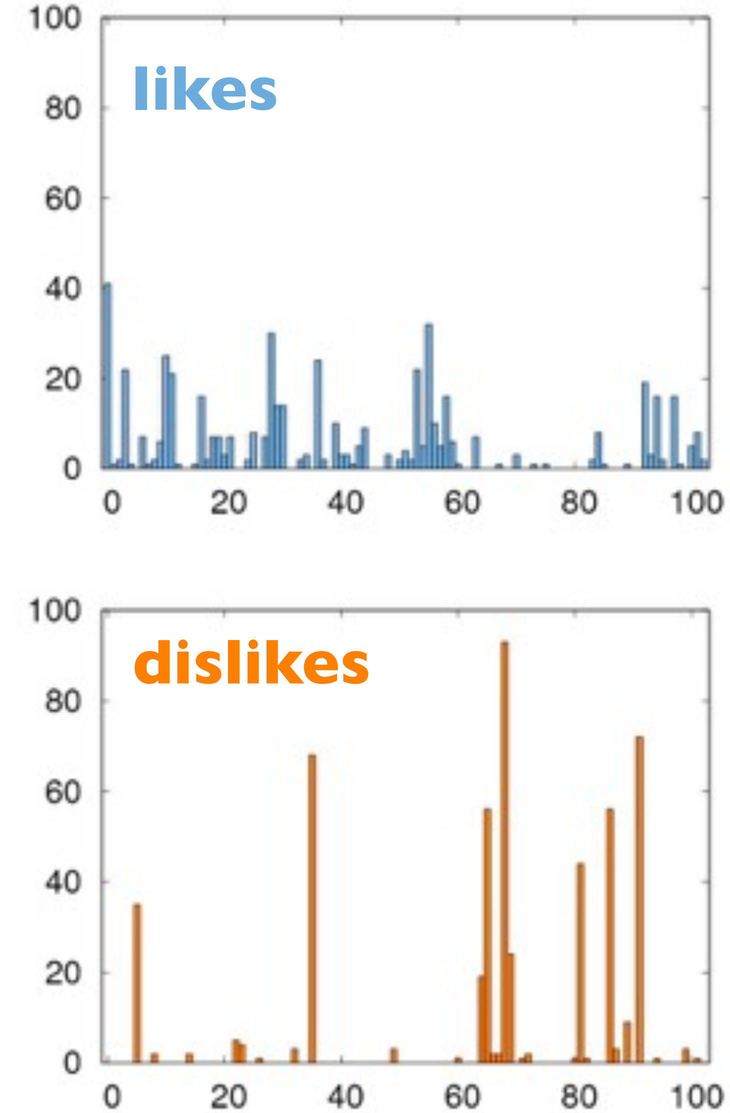
In-degree sequences

03'



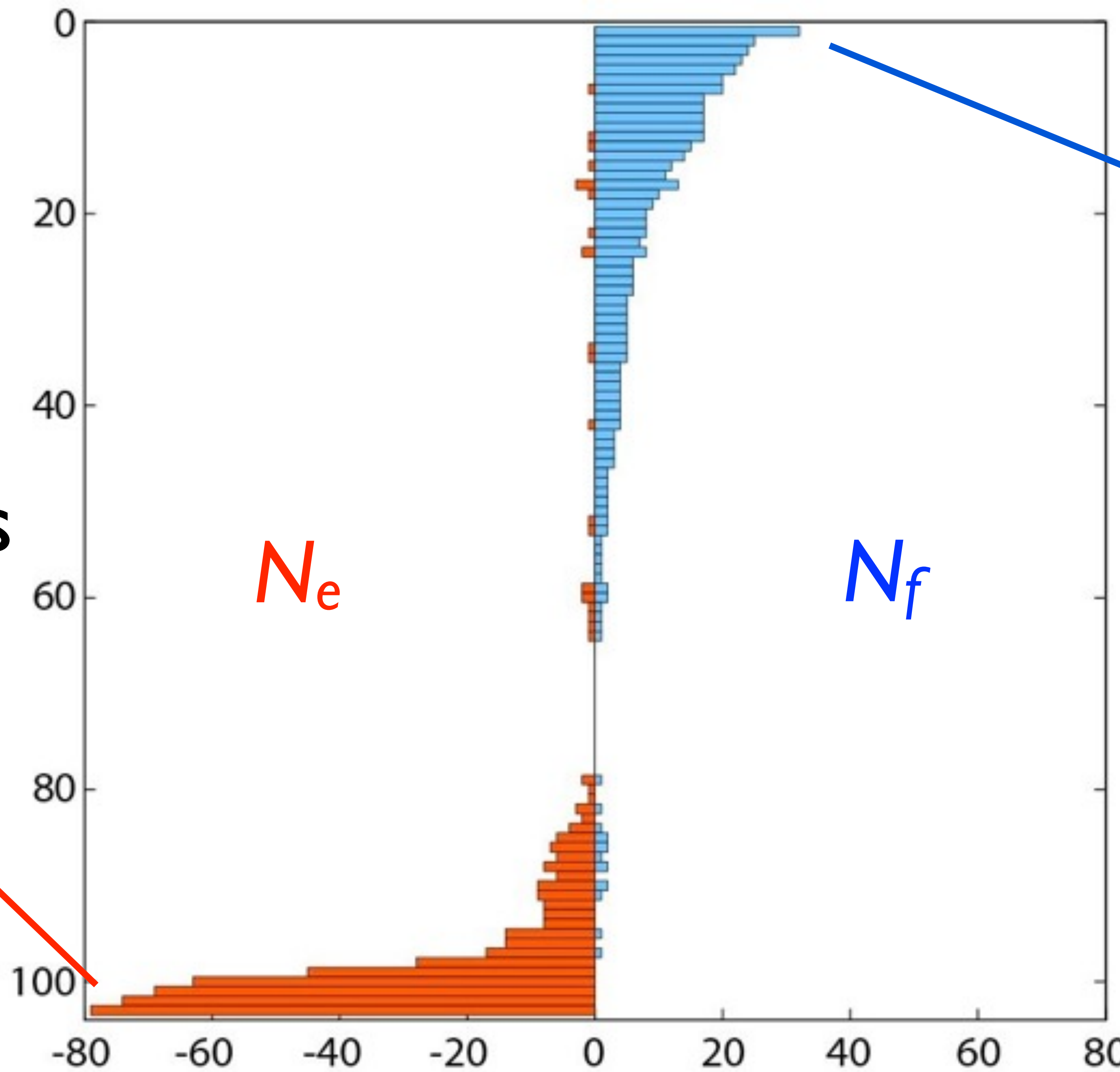
Change of preferences!

06'



In-degree sequences

Node id (sorted w.r.t. N_f - N_e)



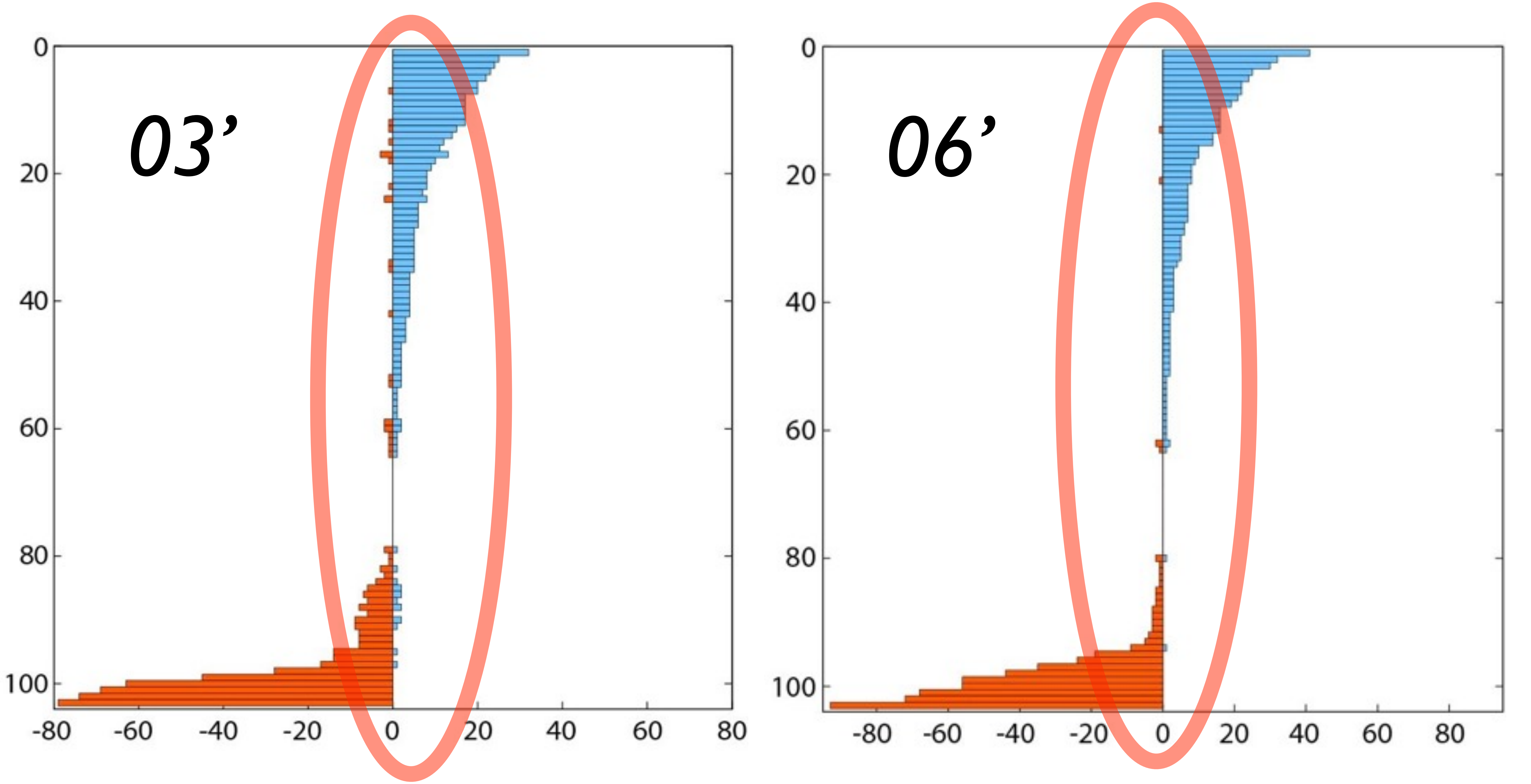
40 members like her.

80 members dislike her.

Many friends → few enemies.

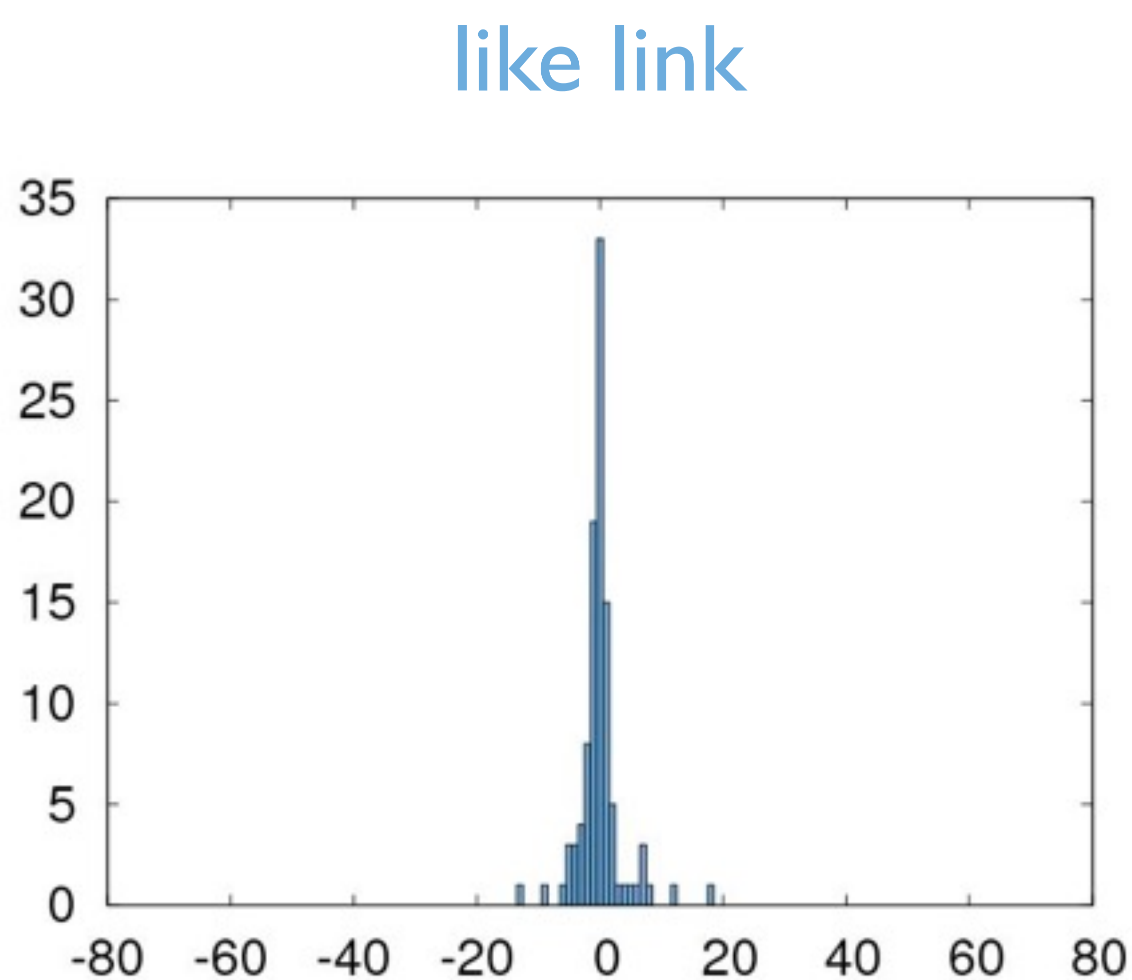
Many enemies → few friends.

In-degree sequences

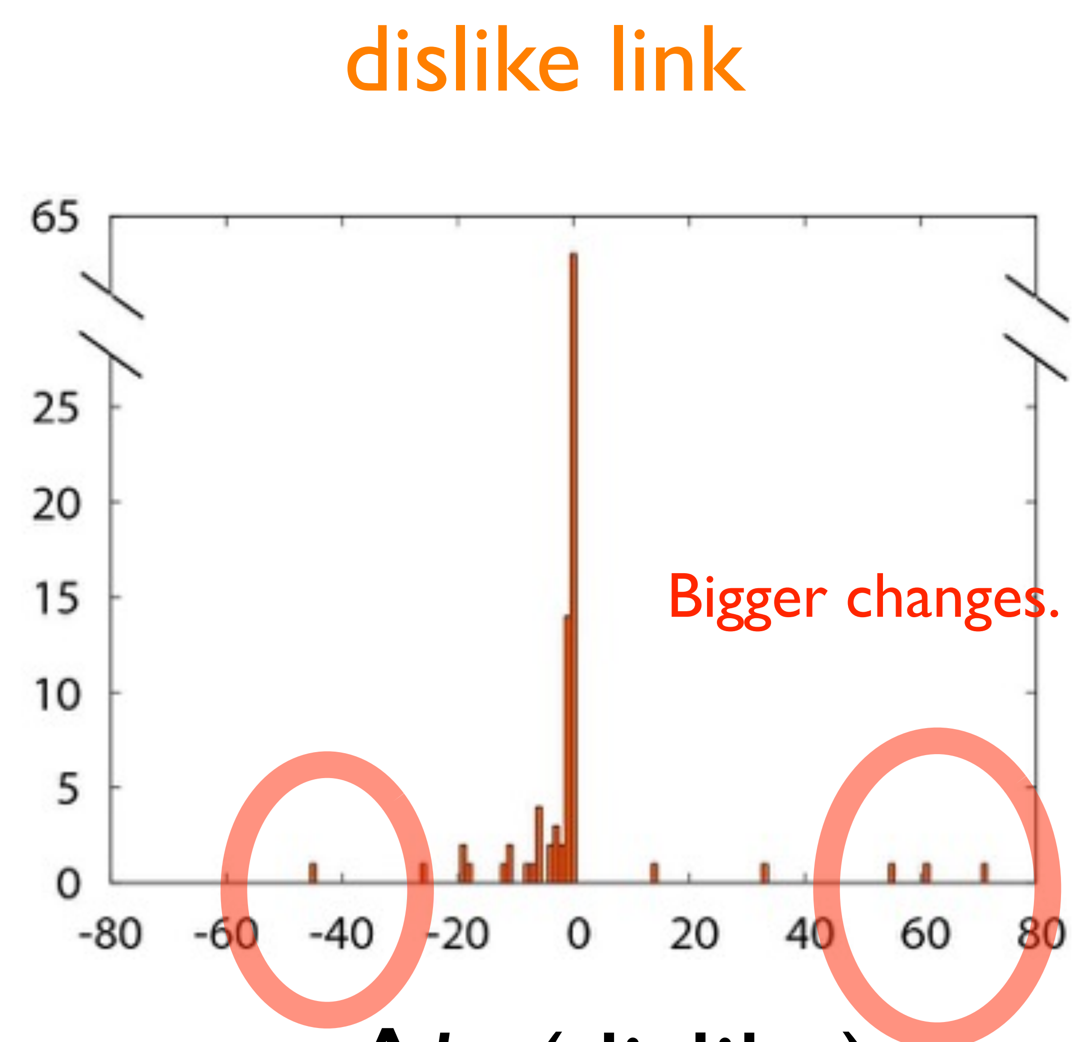


The good and the bad become clearer.

Distributions of changes of in-degrees



Δk_{in}(like)



Δk_{in}(dislike)

- Your number of friends does not change much.
- You can be hated by many in three years.

Transition Matrix of Link Colors

03' \ 06'	Neutral	Like	Dislike
Neutral	-	165	238
Like	161	350	4
Dislike	242	0	273

- Some of friends become enemies, but no single case for the other way (no enemies become friends):
  Try not to make enemies.

Questions

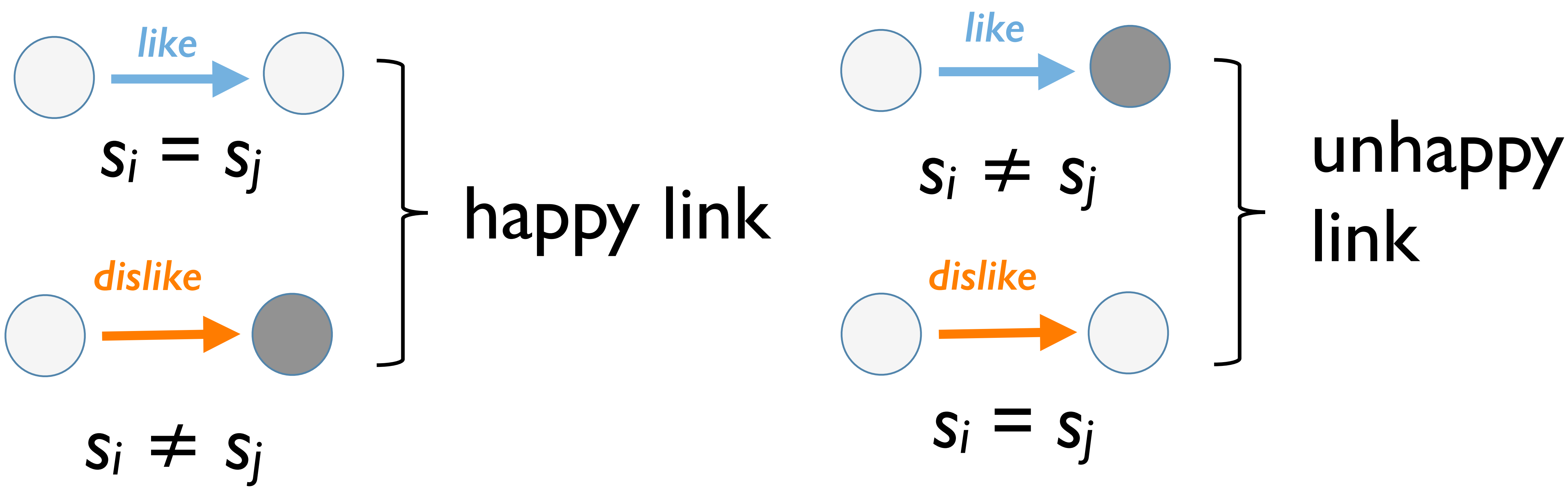
- Community detection ≃ How to assign divisions or teams for all members to make everyone happy? Is it possible? Number of divisions?
- Conflict resolution in time?
- Is enemy of enemy my friend? Does enemy of enemy become my friend? Common enemies make new friends?

How to answer ?

- Use the q-state voter model.
- After long run, find steady state.
- State of each member can be interpreted as her membership (or the division she is assigned to).

q-State Voter Model

- The node i's state (or opinion or membership): $s_i = 1, 2, \ldots q$.
- Active and inactive links: Happy (balanced) and unhappy (unbalanced) links.



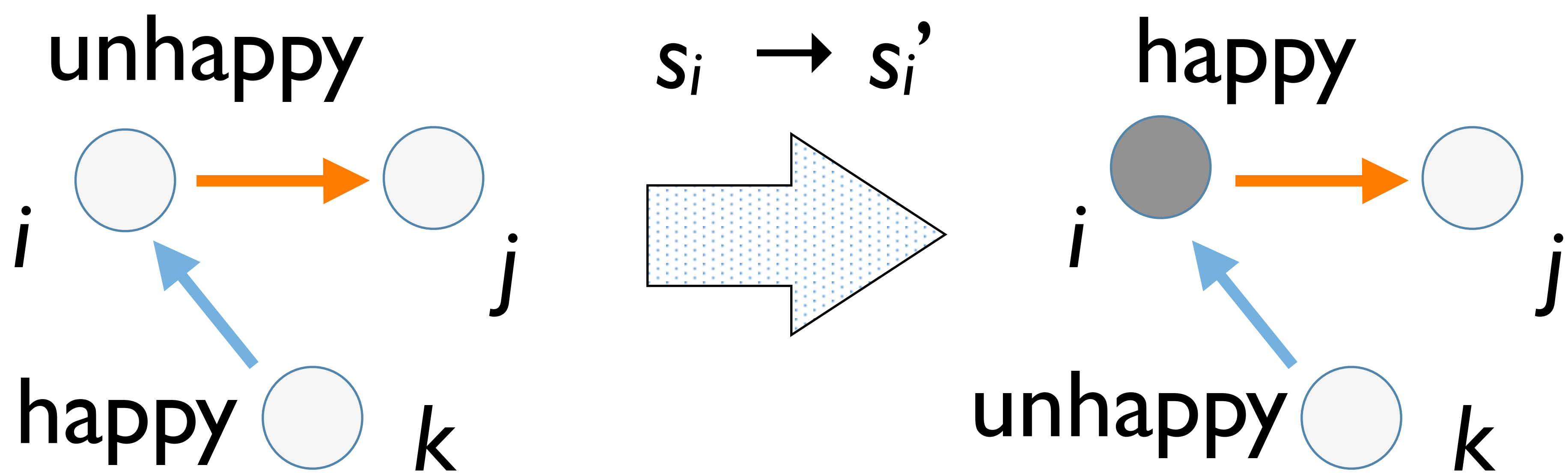
Happiness defined on directed links, not nodes.

q-State Voter Model

- Initial condition: a state s_i (= 1,2, ... q) is randomly assigned to each node i.
- One node is selected randomly. Try $s_i \rightarrow s_i'$.
  If s_i' reduces the number of unhappy links, accept.
  Otherwise, reject (change back to s_i) ≈ Monte Carlo.
- After a long run, find steady state.
  Measure the unhappy link density u.
- To avoid falling into local minima, apply the annealing technique (introduce noise and slowly decrease noise strength).

q-State Voter Model

- Reduction of unhappy links: global vs local.



unhappy links of i (local): $\Delta U_i = -1$ (direction matters)

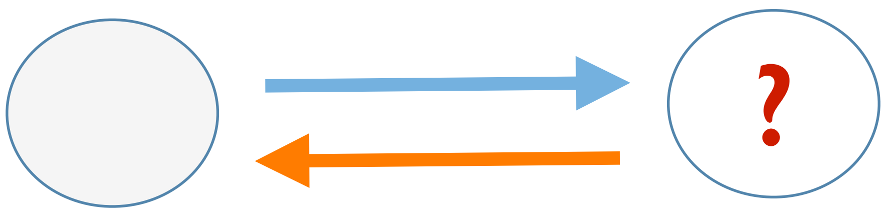
unhappy links (global): $\Delta U = 0$ (undirected network)

q-State Voter Model

- Reduction of unhappy links: global vs local.
- Company's view: Reduction of total number of unhappy links is desirable (global) → undirected voter model.
- Employee's view: Reduction of number of her unhappy links is desirable (local) → directed voter model.
- Global/local reduction of unhappy links:
  Who decides the membership of each employee?
    Company (or the boss): global reduction.
    Employee: local reduction.

q-State Voter Model

Irreducible misery for frustrated pair:



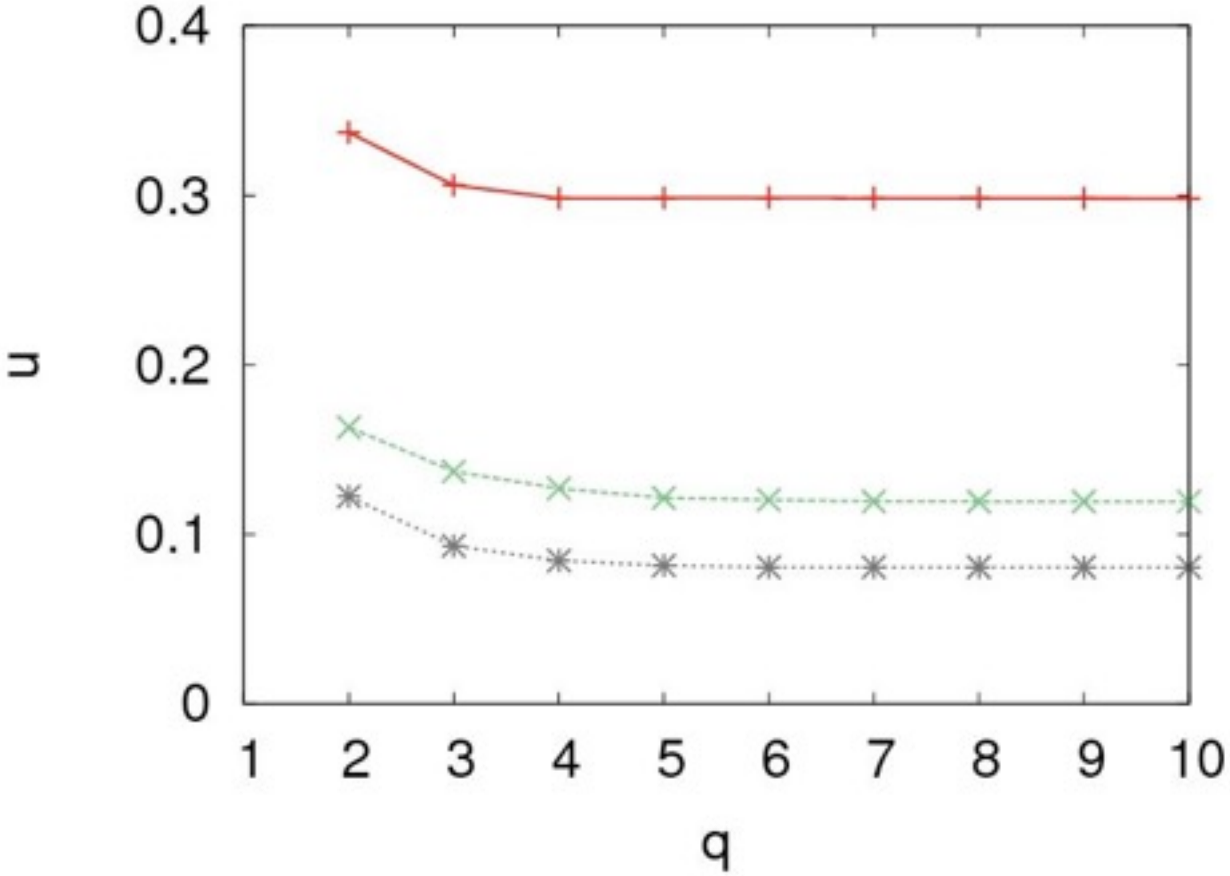
This couple can never be happy.
(21 & 27 such couples in 03' and 06')

Always unhappy link regardless of states.

Appolo & Daphne in Greek mythology

q-State Voter Model

Converge to stationary state [$u(t) \to u$].



random network
(same out-degrees)

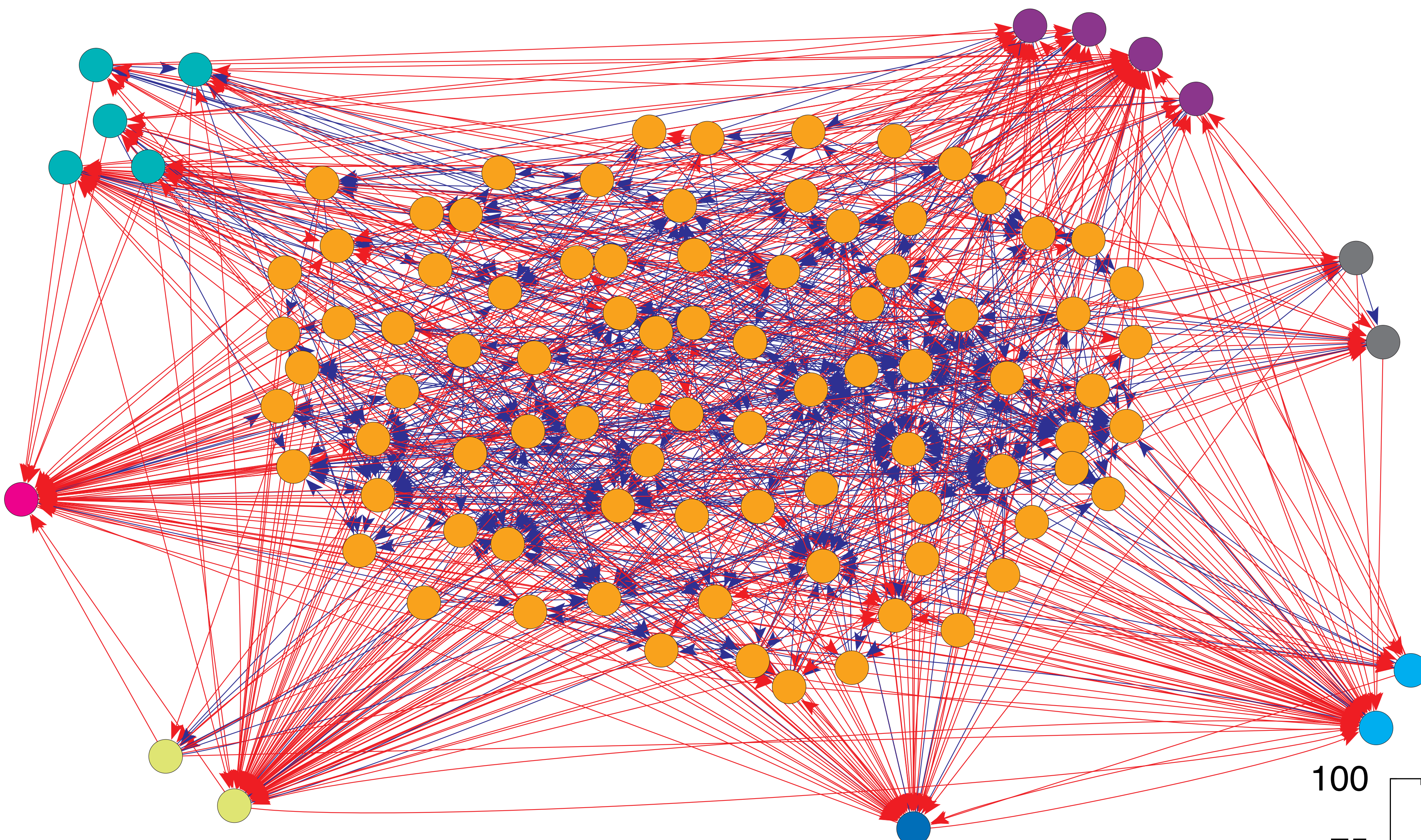
03’ : 123 unhappy links

06’ : 83 unhappy links

- Unhappy link density *u* saturates at $q = q_c \gtrsim 6$:
  6 divisions are enough to reduce conflict among members.

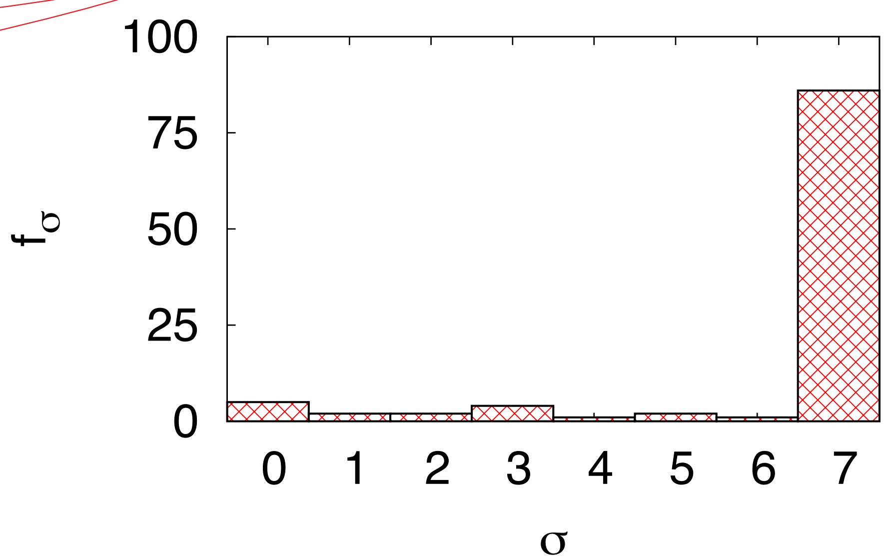
- *u*(random) > *u*(at 03’) > *u*(at 06’): Conflict reduction?

q-State Voter Model



- q=8

- Non-uniform group size



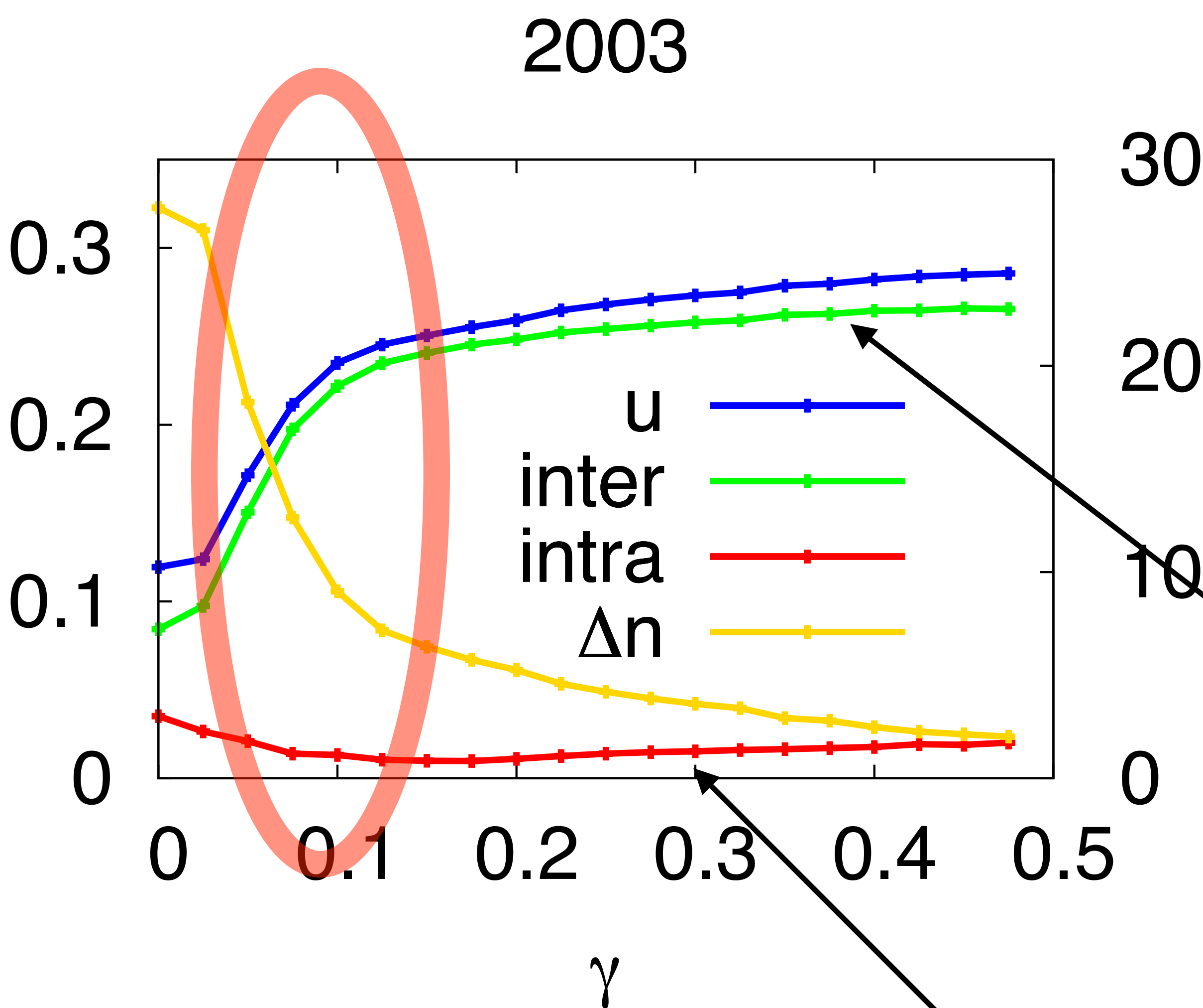
q-State Potts Model

- Energy cost for non-uniform group sizes.

$$H = -\sum_{\langle ij \rangle} J_{ij} \delta_{\sigma_i \sigma_j} + \gamma \sum_{\sigma=0}^{q-1} \frac{n_\sigma (n_\sigma - 1)}{2}$$

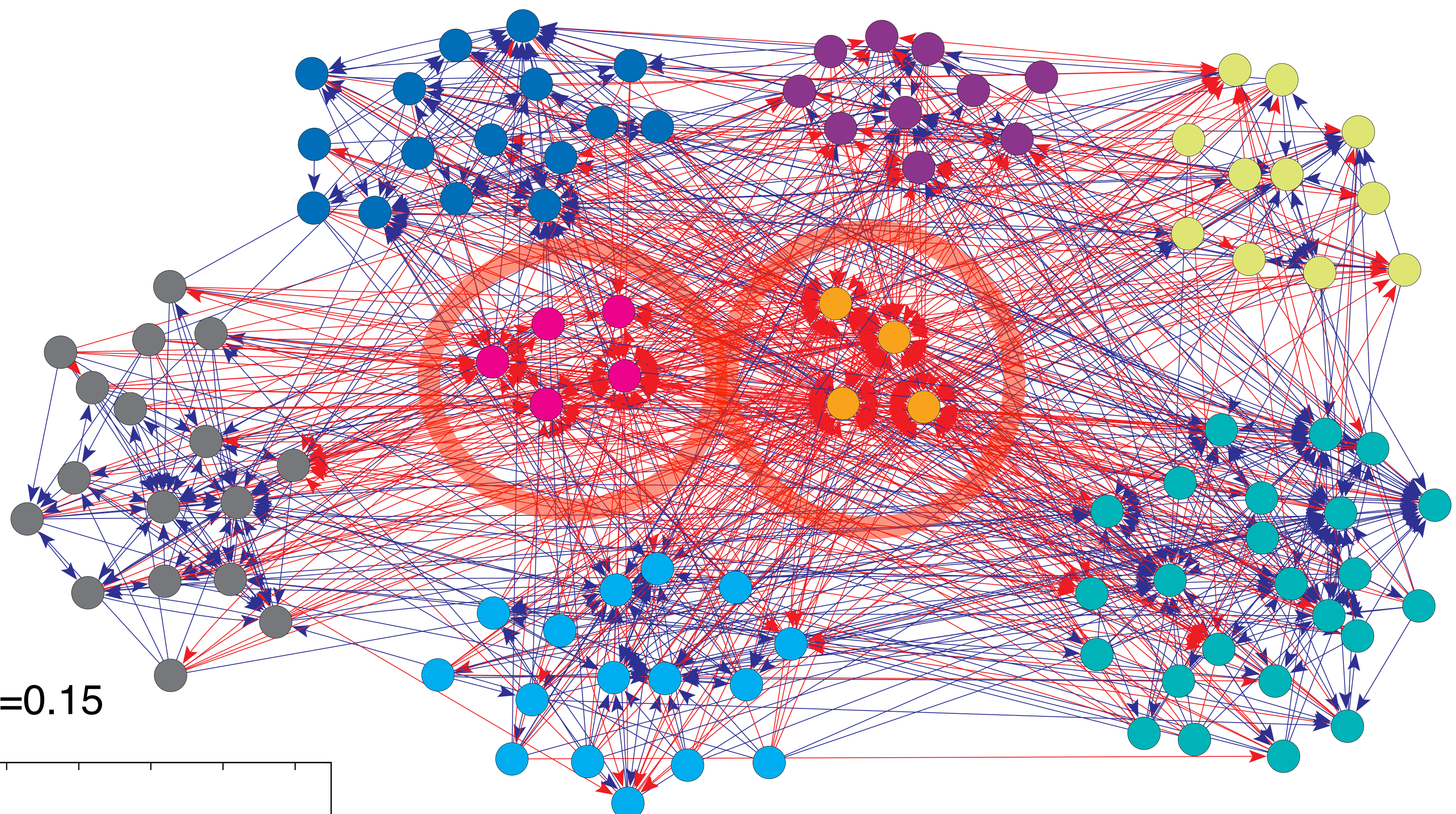
- Goal: less unhappy links & uniform group sizes.
- q = 8 (fixed).

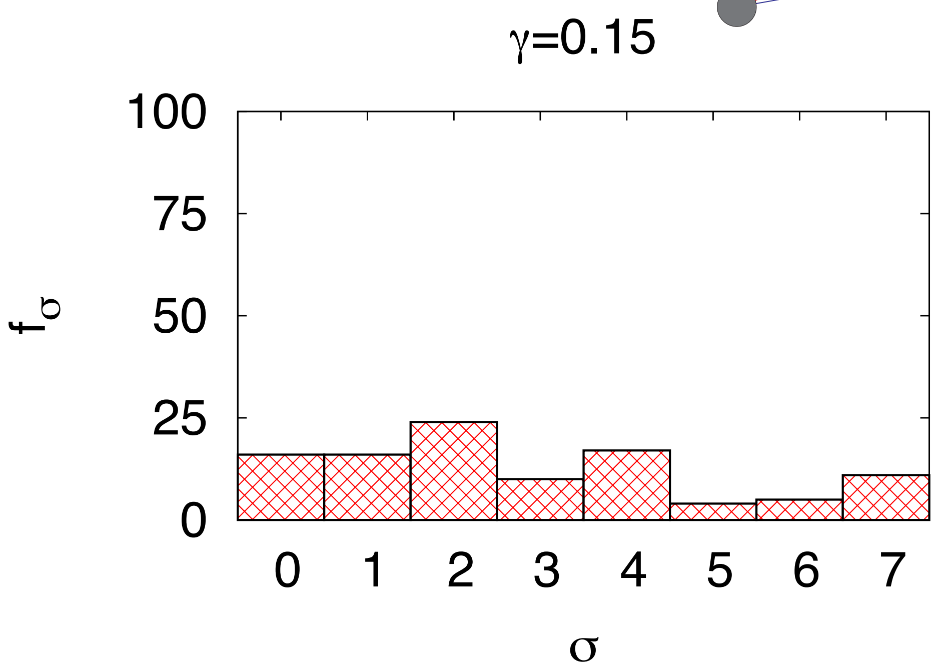
q-State Potts Model



- u = unhappy link density (↓)
- Δn = how uniform group sizes are (↓)
- inter-group unhappy link density.
- intra-group unhappy link density (↓)

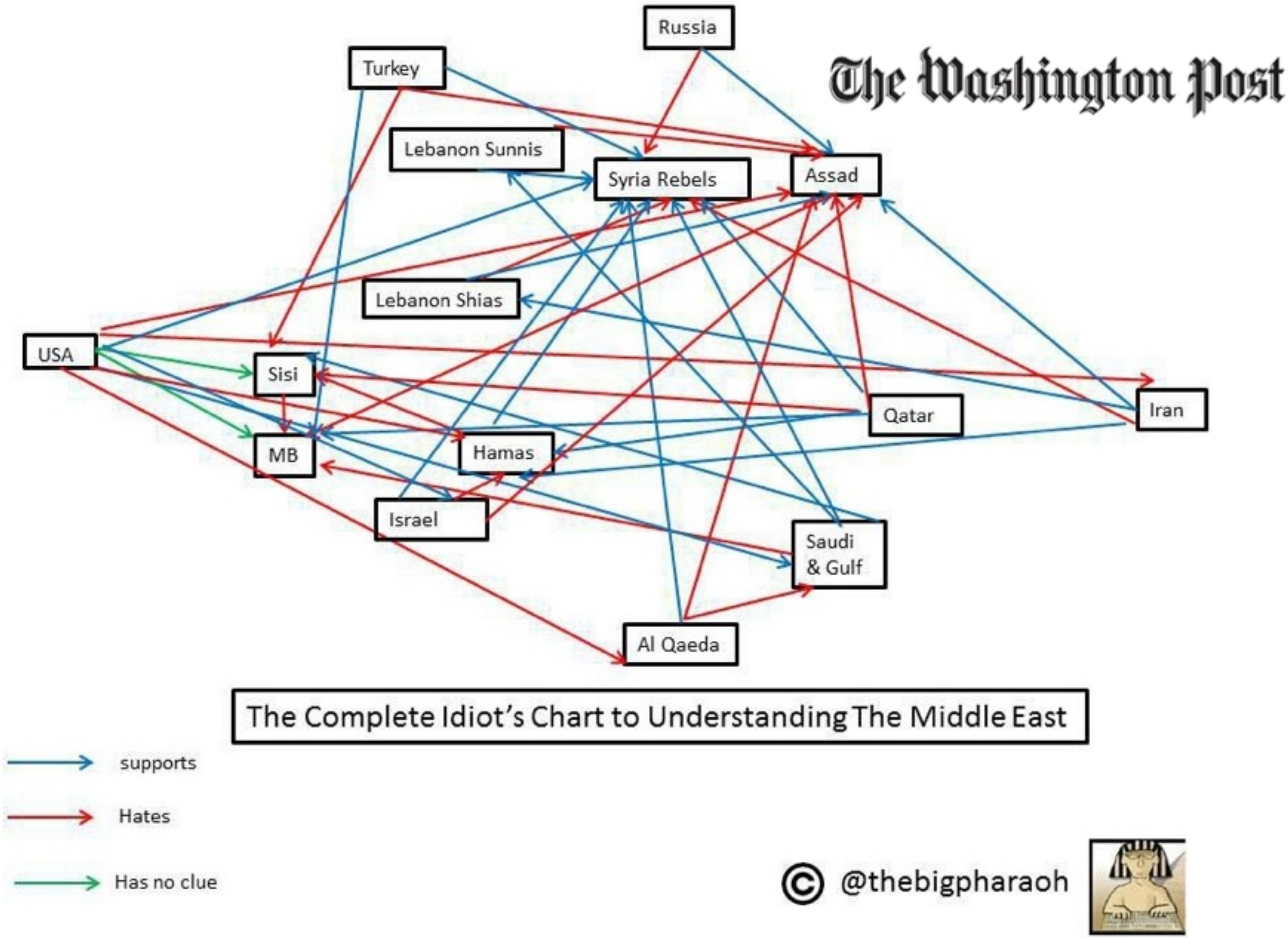
q-State Potts Model



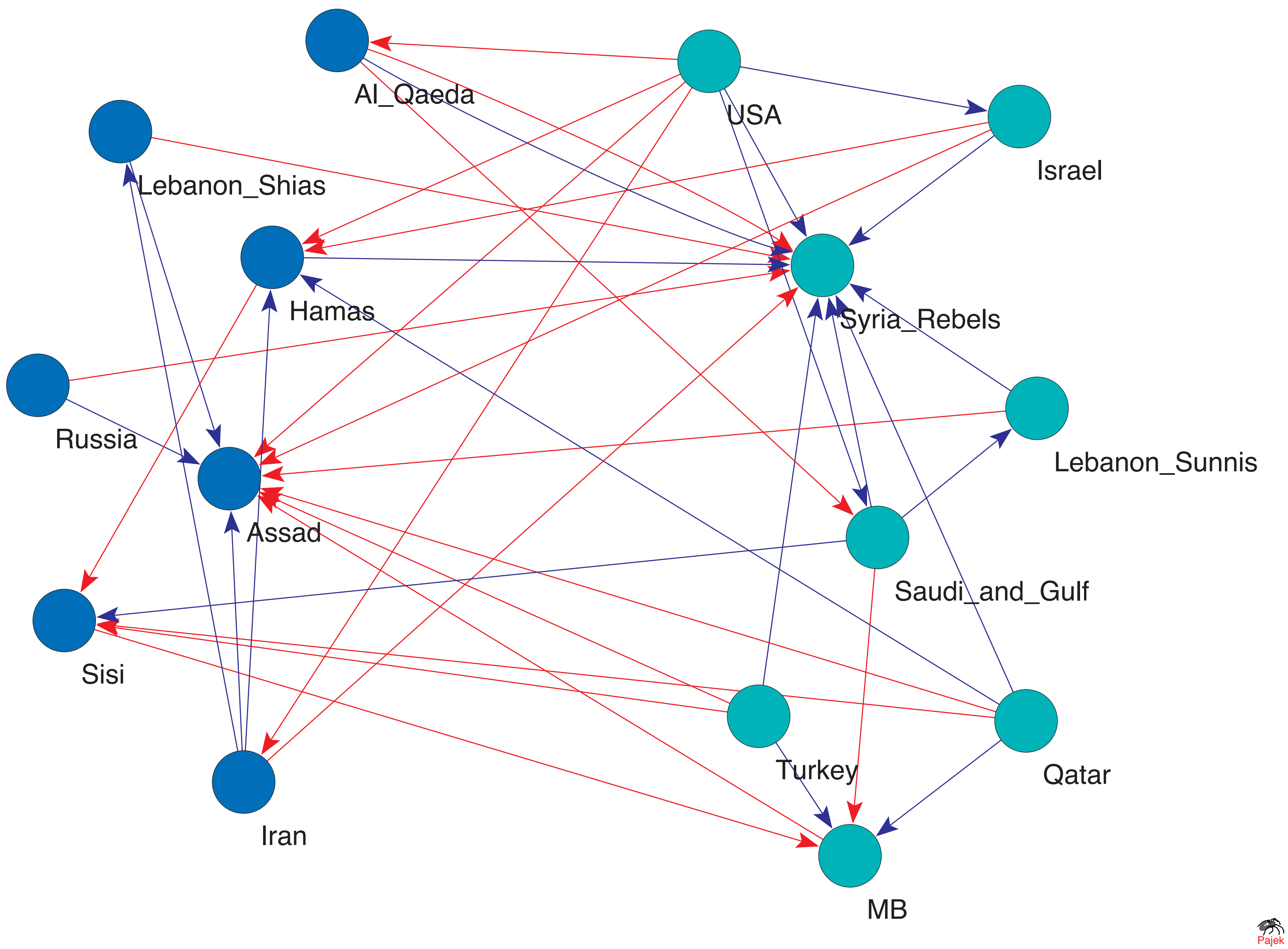


- Teams of hated members.

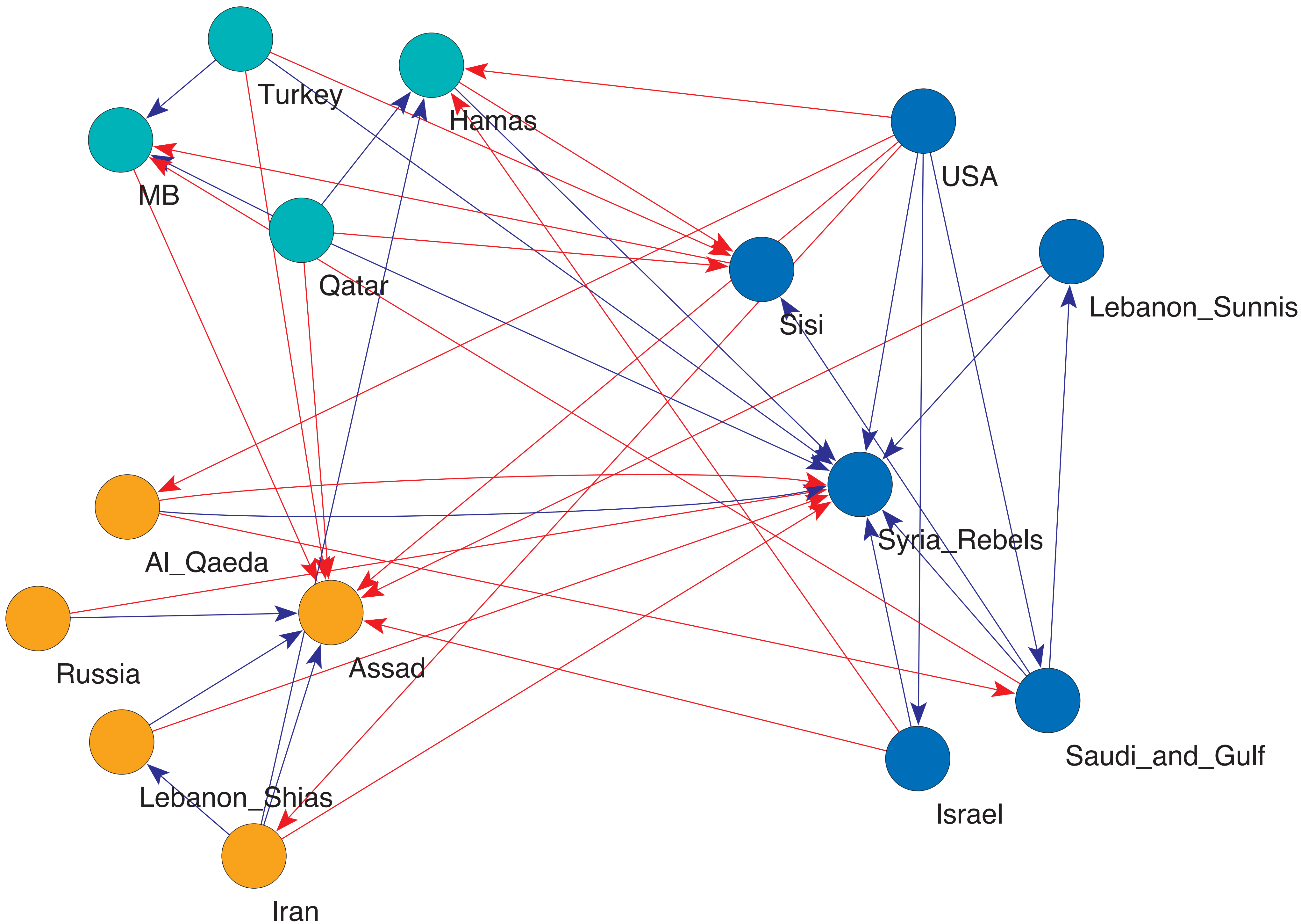
Application?



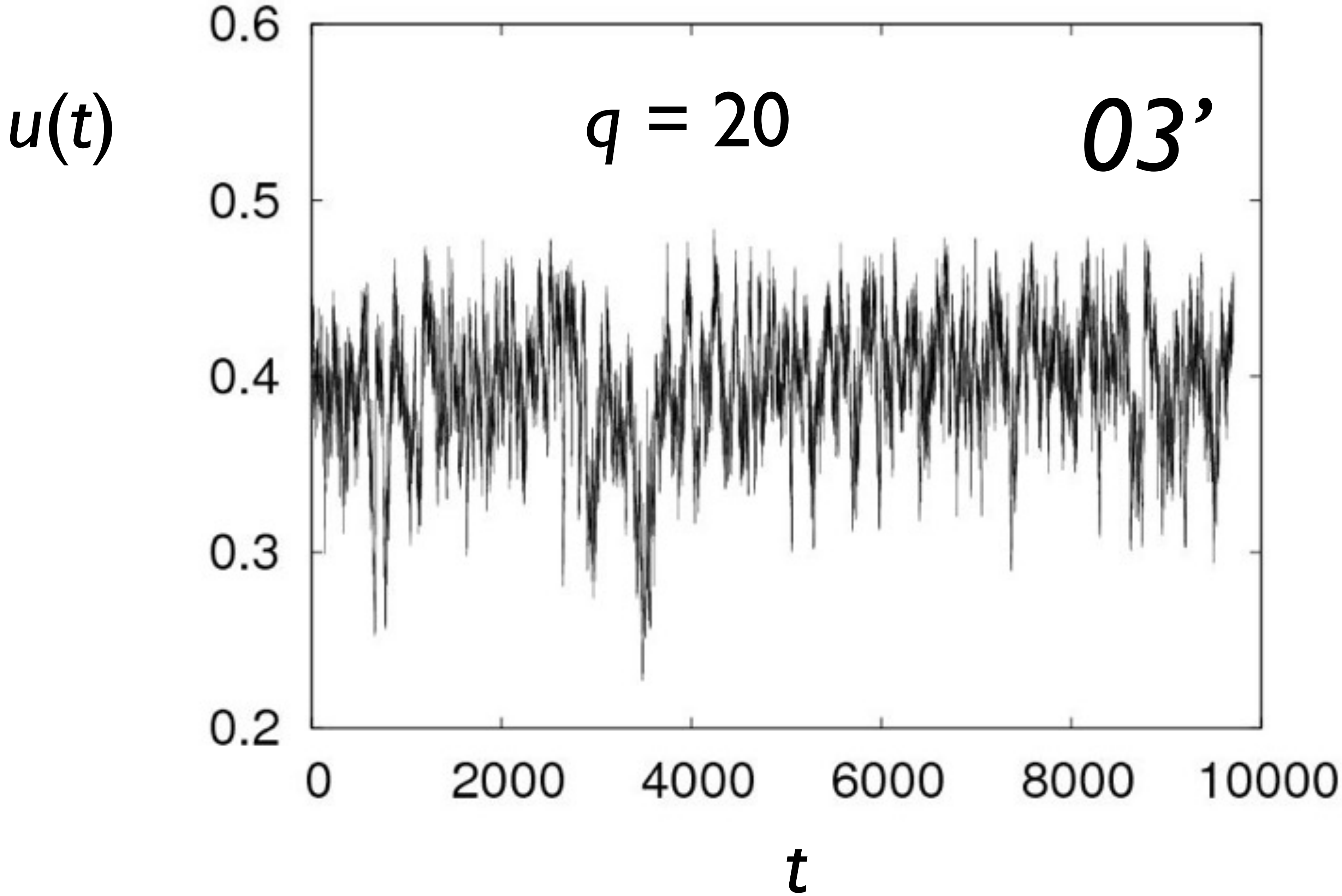
Application?



Application?

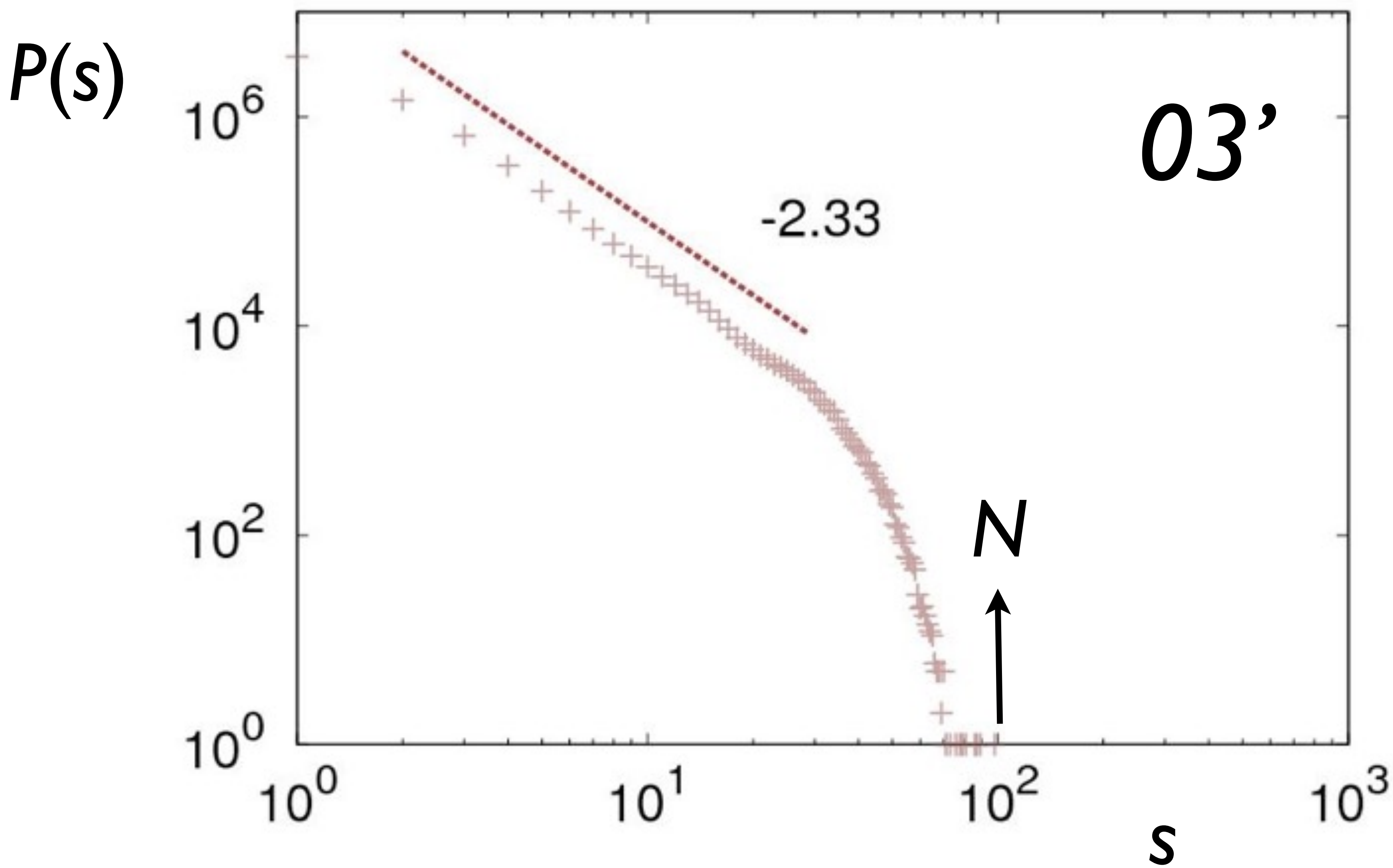


Employee's View: Directed Voter Model



$u(t)$ keeps fluctuating as $t \to \infty$.

Employee's View: Directed Voter Model



- Avalanche-size (change of # of unhappy links) distribution: Power-law with (finite-size) cutoff.
- Self-organized criticality?

Summary

- Real network of friends and enemies.
- q-state voter model & q-state Potts model.
- Membership assignment.
- Reduce unhappy link density.
- Reduce inhomogeneity of group sizes.