

# Opinion and spreading information models in complex networks

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Human Relationships-Social Network

# FOUR QUESTIONS ON SOCIAL NETWORKS---PARTIAL ANSWERS

How social networks are created?

**Gallos et al PRX (2012)**

How to identify influential spreaders?

**Kitsak et al Nature Phys. (2010)**

How opinions are formed?

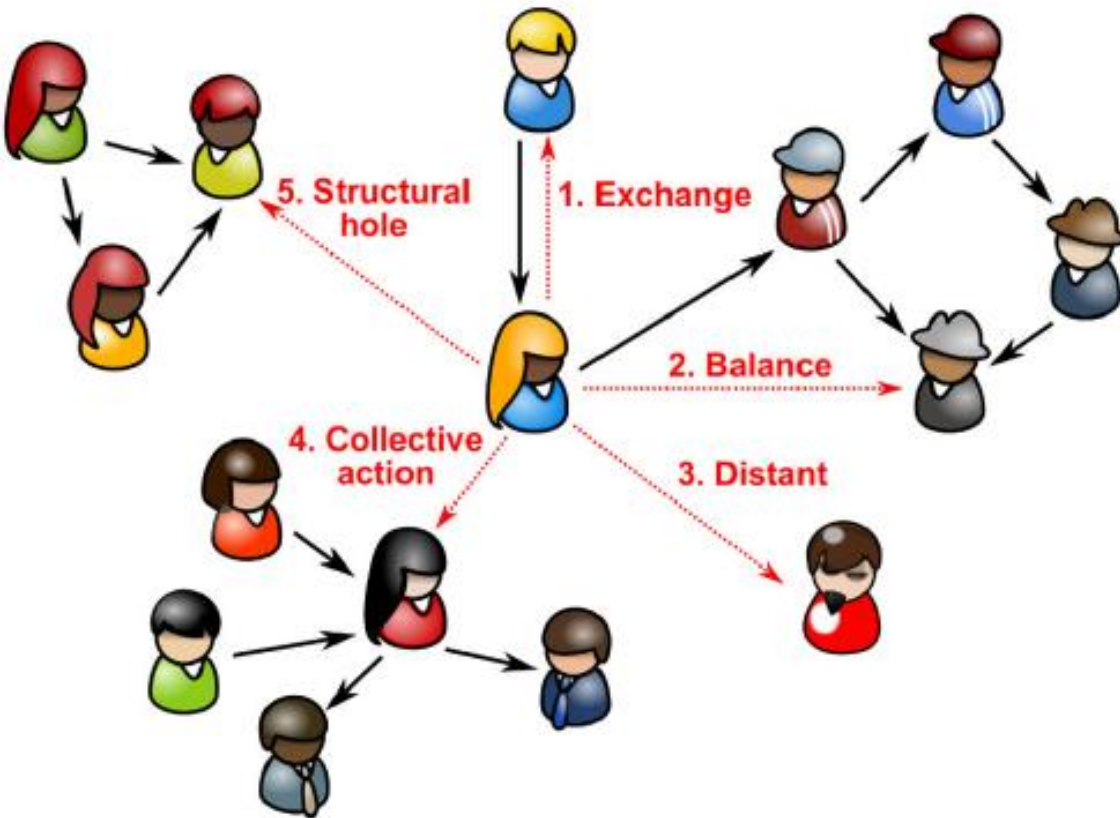
**Shao et al, PRL (2009)**

**Qian Li et al J. Stat. Phys (2013)**

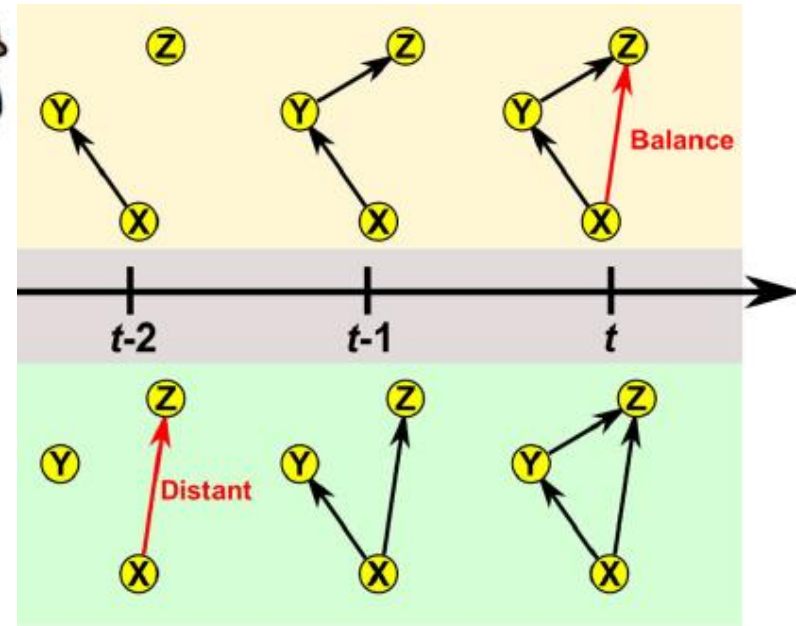
How extreme opinions occur?

**Makse et al preprint (2013)**

# How People Interact in Online Networks?



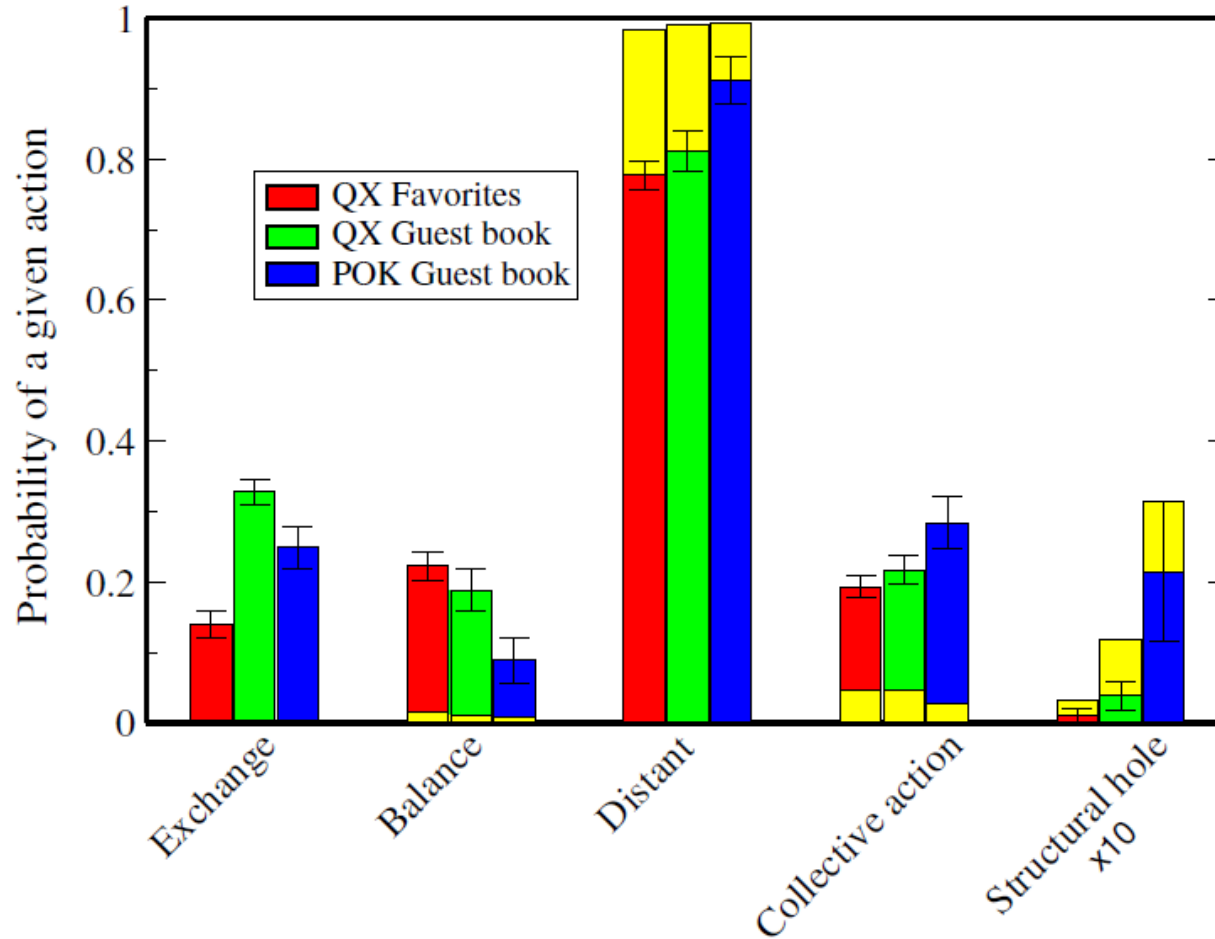
*Following dynamics*



P. R. Monge and N. S. Contractor, *Theories of Communication Networks* (Oxford University Press, New York, 2003).

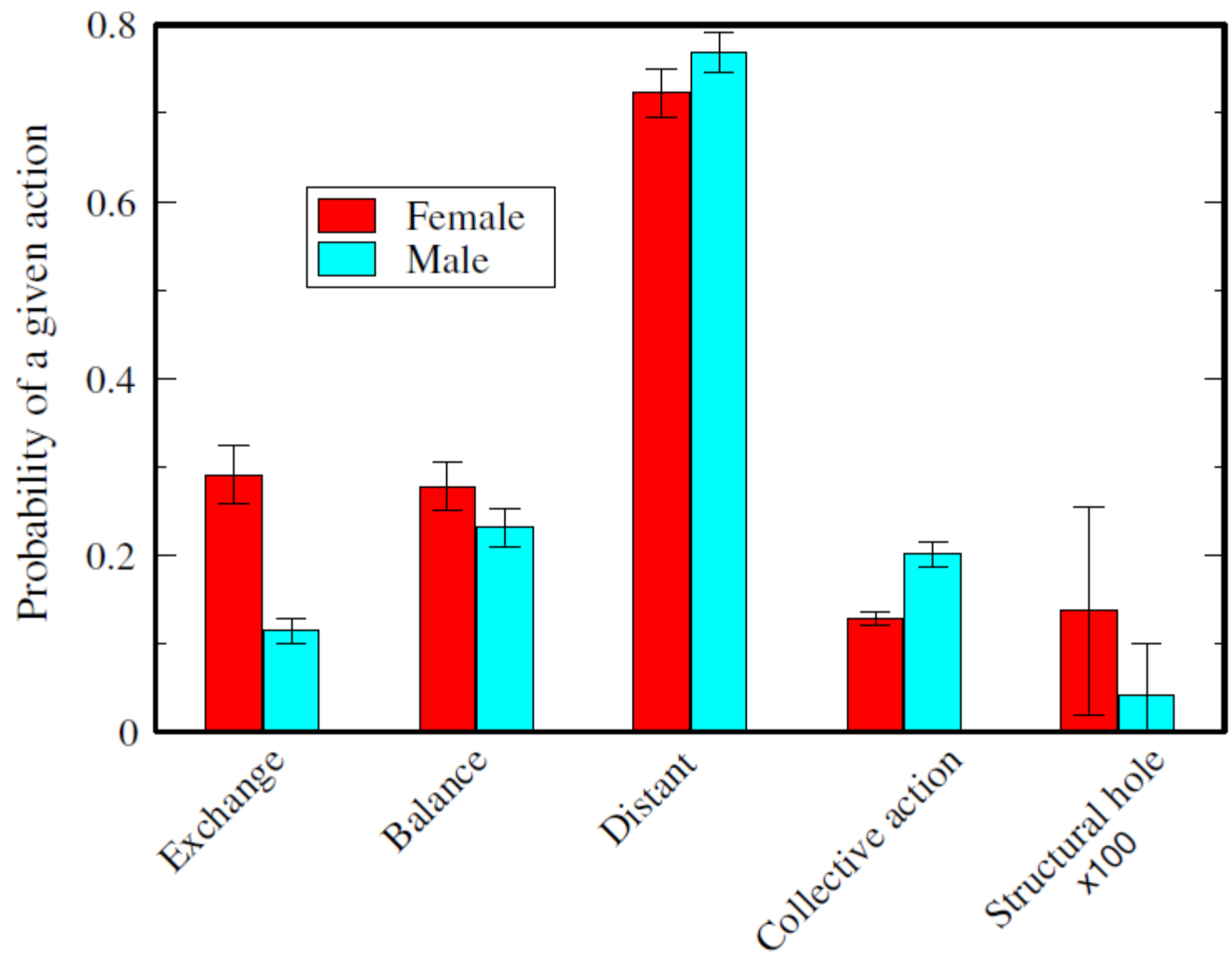
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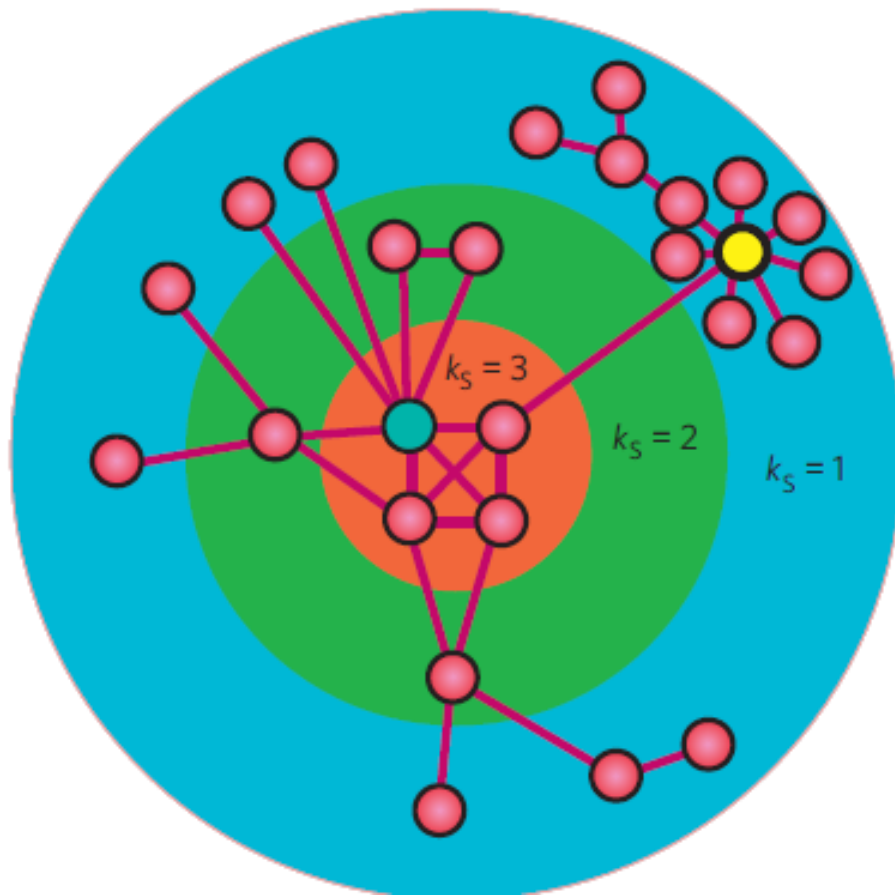


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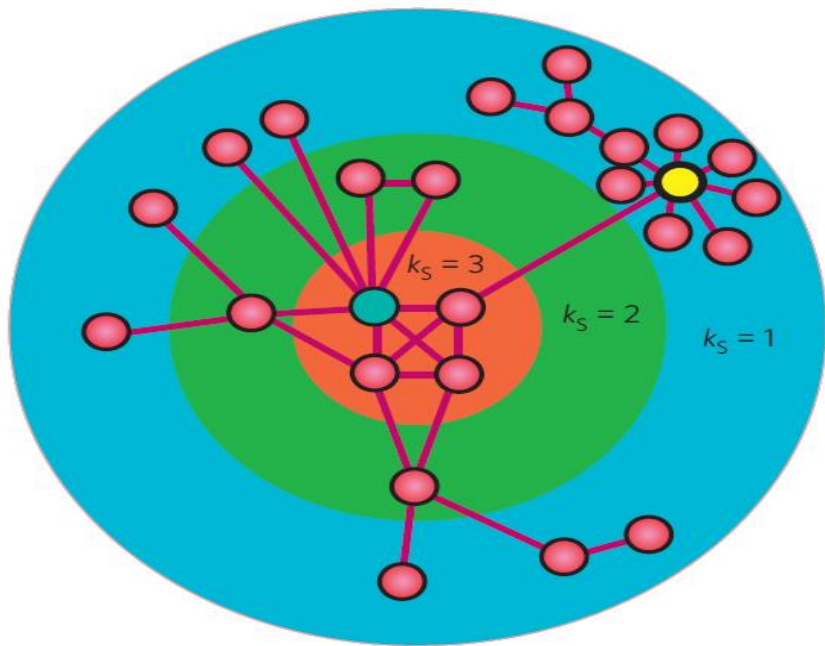


# Identification of influential spreaders in complex networks

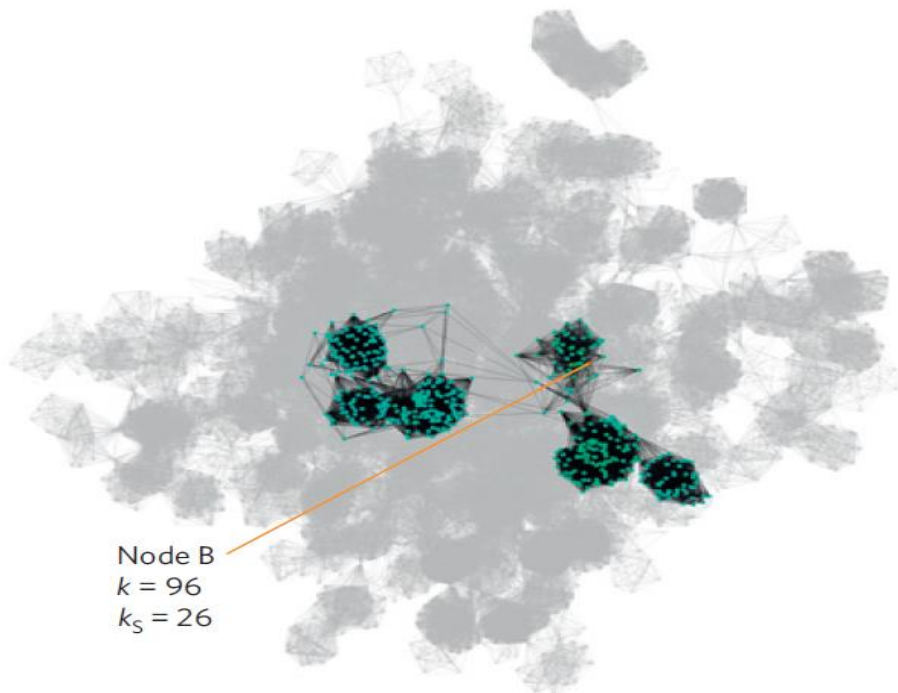
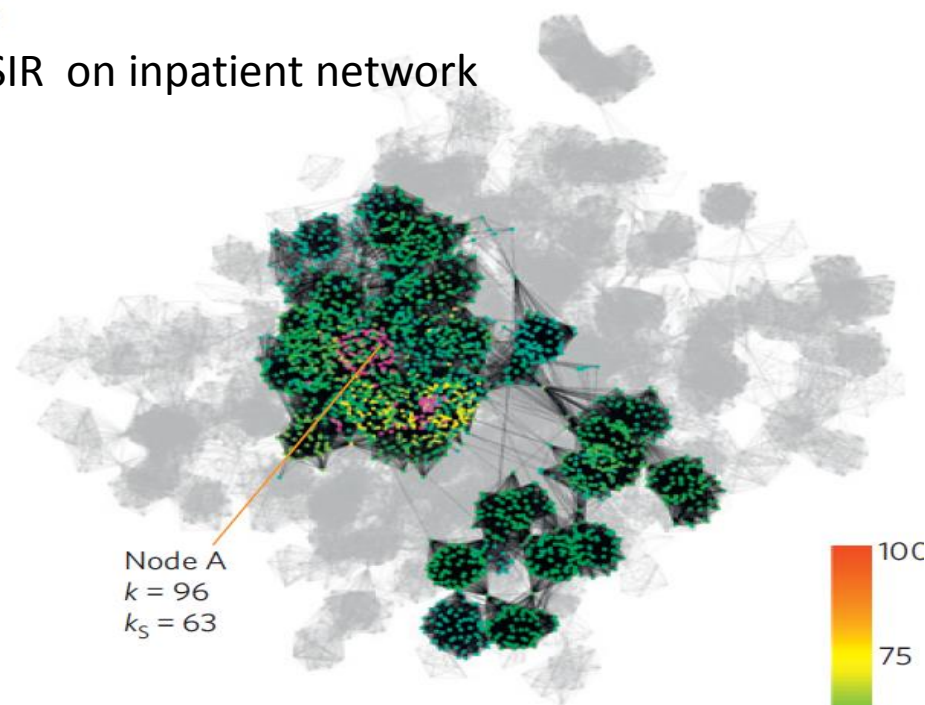


METHOD: k-shell decomposition analysis  
Carmi et al: PNAS (2009)

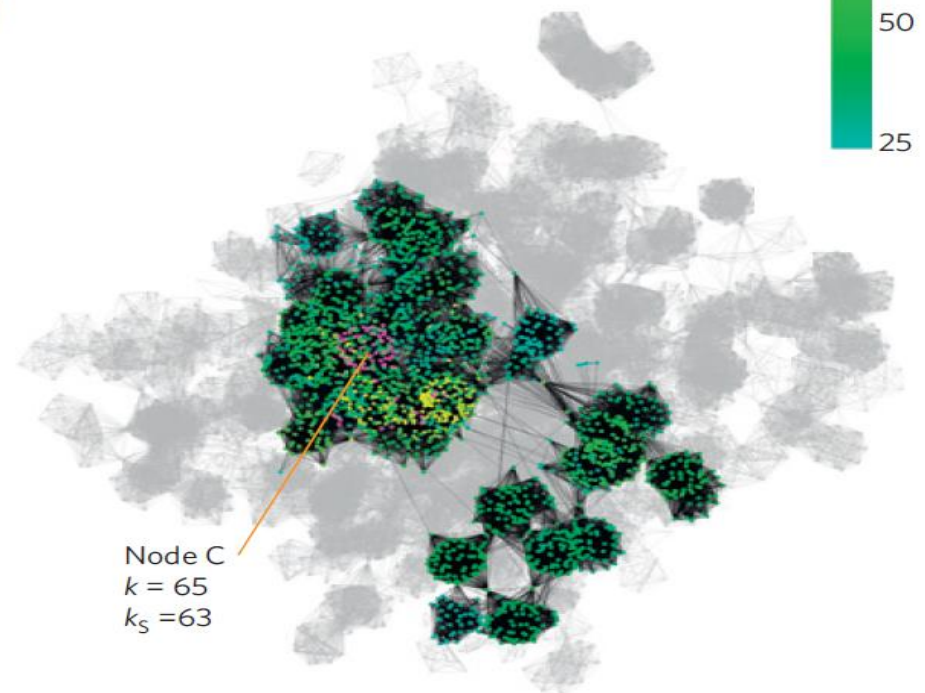




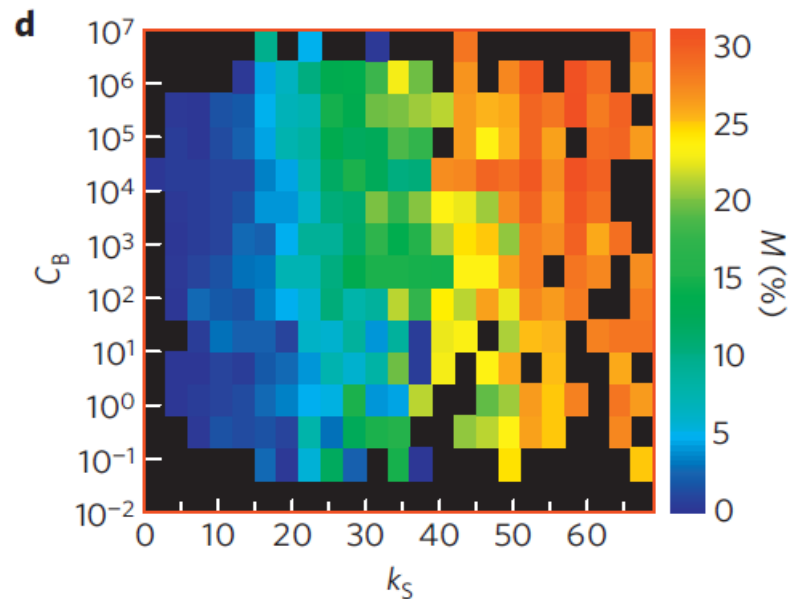
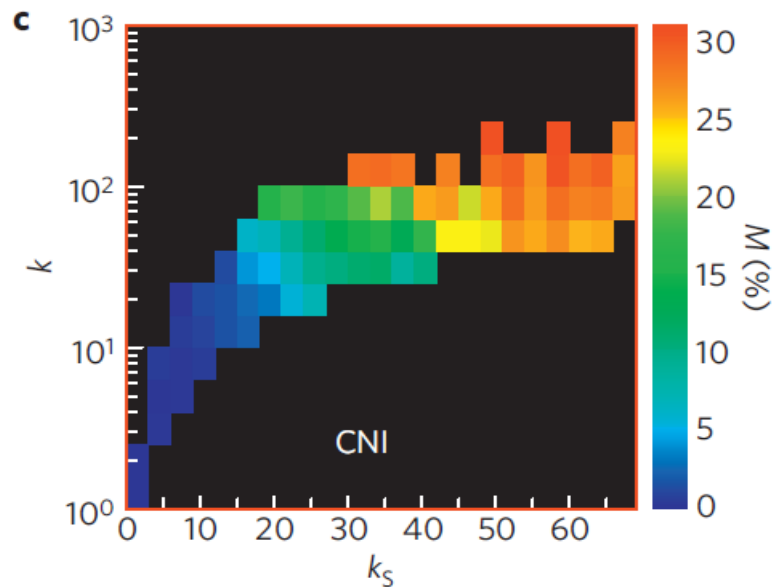
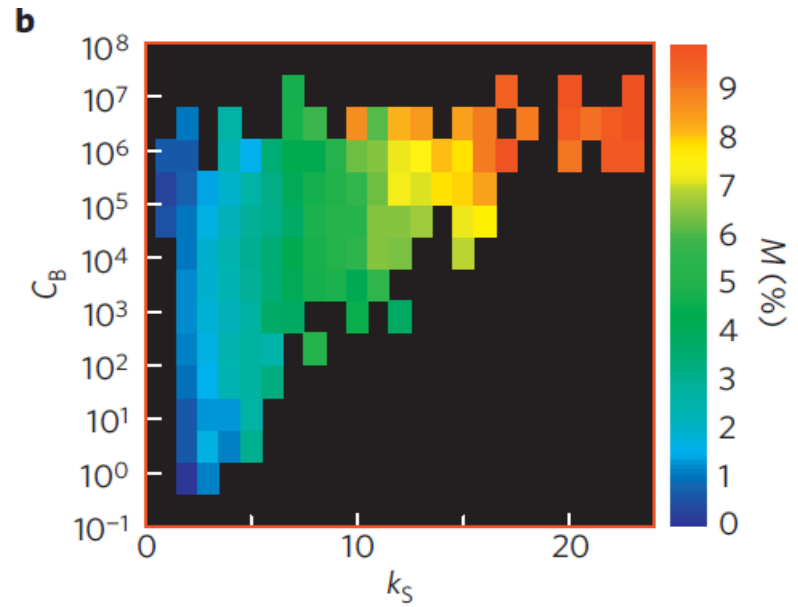
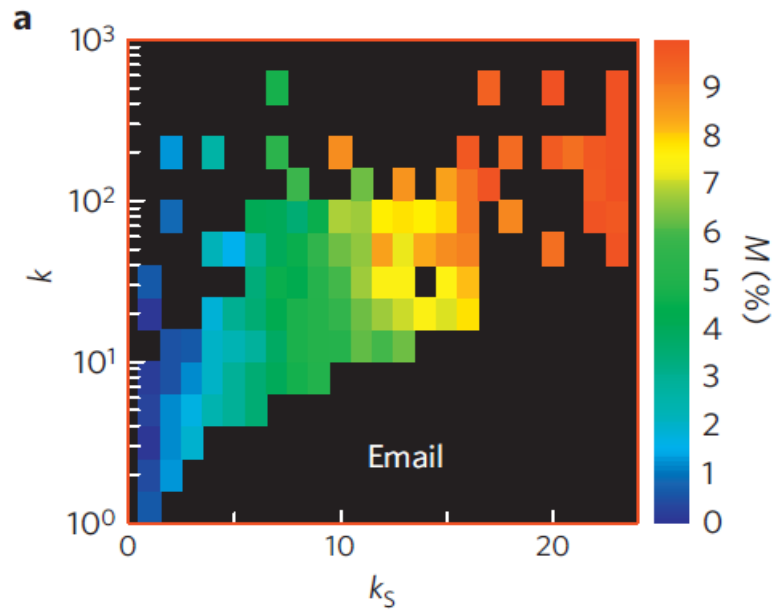
**b** SIR on inpatient network



**d**



# Test: SIR on real networks: email ( $\beta=0.08$ ) and inpatient networks ( $\beta=0.04$ )

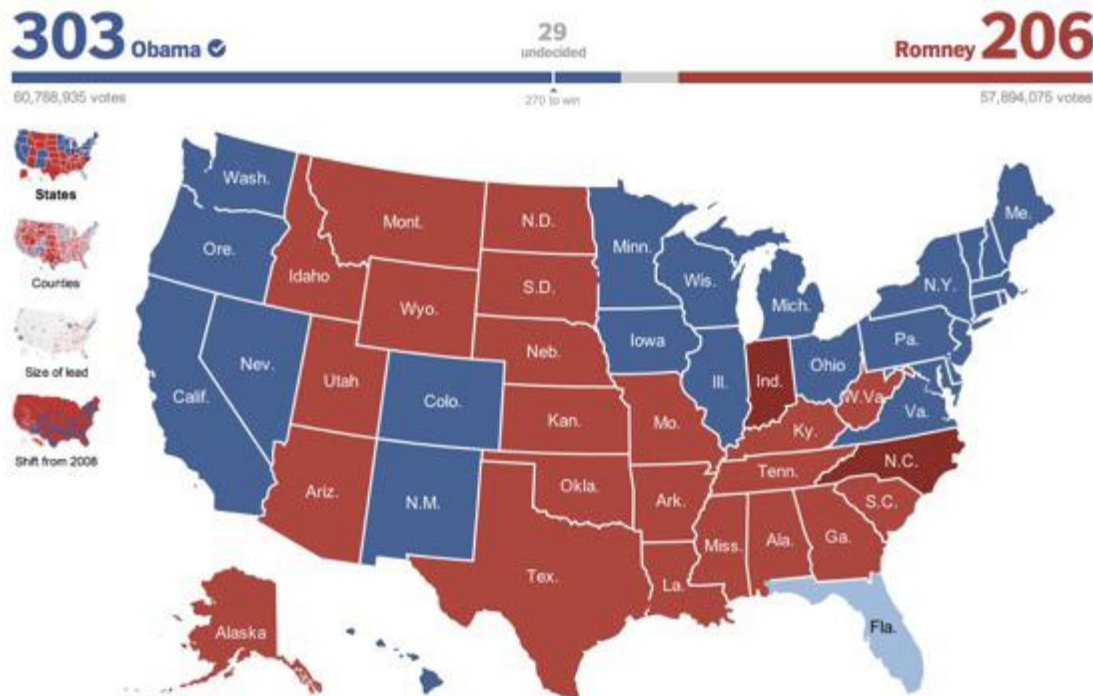




# How opinions are formed?

## Consensus Opinion Models

- Voter Model (Holley and Liggett 1975, Redner 2005): The agents imitate their neighbors
- Majority Rule Model (S. Galam et. al, 2002, P. L. Krapivsky et. Al 2003) : Agents follow the majority opinion of their friends



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## Non-Consensus Opinion (NCO) Models (J. Shao et.al, 2009):

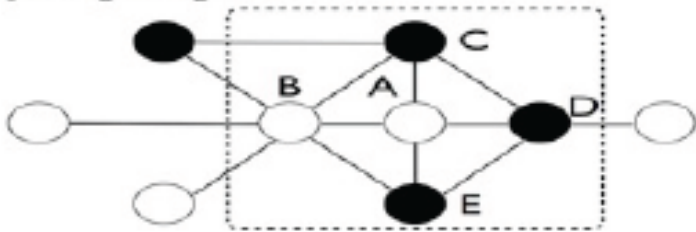
- Agent's opinion is influenced by both its own current opinion and the opinions of his friends
- Agent follows the majority opinion of his local community, which include agent's friends and itself

# Majority Model

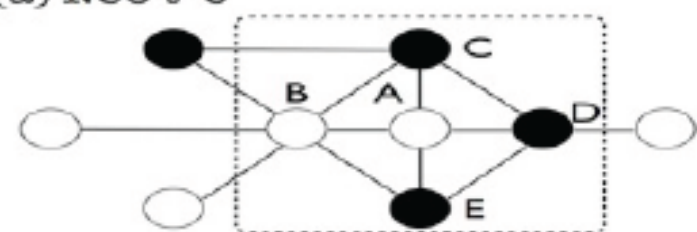
VS

# NCO Model

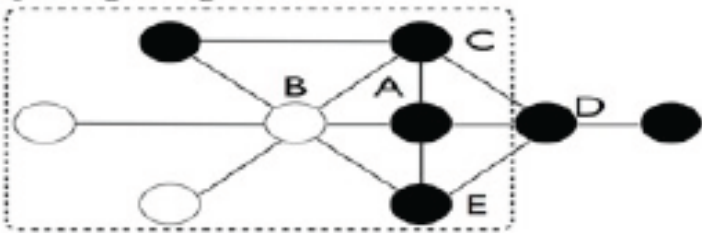
(a) Majority  $t=0$



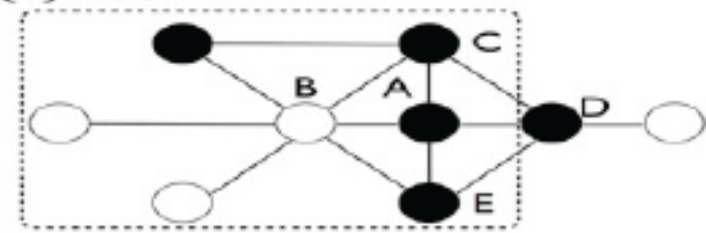
(a) NCO  $t=0$



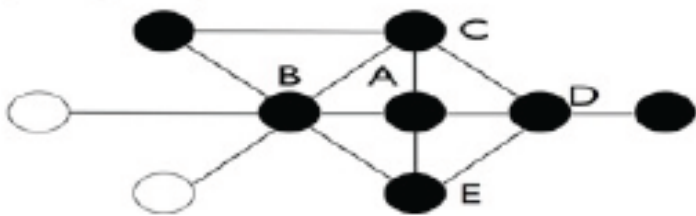
(b) Majority  $t=1$



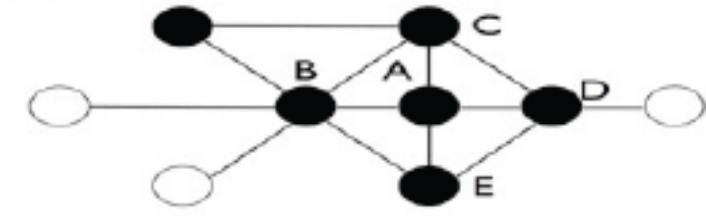
(b) NCO  $t=1$



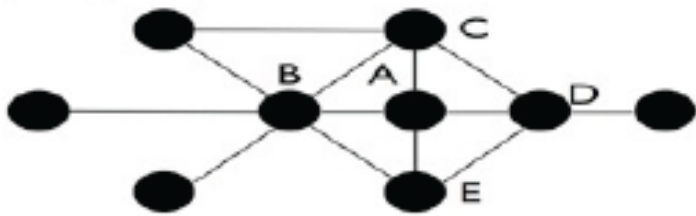
(c) Majority  $t=2$



(c) NCO  $t=2$



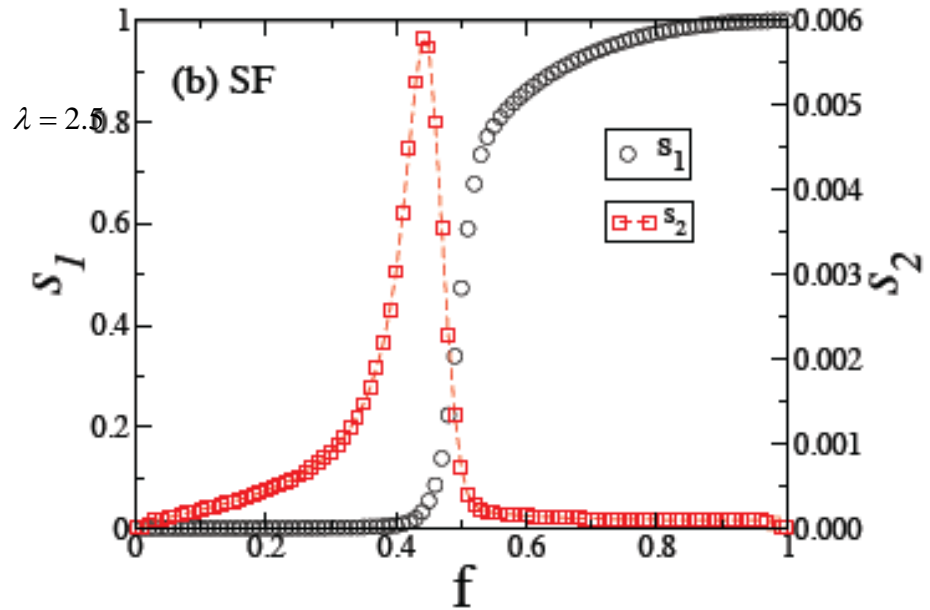
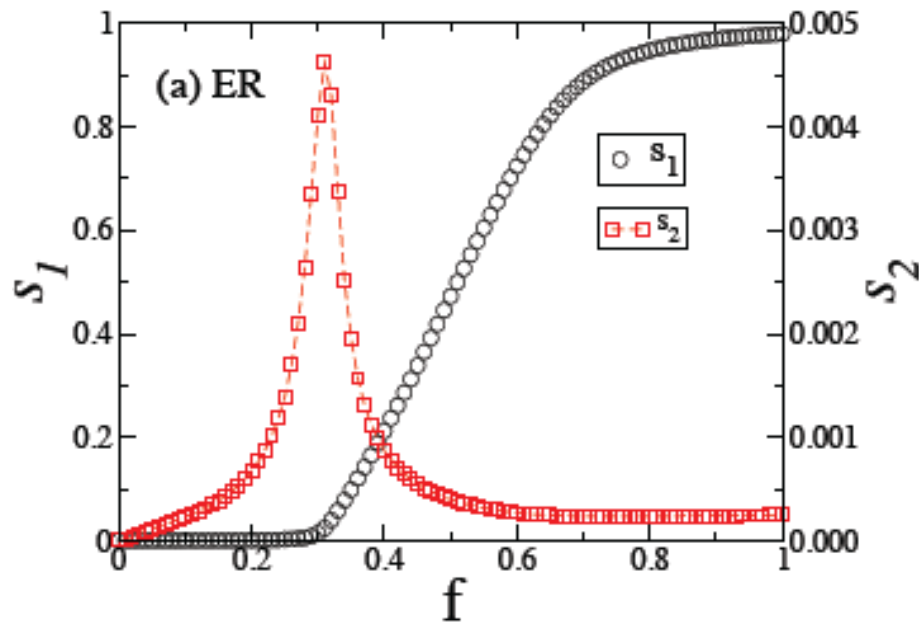
(d) Majority  $t=3$



Considering the agent's own opinion leads to **non-consensus** state

# NCO Model on Single Networks

$f$  : Initial fraction of one of the opinions

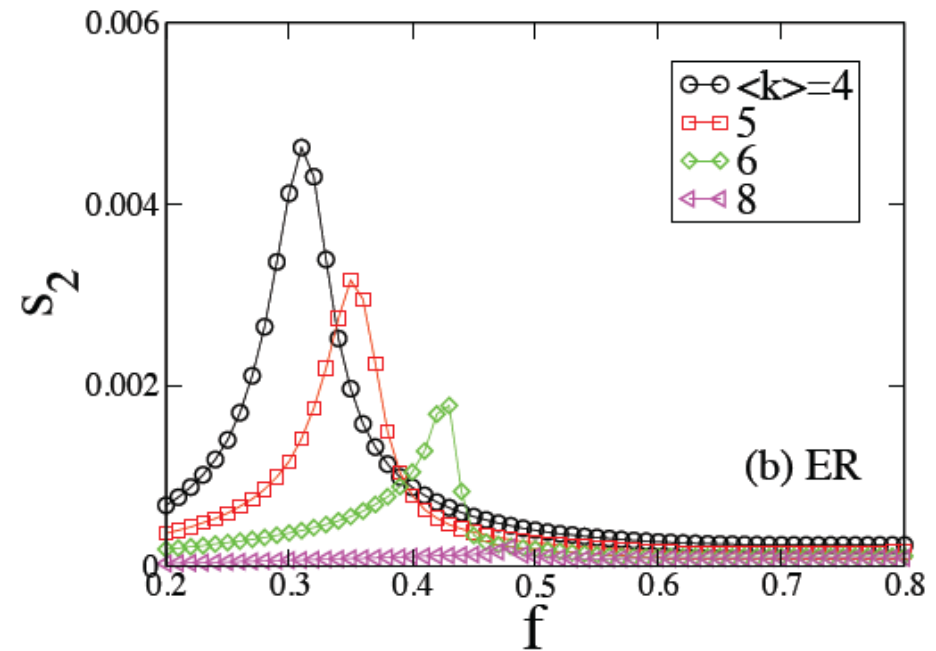
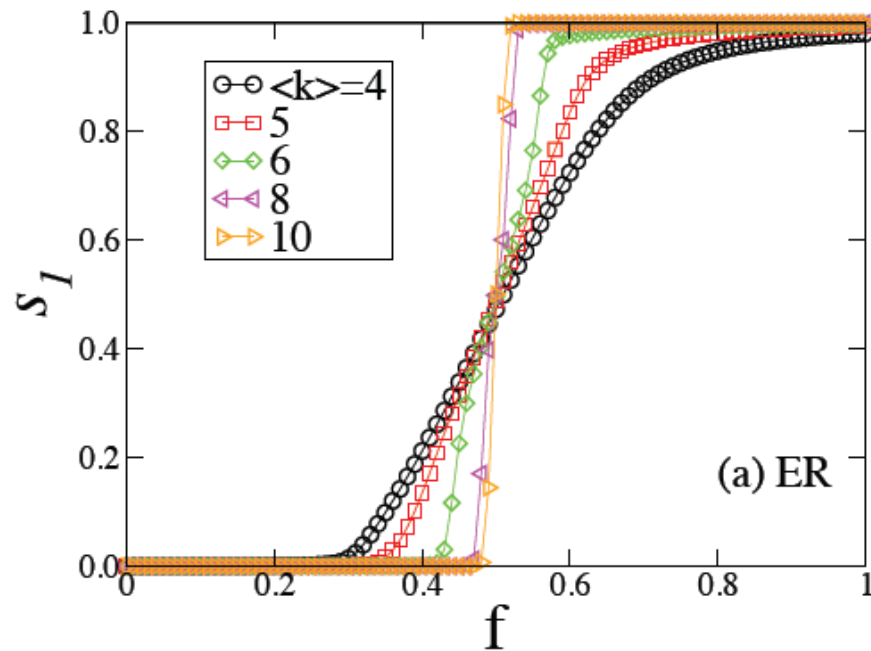


ER networks with  
average degree=4

SF networks with

# Consensus Opinion Models Non-Consensus Opinion Models

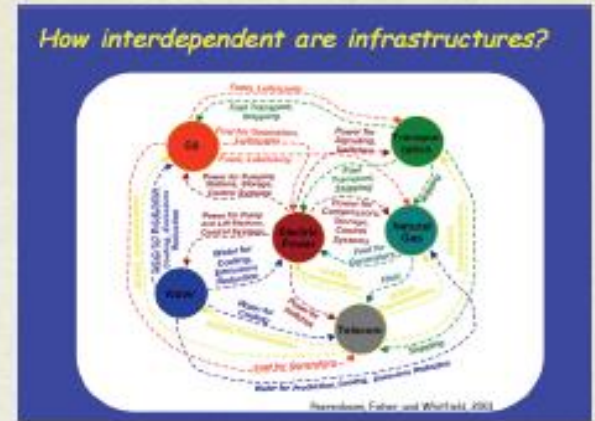
- Increase The Average Degree of the Networks



When the average degree of the networks increases, the importance of one's own opinion decreases and the NCO model converges to the Majority Rule model

# NCO on Coupled Networks

## Why Coupled Networks ?

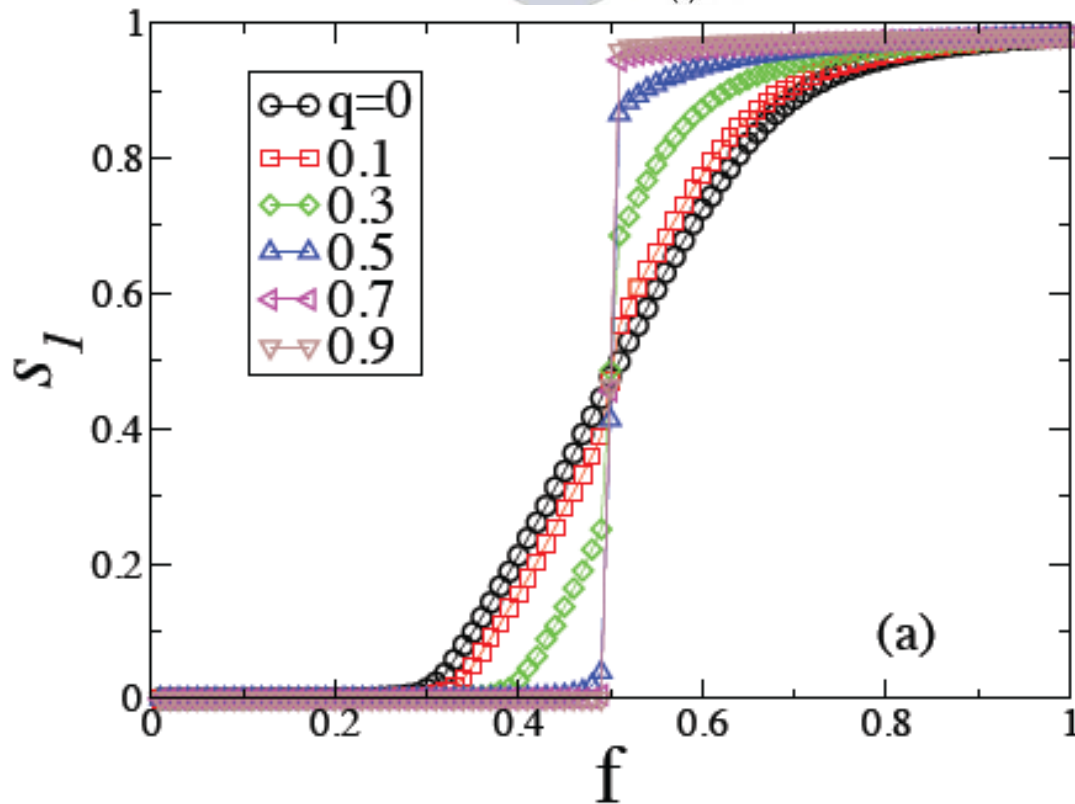
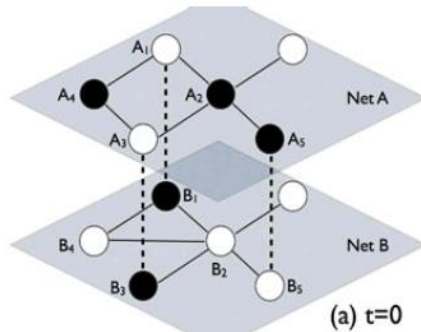


**Almost All  
Real  
Networks  
are Inter-  
connected**

Interdependent networks model: S. V. Buldyrev, R. Parshani, G. Paul, H. E. Stanley, and S. Havlin, *Nature* (2010)



# NCO Model on Coupled Networks



Second Order  
Transition (NCO on  
Single Network)



Hybrid Transition  
(Abrupt Transition  
Dominate)

Similar to percolation in  
interdependent networks  
Buldyrev et al , Nature (2010)



# FOUR QUESTION ON SOCIAL NETWORKS---PARTIAL ANSWERS

## MAIN MESSAGES:

How social networks are created?

Gallos et al PRX (2012)

**Motifs occur significantly in social interactions**

How to identify influential spreaders?

Kitsak et al Nature Phys. (2010)

**In many cases K-shell better than degree or betweenness**

How opinions are formed?

Shao et al, PRL (2009)

Qian Li et al J. Stat. Phys (2013)

**Agent's own opinion should be considered**

How extreme opinions occur?

Makse et al preprint (2013)

**Agents surrounding by less extreme people are more stubborn**