



UNIVERSITÀ
DEGLI STUDI
DI PADOVA

Network Science

A.Y. 23/24

ICT for Internet & multimedia, Data science, Physics of data

Homophily and Polarization

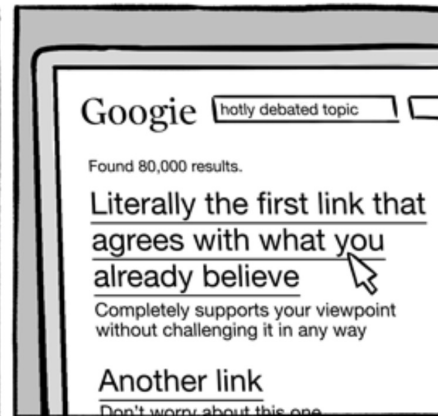
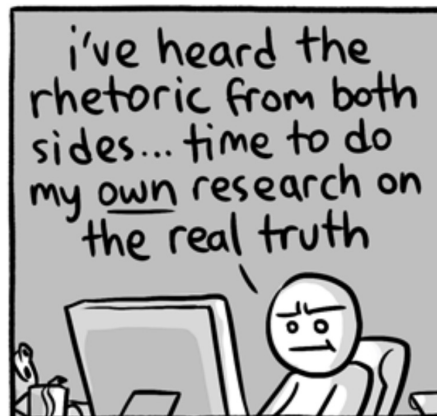
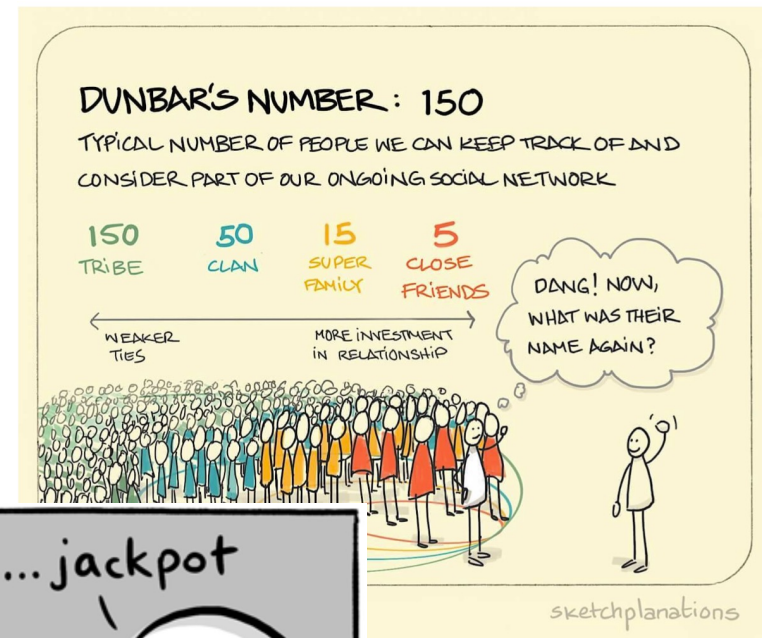
an overview

We have access to an unlimited amount of information, but we follow a **limited** number of sources

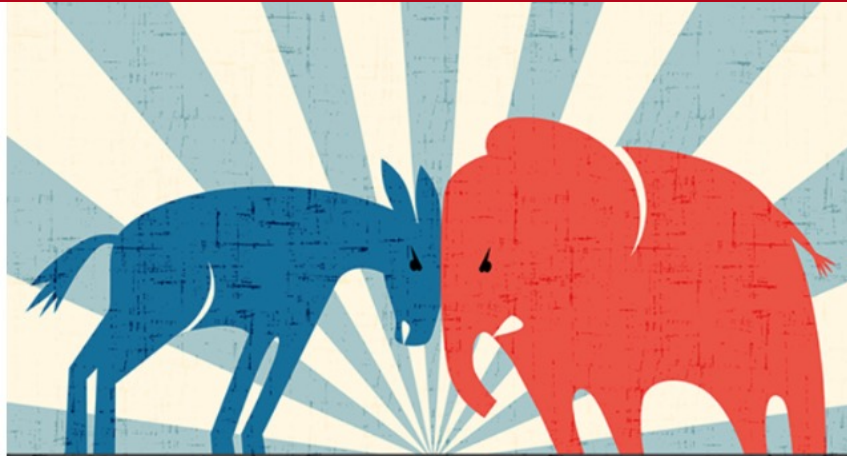
Because we are...

Bounded

Biased



Polarization



Homophily



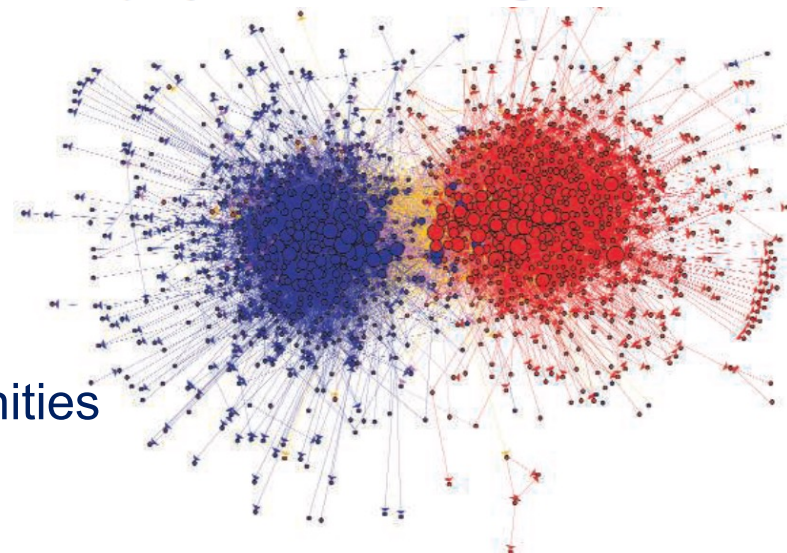
Selective exposure





Homophily

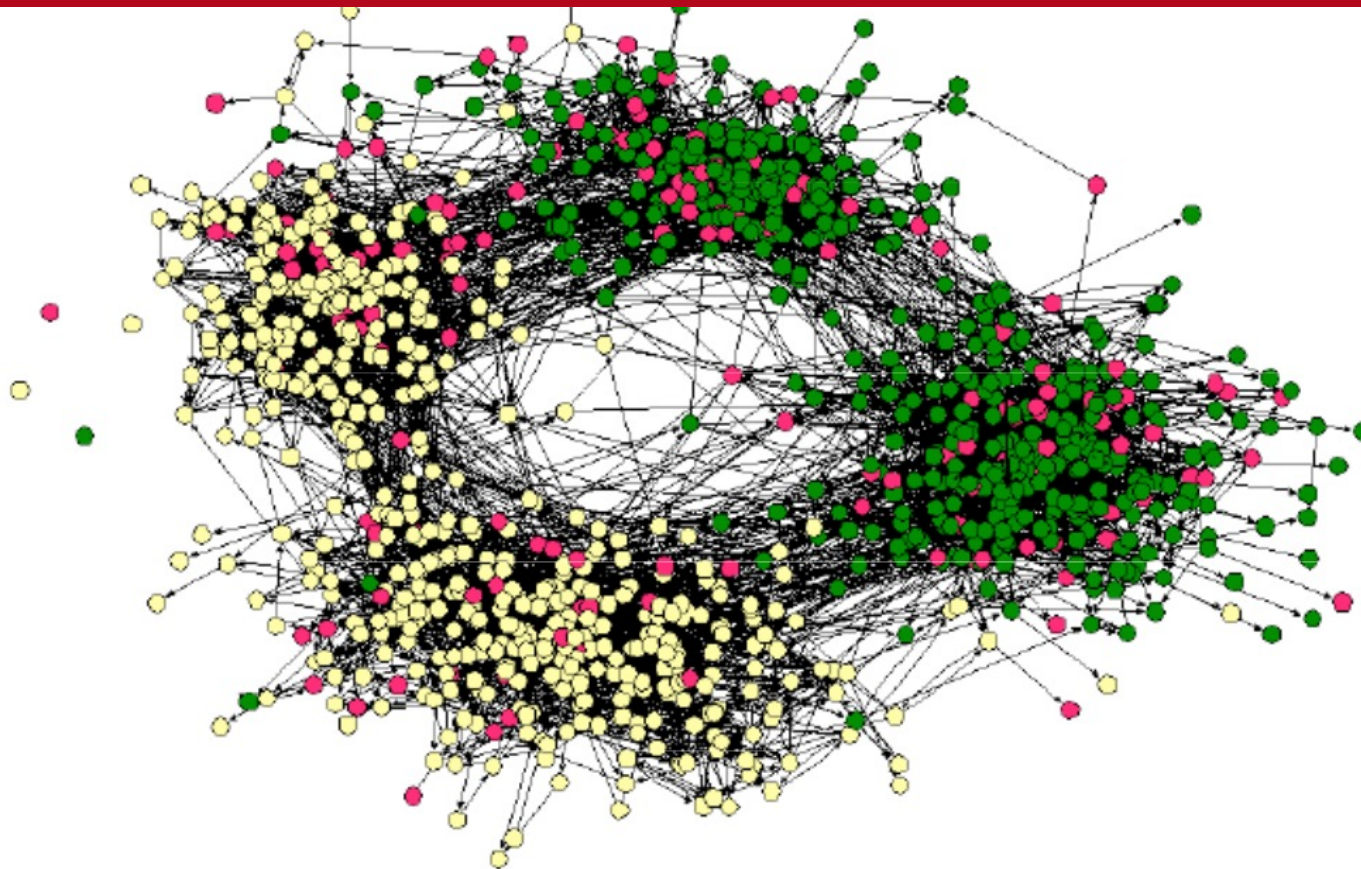
Homophily (from **Ancient Greek**: *homou*, 'together' + *philiē*, 'friendship, love') is the tendency of individuals to associate and bond with similar others, as in the proverb "birds of a feather flock together."^[1] The presence of homophily has been discovered in a vast array of **network** studies: over 100 studies have observed homophily in some form or another, and they establish that similarity is associated with connection.^[2] The categories on which homophily occurs include **age**, **gender**, **class**, and organizational role.



Political blog communities

Homophily in action

racial segregations

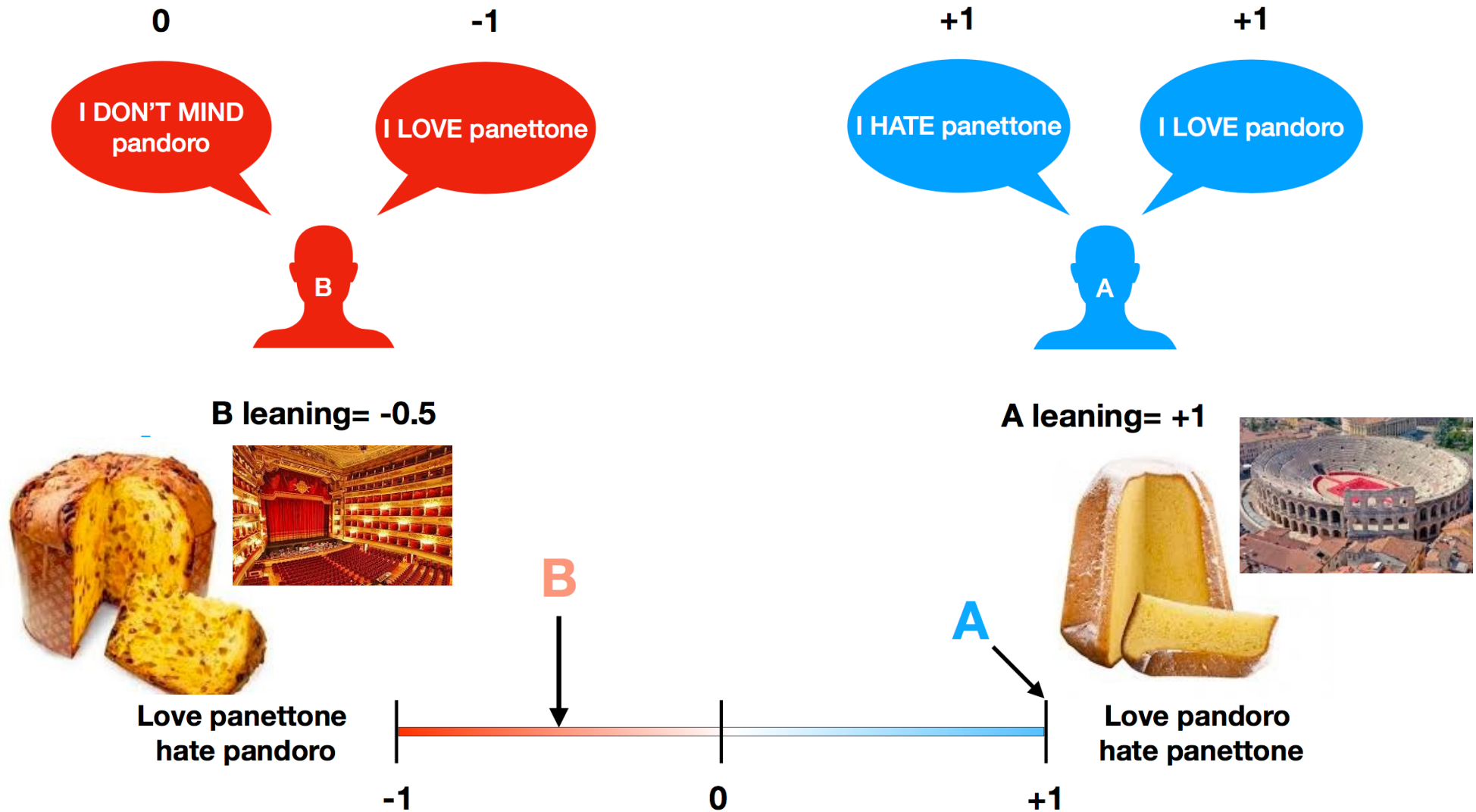


(Easley and Kleinberg, 2010)

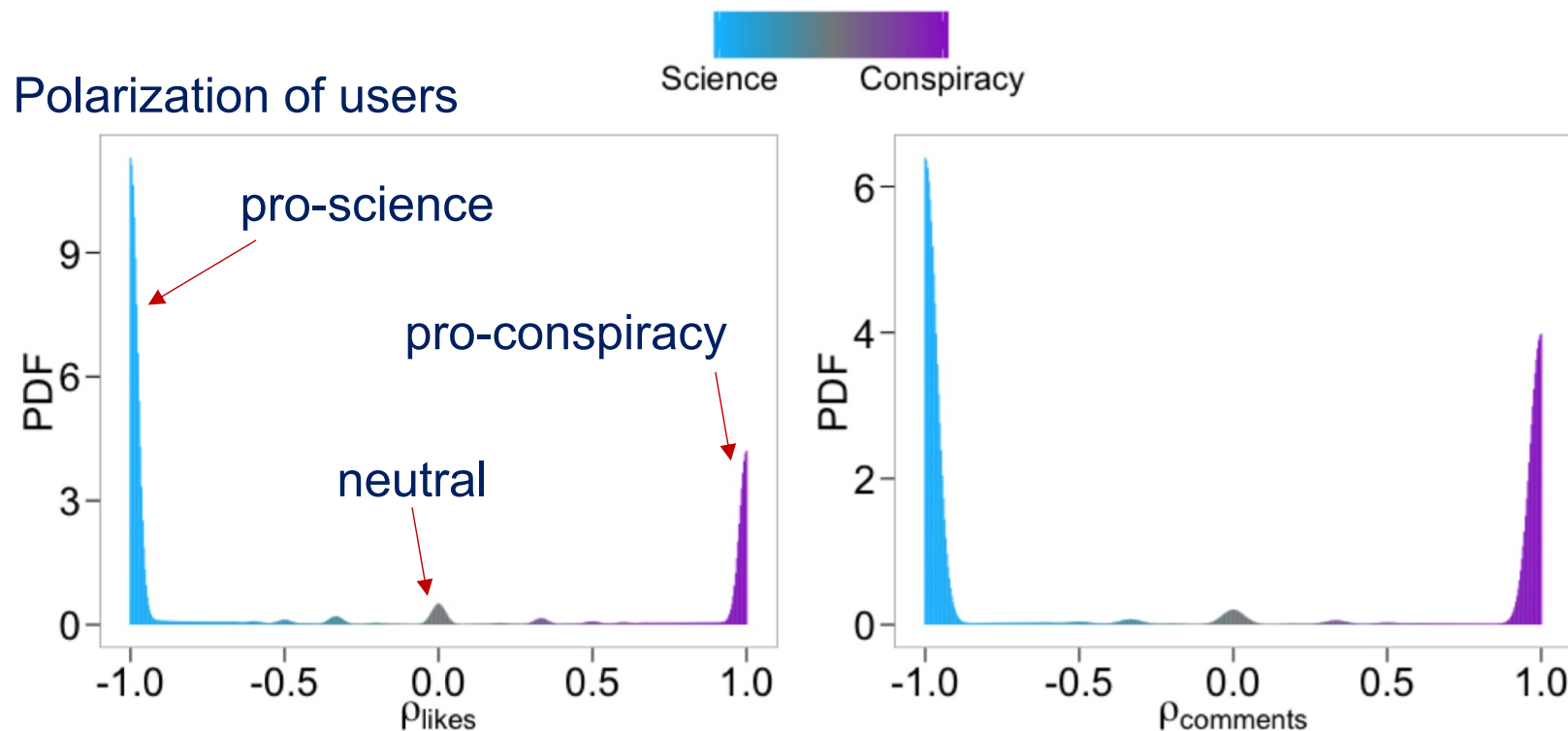
Figure 4.1: Homophily can produce a division of a social network into densely-connected, homogeneous parts that are weakly connected to each other. In this social network from a town's middle school and high school, two such divisions in the network are apparent: one based on race (with students of different races drawn as differently colored circles), and the other based on friendships in the middle and high schools respectively [304].



Users leaning on a controversial topic

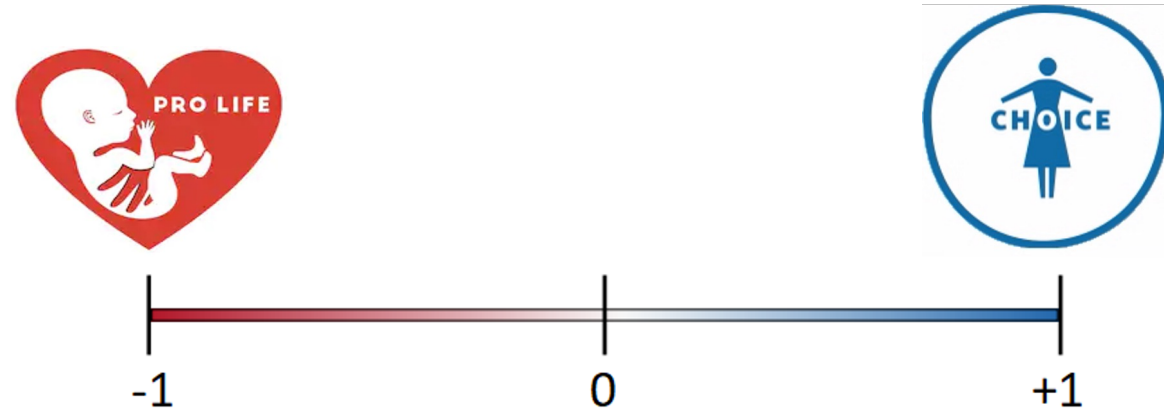


The extreme **segregation** of users into homogeneous communities based on their opinion on a controversial topic



Hashtag polarization

polarization in pro-life/pro-choice networks IP (2019)



- ❑ Measure hashtags centralities among the two dataset
- ❑ Extract which **opinion** an hashtag holds

$$P_i = \frac{W_{pc_i} - W_{pl_i}}{W_{pc_i} + W_{pl_i}}$$

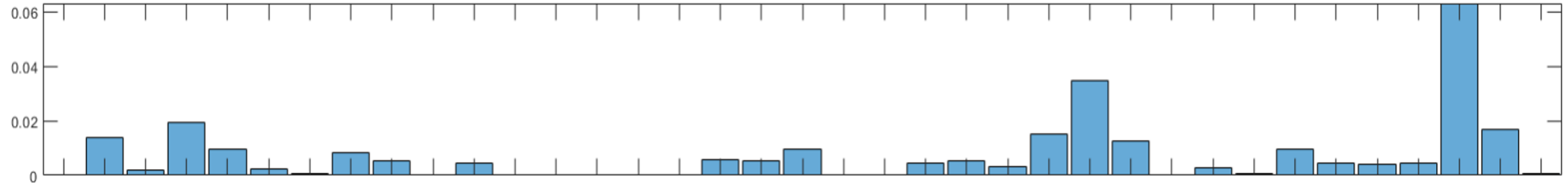
ranking values for word i

prestige mapping

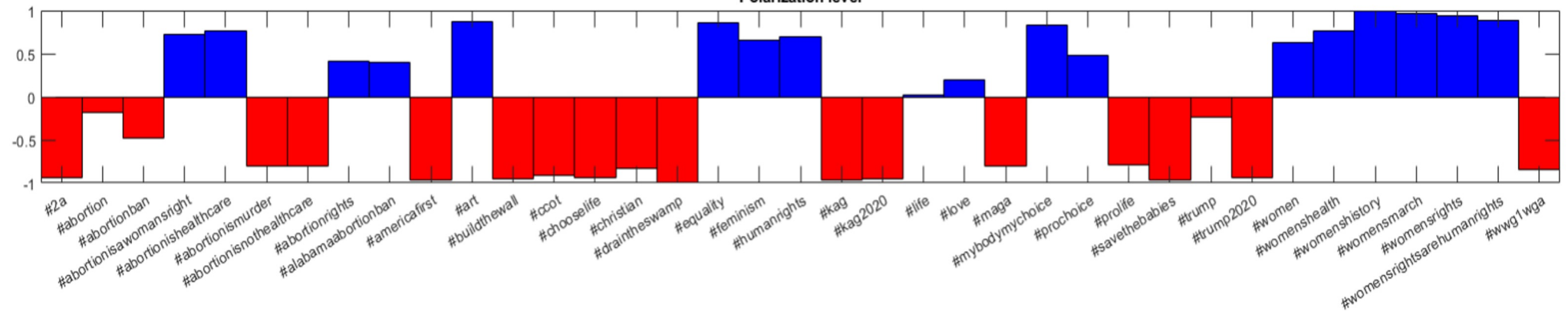


Hashtag polarization

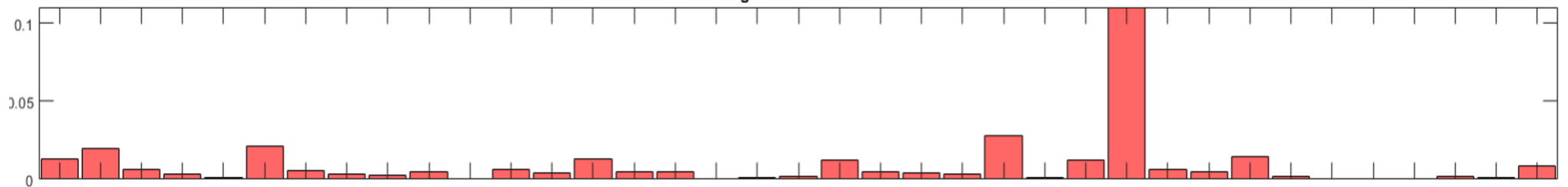
Ranking in the ProChoice dataset



Polarization level



Ranking in the ProLife dataset

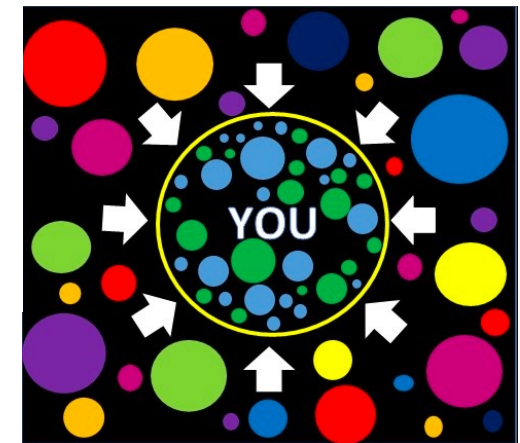




Echo chamber (media)

From Wikipedia, the free encyclopedia

In **news media**, an **echo chamber** is a metaphorical description of a situation in which **beliefs** are amplified or reinforced by communication and repetition inside a closed system and insulates them from rebuttal.^[1] By visiting an "echo chamber", people are able to seek out information that reinforces their existing views, potentially as an unconscious exercise of **confirmation bias**. This may increase social and **political polarization** and extremism.^[2] The term is a metaphor based on the acoustic **echo chamber**, where sounds **reverberate** in a hollow enclosure. Another emerging term for this echoing and homogenizing effect on the Internet within social communities, such as Facebook, Instagram, Twitter, Reddit, etc; is cultural **tribalism**.^[3]

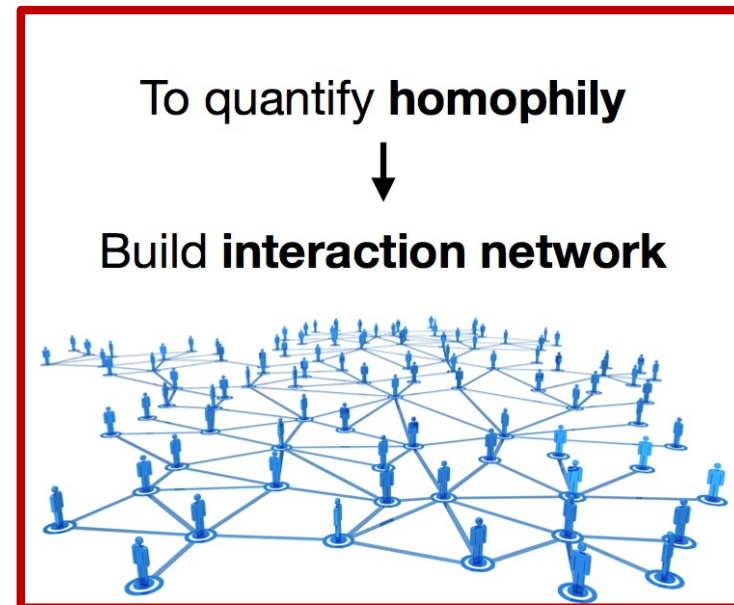
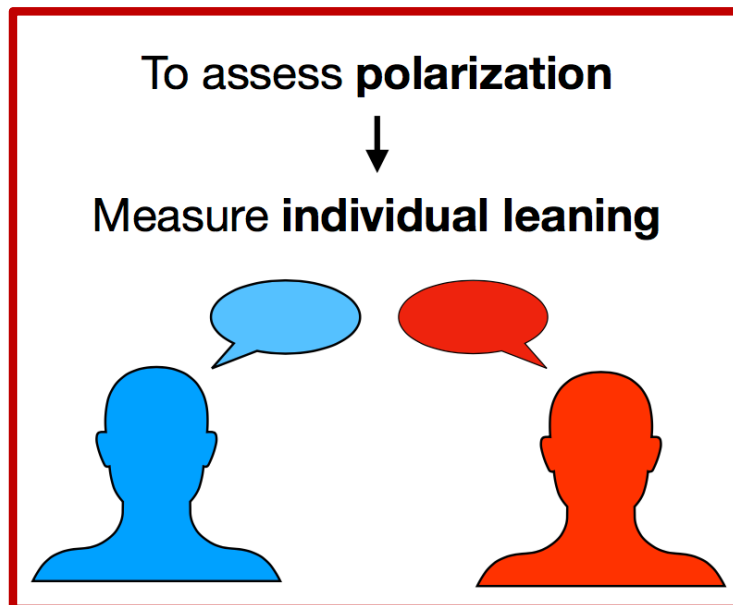




Cinelli, Morales, Galeazzi, Quattrociocchi, Starnini (2020)
Echo chambers on social media: A comparative analysis
<https://arxiv.org/pdf/2004.09603.pdf>

Coexistence of

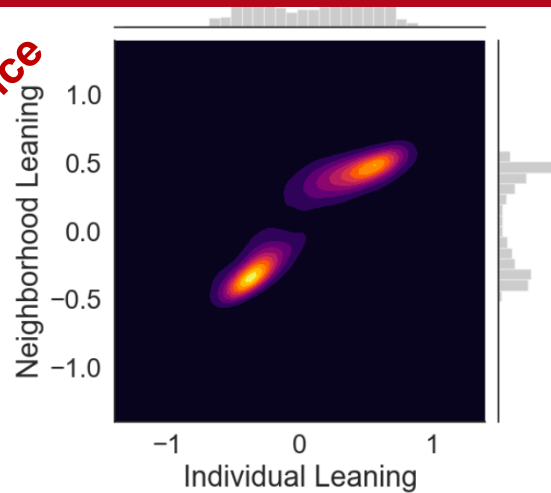
- ❑ opinion **polarization** with respect to a controversial topic
- ❑ **homophily** in interactions



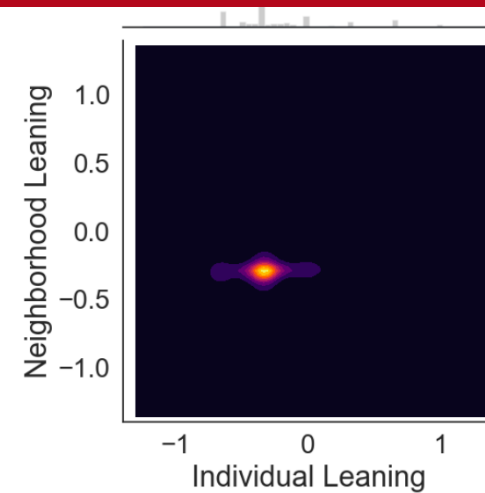


Echo chamber effect in social networks

pro-life vs pro-choice



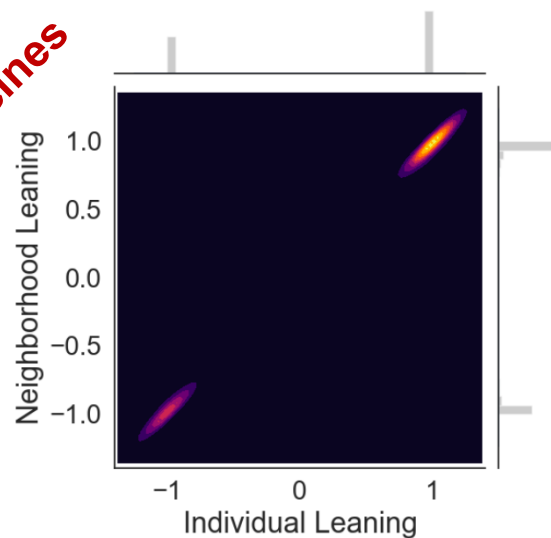
(a) Twitter



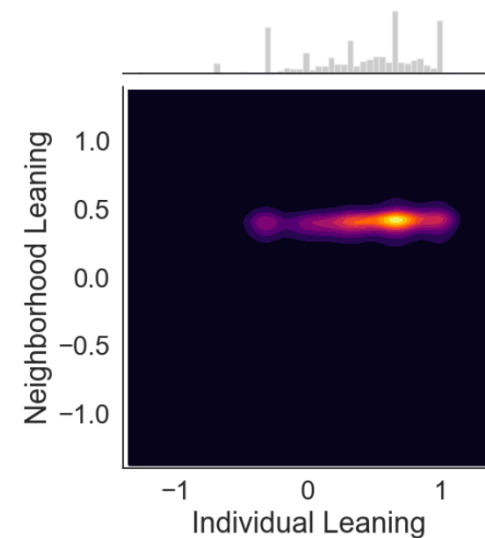
(b) Reddit

left- vs right-wing

pro- vs anti-vaccines



(c) Facebook



(d) Gab

left- vs right-wing



Filter bubble

From Wikipedia, the free encyclopedia



A **filter bubble** – a term coined by internet activist [Eli Pariser](#) – is a state of intellectual isolation^[1] that allegedly can result from [personalized searches](#) when a website [algorithm](#) selectively guesses what information a user would like to see based on information about the user, such as location, past click-behavior and search history.^{[2][3][4]} As a result, users become separated from information that disagrees with their viewpoints, effectively isolating them in their own cultural or ideological bubbles.^[5] The choices made by these algorithms are not transparent.^[6]

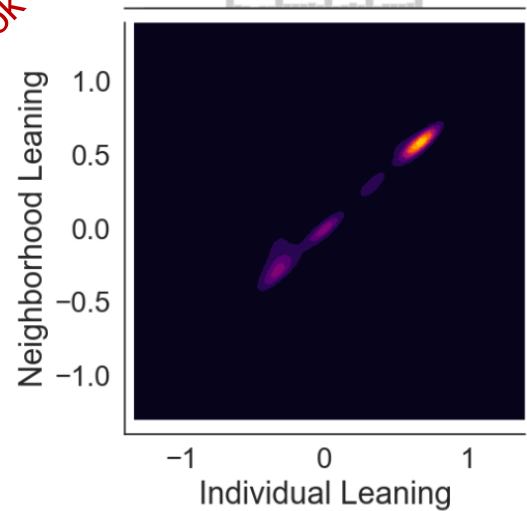


The term was coined by internet activist [Eli Pariser](#) circa 2010

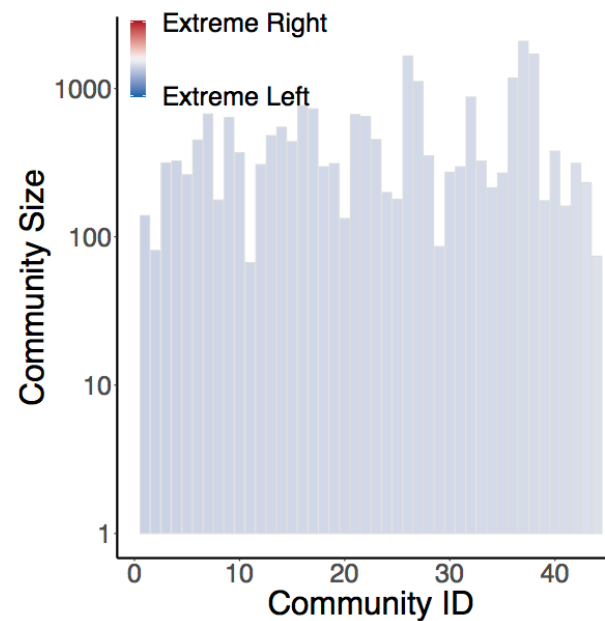
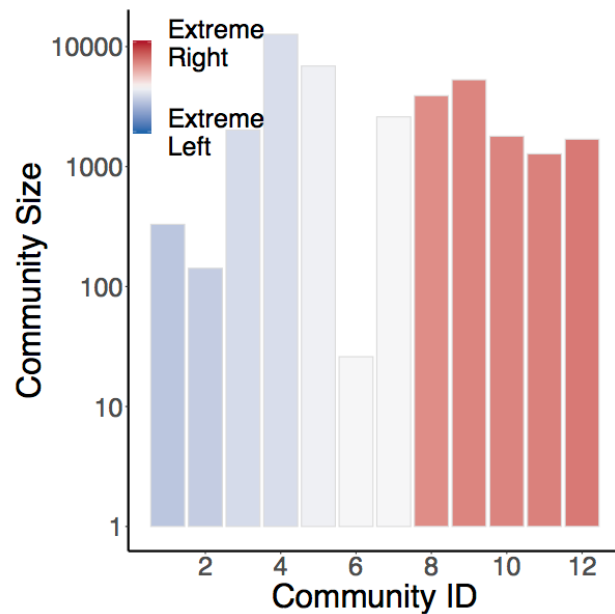
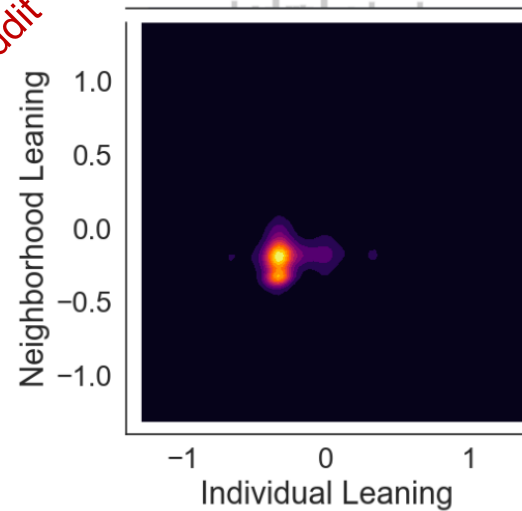


Filter bubbles in social networks

FaceBook



Reddit



- Same Topic: **News**
- Same leaning assigned to **news sources**
- Different platforms: Facebook has a strong **social feeding algorithm**, Reddit has not
- Different characteristics: Facebook shows **segregation** among groups with different leaning, Reddit has one group

Assortativity

i.e., degree homophily

Correlation between hubs

- ❑ In some networks, hubs frequently **connect** with other hubs

e.g., celebrity dating, actor networks



- ❑ In other cases hubs **avoid** connections with other hubs

e.g., metabolic graphs, food webs (predators tend to differentiate their diet)



- ❑ **Assortative** network: high degree nodes connect with each other avoiding low degree nodes (tend to cliques)
- ❑ **Disassortative** network: opposite trend, hubs tend to avoid each other
- ❑ **Neutral** network: one with random wiring, i.e., aside from the (marginal) degree distribution of nodes, there is no correlation



(dis)**assortativity** quantifies homophily in social networks, e.g., effects like:

- ❑ Rich people tend to be friends with each other
- ❑ People with the same education tend to hang out together

i.e., we expect social networks to be assortative

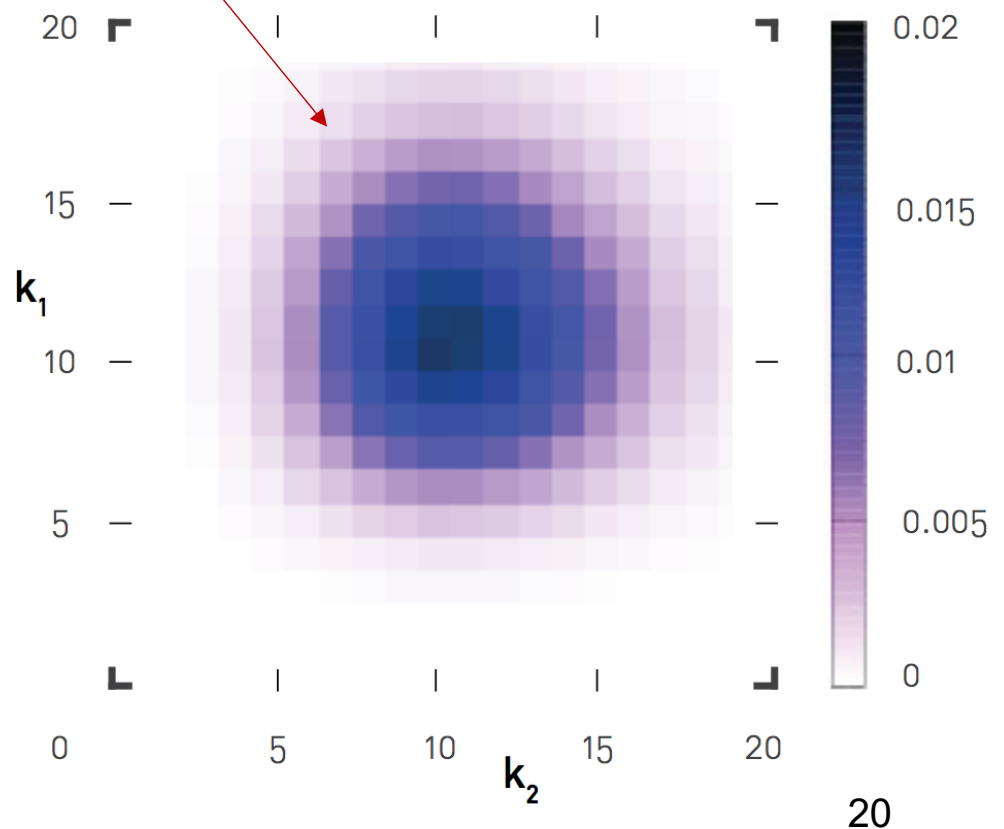
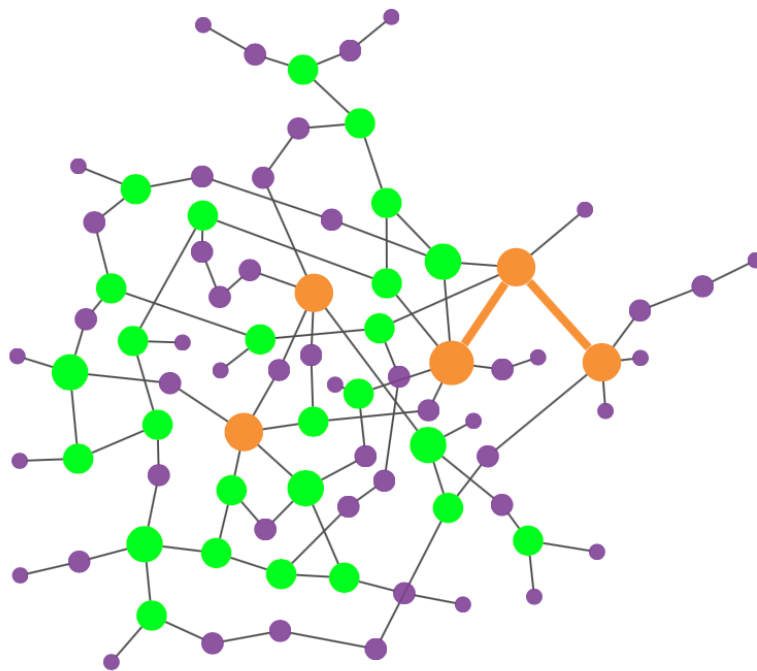


Neutral networks

The **degree correlation matrix** E_{k_1, k_2} is visually centred around the average degree

In the neutral case we expect
 $E_{k_1, k_2} = q_{k_1} q_{k_2}$, i.e., independence

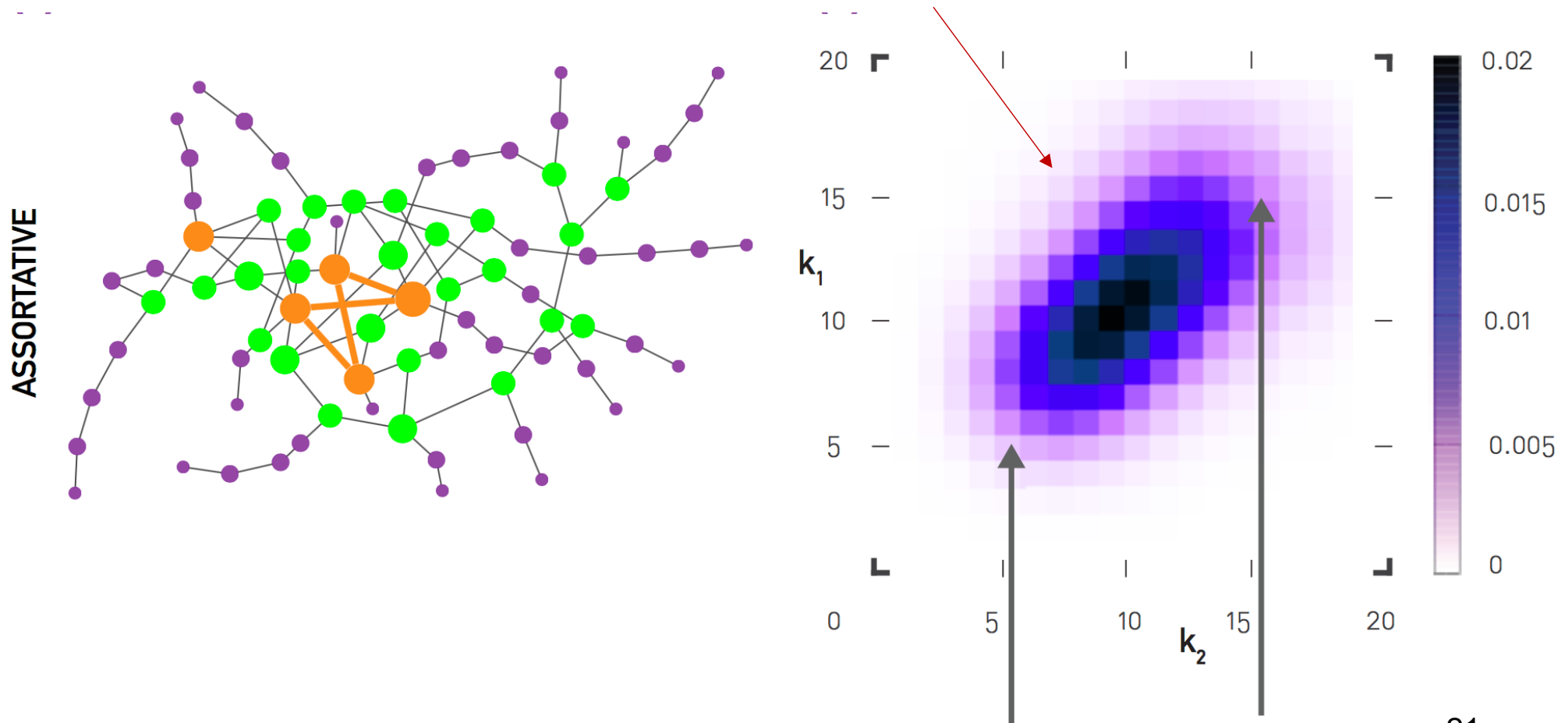
NEUTRAL





Assortative networks

The degree correlation matrix
 E_{k_1, k_2} is turning to the right

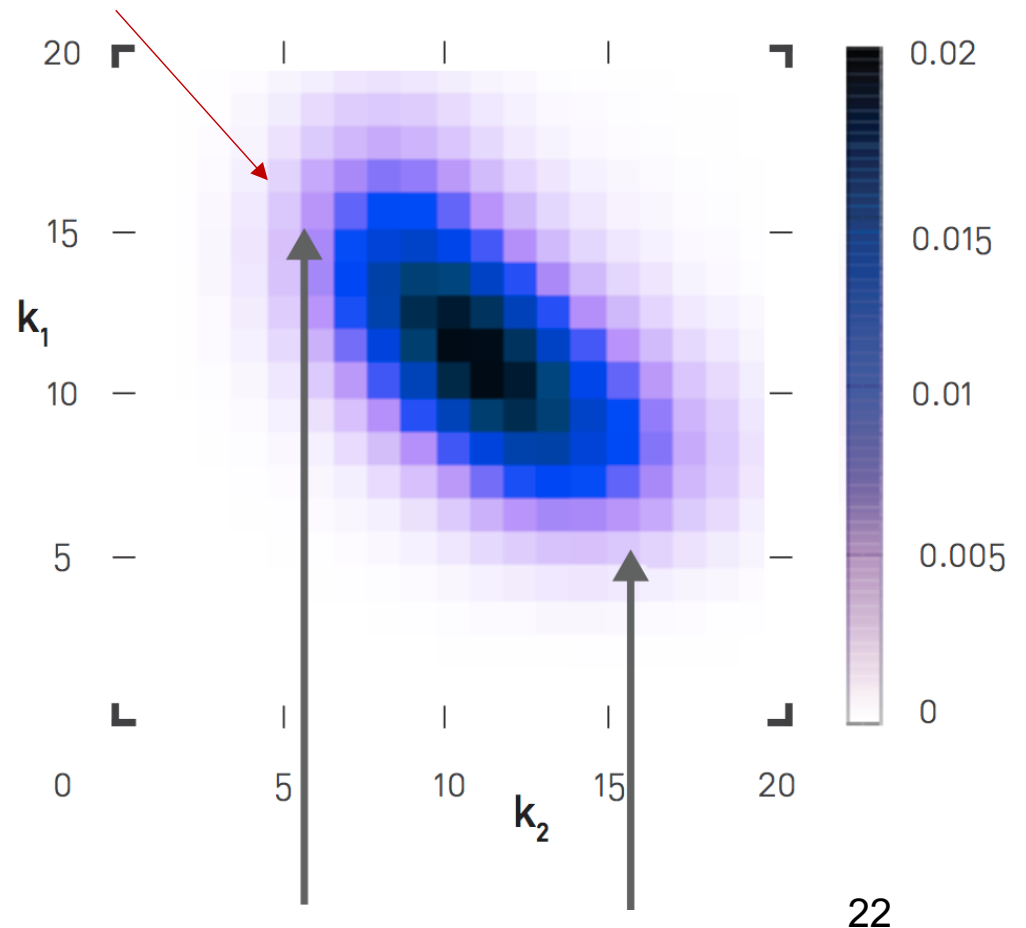
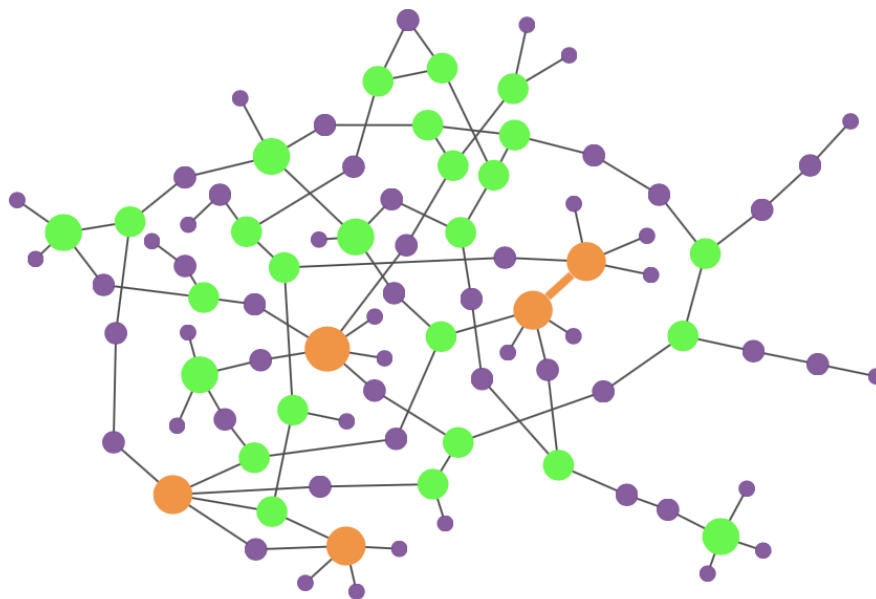




Disassortative networks

The degree correlation matrix
 E_{k_1, k_2} is turning to the left

DISASSORTATIVE

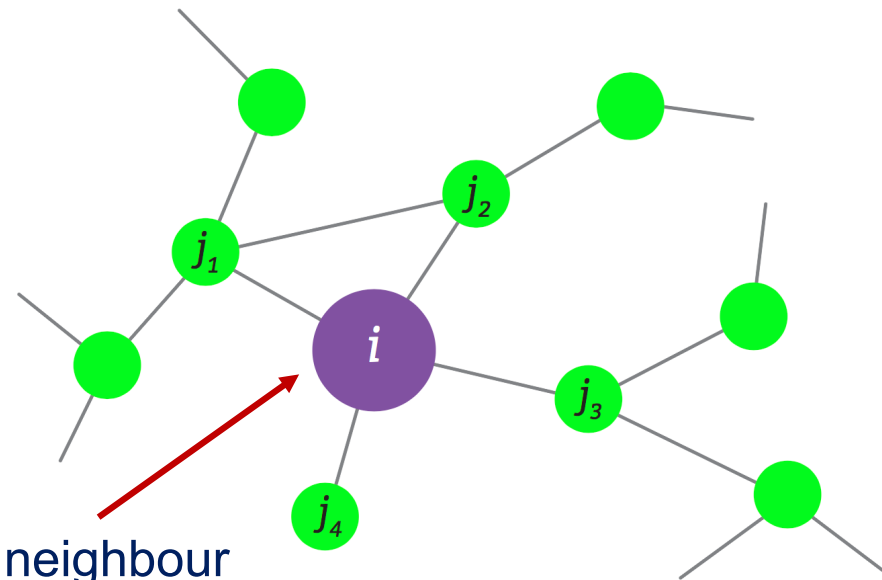




Nearest neighbour degree

how to simplify plots from 2D to 1D

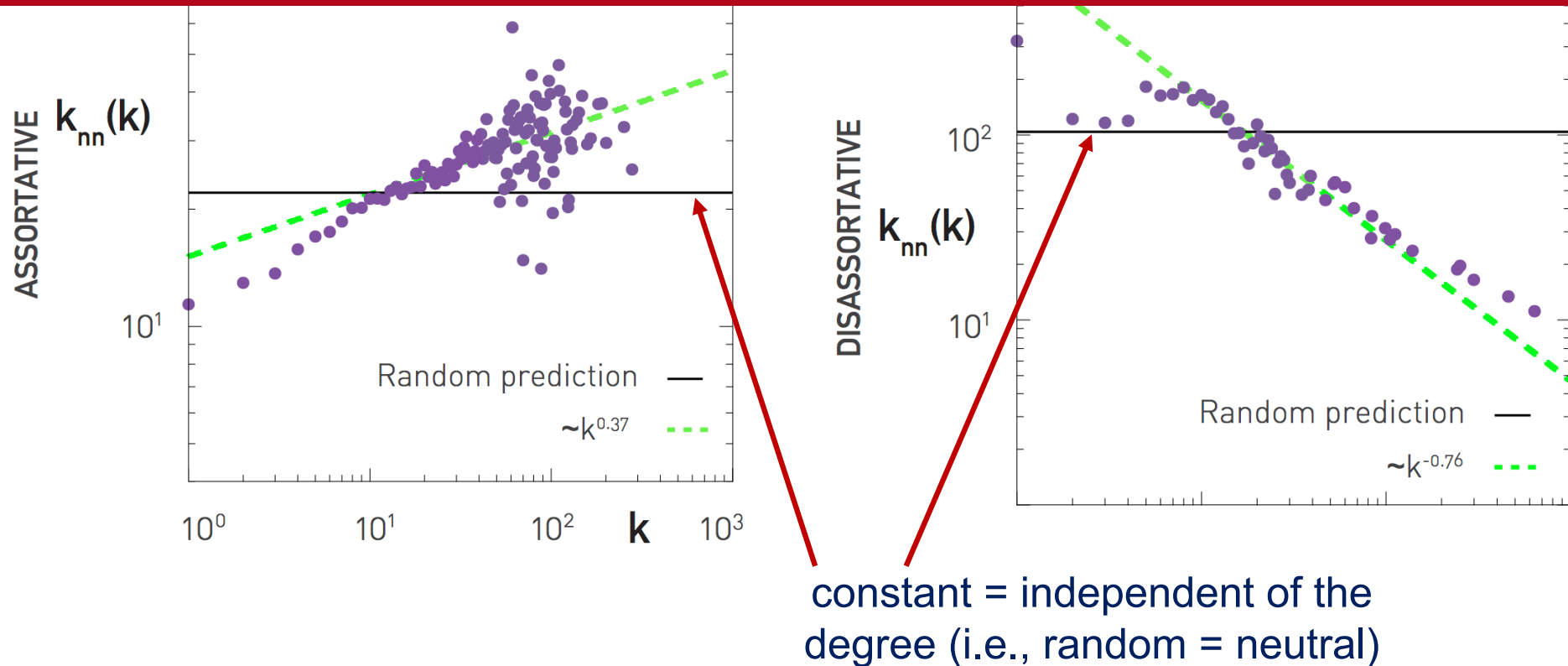
- ❑ **Idea** : inspect the degrees of the **neighbouring** nodes (easier than matrices)



average neighbour
degree of node *i* is
 $\frac{1}{4} (4 + 3 + 1 + 3) = 2.75$



Nearest neighbour degree plots



$$\ln(k_{nn}) = \mu \ln(k_i)$$

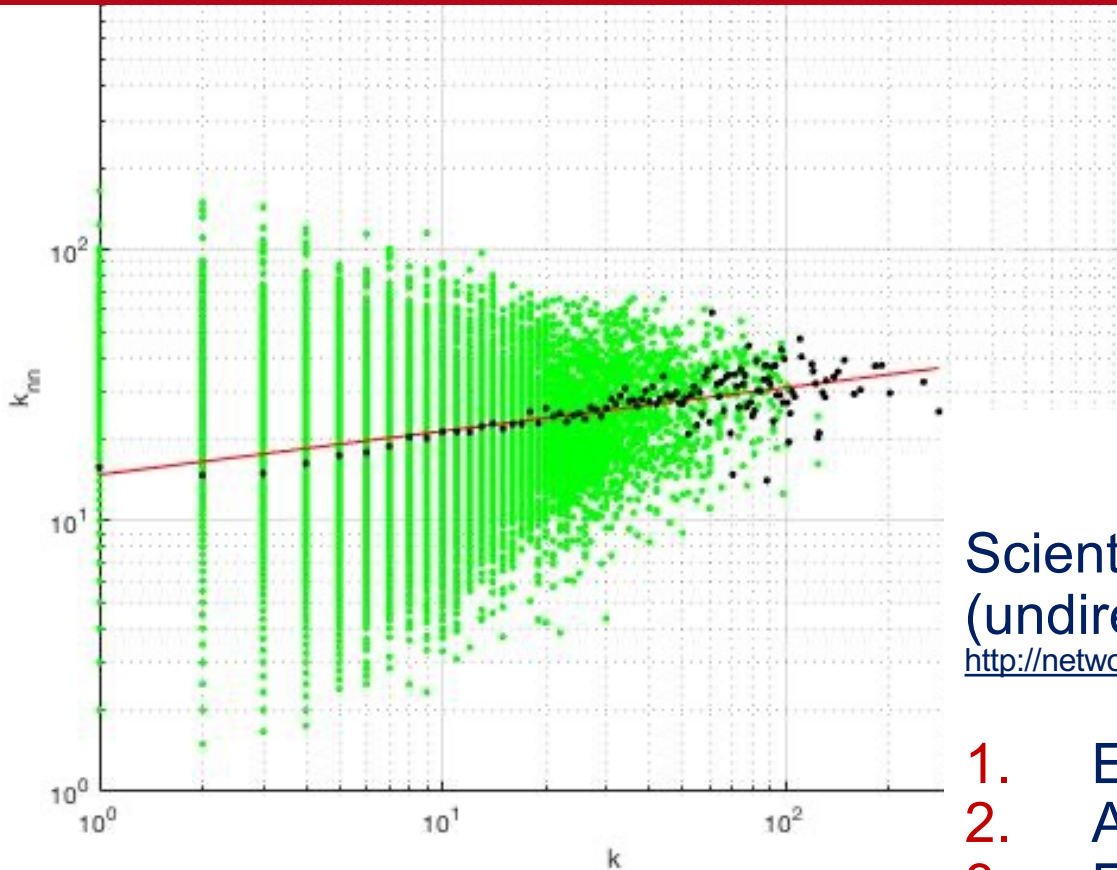
→

$\mu > 0$ = assortative

$\mu < 0$ = disassortative



A visual example scientific collaboration network



Scientific collaboration network
(undirected, **assortative**)

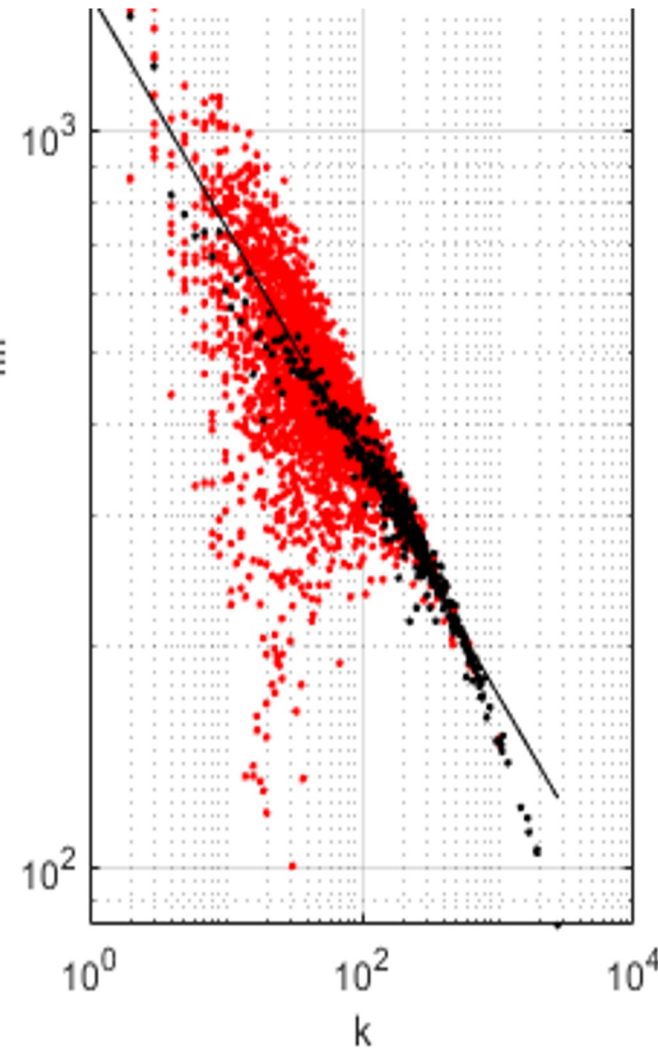
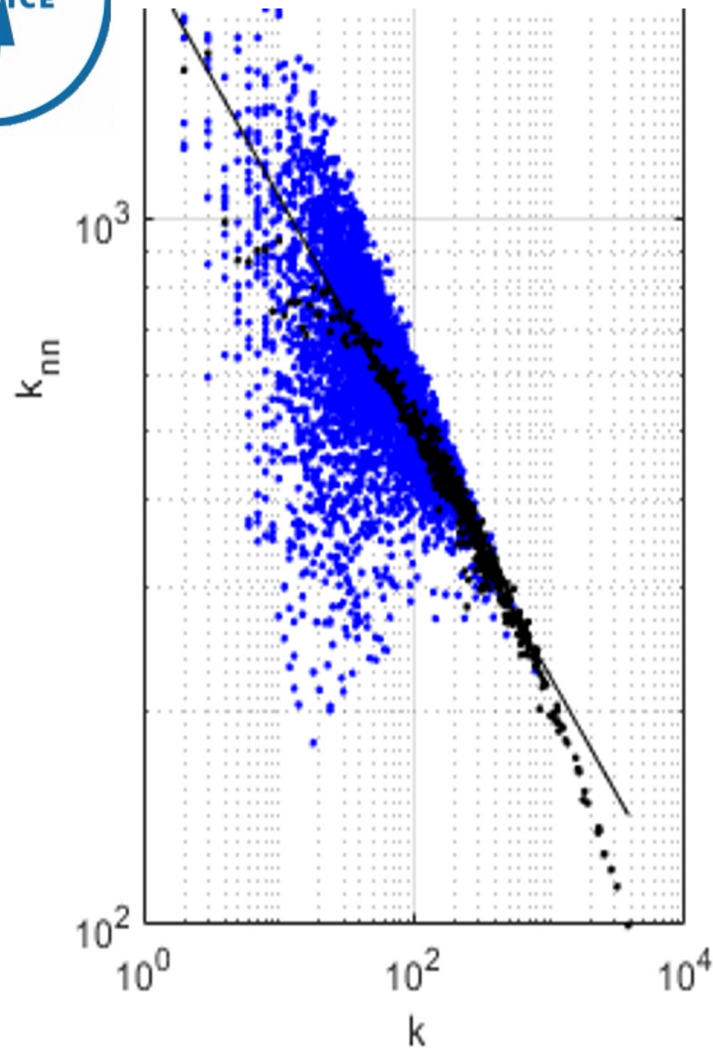
<http://networksciencebook.com/translations/en/resources/data.html>

1. Evaluate average neigh. deg. k_{nn}
2. Average w.r.t. k
3. Extract the assortativity value $\mu=0.16$



UNIVERSITÀ
DEGLI STUDI
DI PADOVA

Hashtag network disassortativity on pro-life/pro-choice data

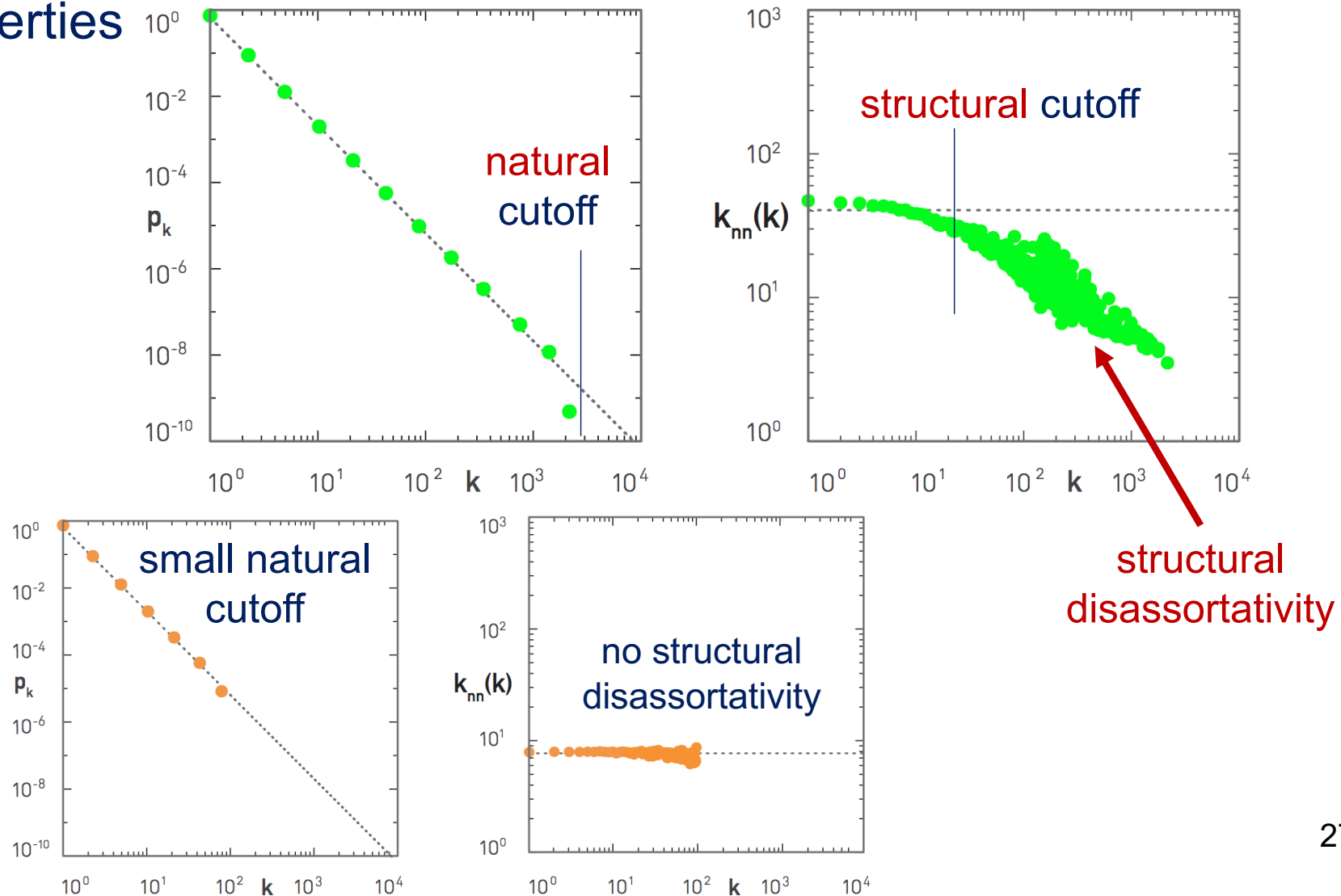




Structural disassortativity

large degrees cannot be supported by a neutral network

(dis)Assortativity can be linked to **structural** network properties



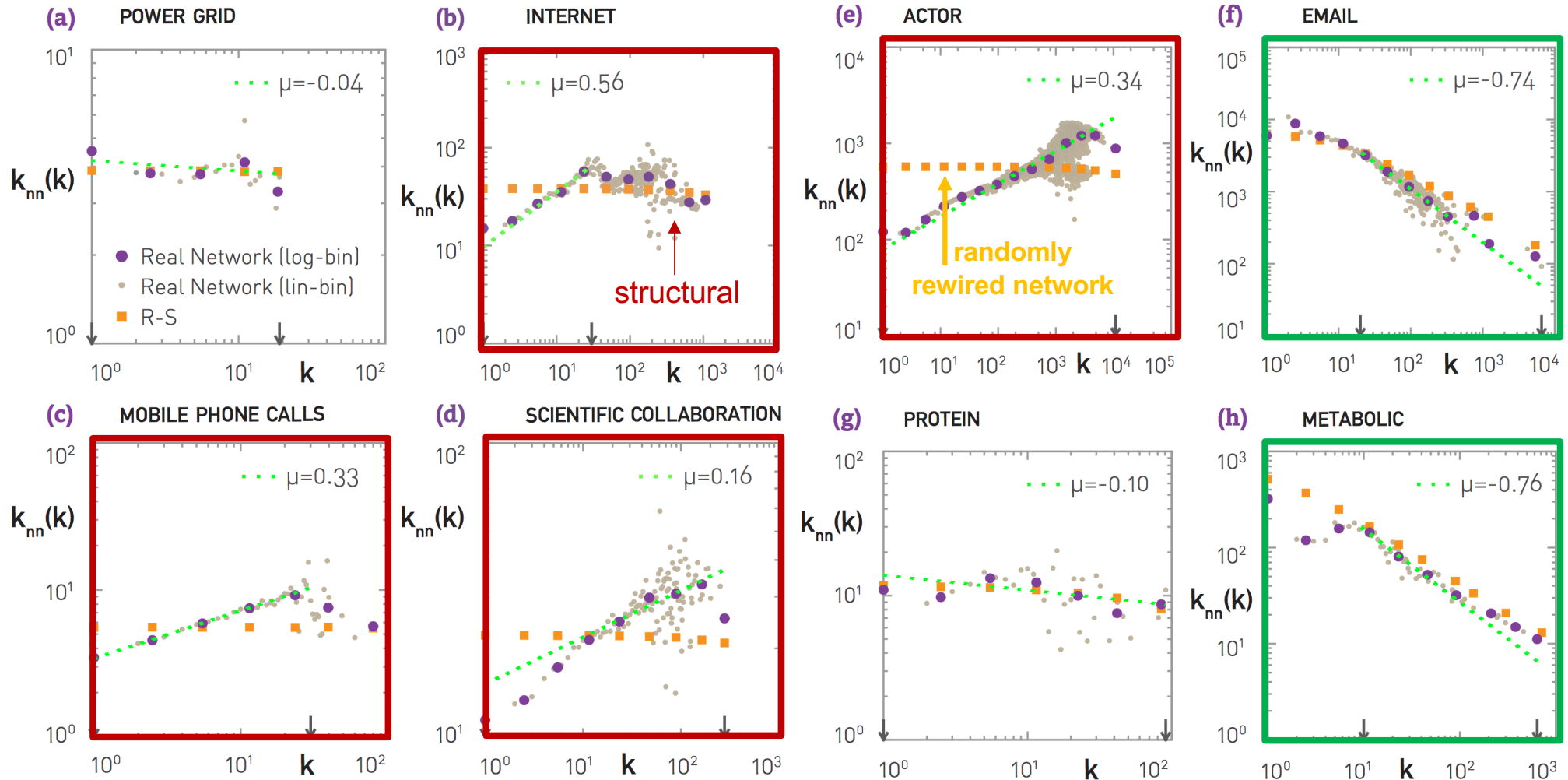


Structural disassortativity in real networks

social networks are assortative, most with a structural cutoff

assortative in red

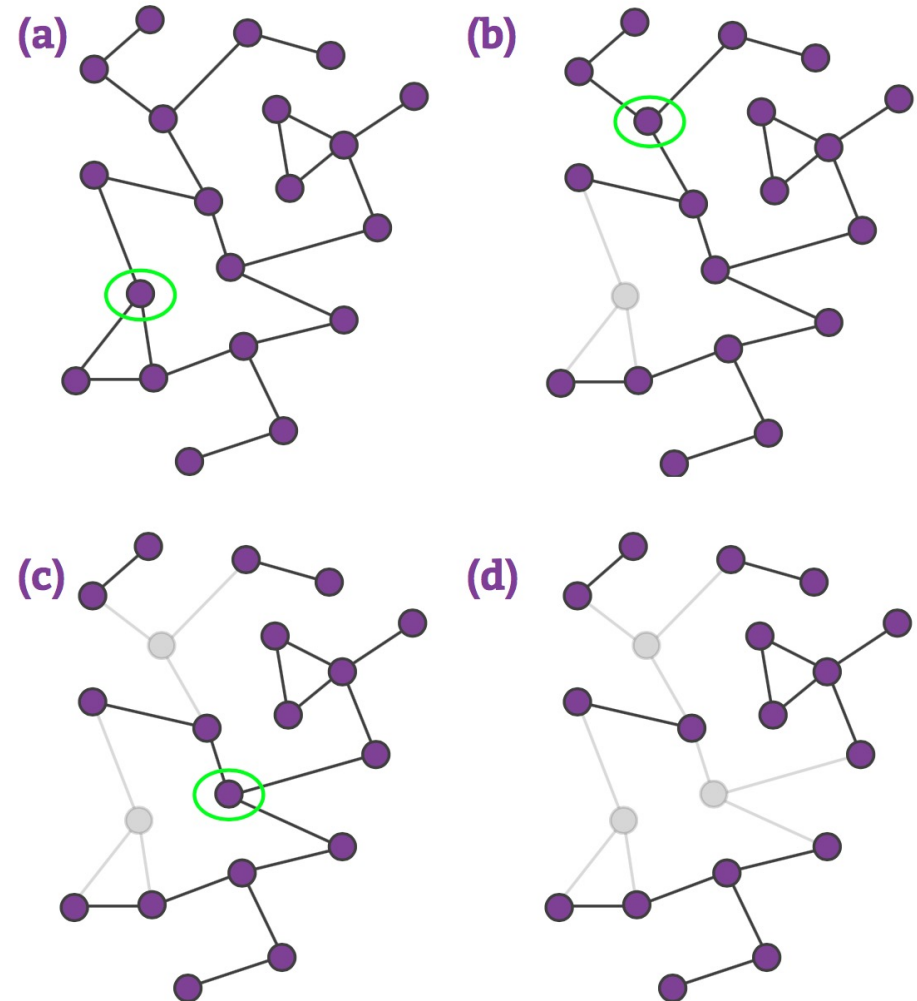
disassortative in green



Robustness

of networks to failures

- ❑ Would the network still “work” in the presence of missing nodes?
- ❑ Failures can lead to either just isolating nodes or **breaking** the whole network apart
- ❑ What is the limit/phase transition?





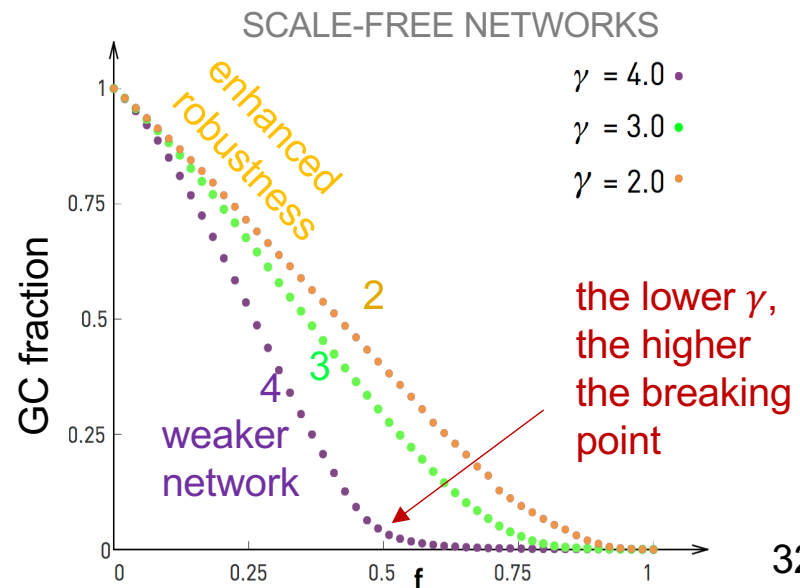
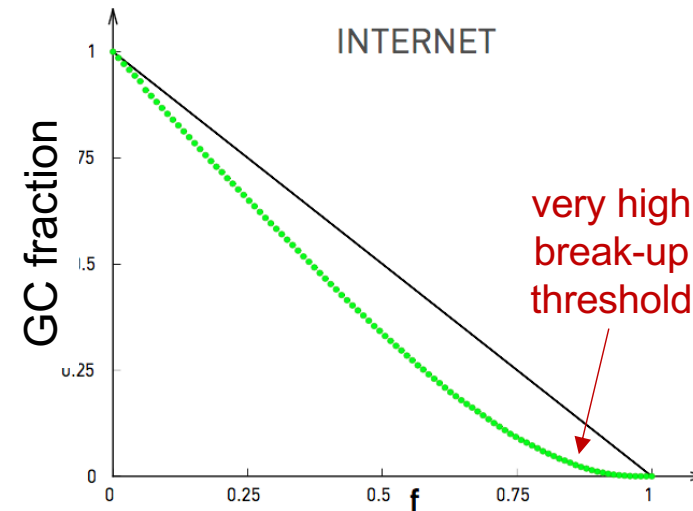
This can serve to identify:

- ☐ robustness of air transportation under random strikes
- ☐ robustness of social contacts even when someone is off
- ☐ possibility of destroying of criminal/terror networks
- ☐ eradication of an epidemics
- ☐ etc.



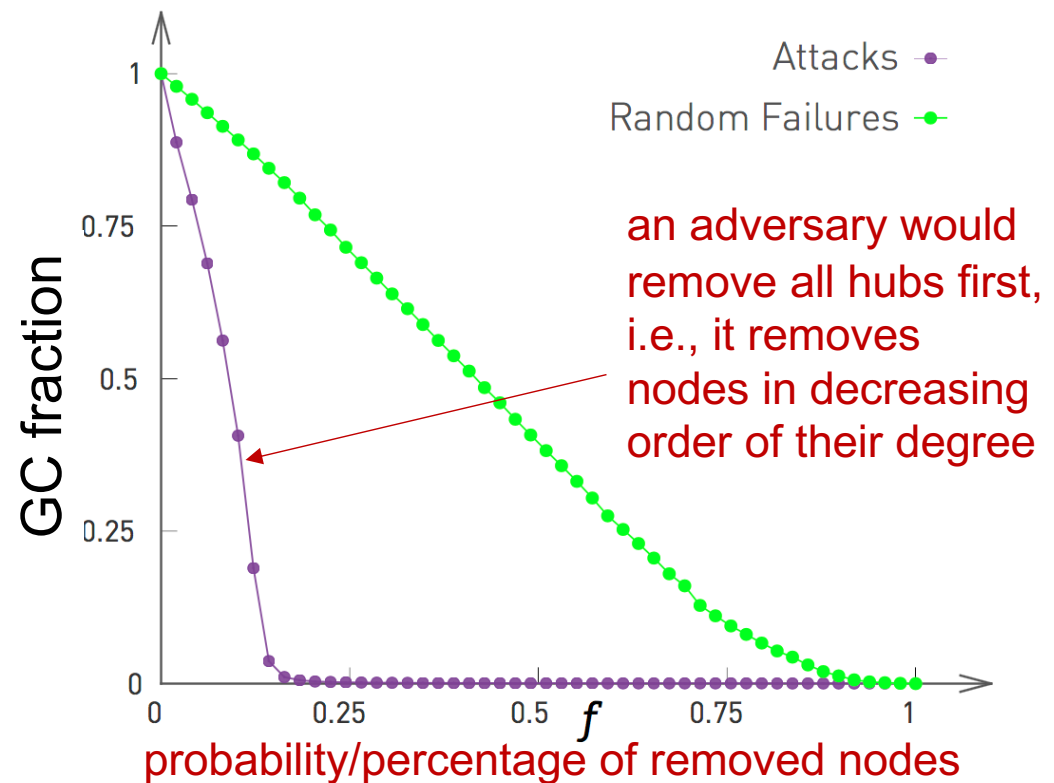
Robustness of scale-free networks under random node removal

- ❑ Robustness of the **Internet** due to scale-free properties
- ❑ Nodes linked to the GC after random removal with rate $f \rightarrow$ still large if $f < 1$
- ❑ Experiments aligned with a scale-free model
- ❑ Reason: random removal of (many) **hubs** is very unlikely



What if removals are not by chance, but caused by an **adversary** with sufficient insights on our network?

- ❑ Scale-free networks are **not very robust** to targeted attacks exactly because they have **vulnerable hubs**
- ❑ good news in medicine (vulnerability of bacteria) 😊
- ❑ bad news for the Internet 😞





UNIVERSITÀ
DEGLI STUDI
DI PADOVA

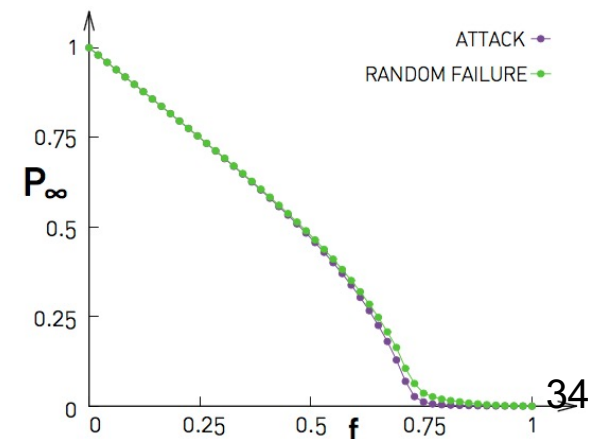
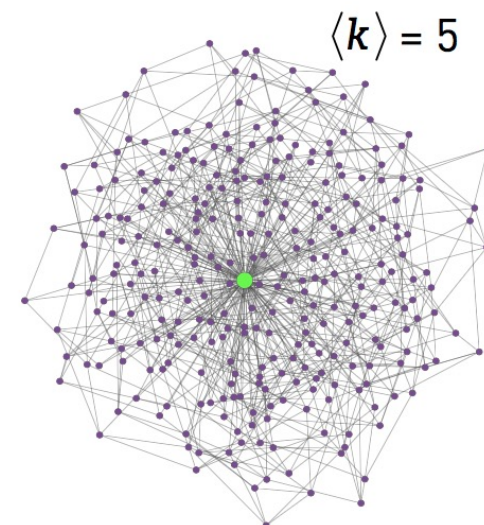
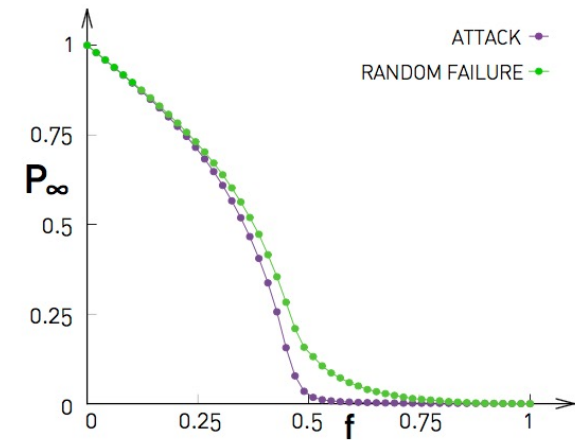
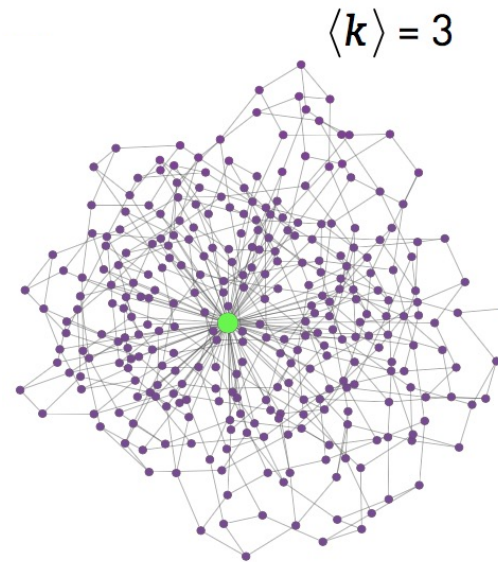
Optimizing robustness is not an option in real-world networks

The best option is a
bimodal distribution

$$p_k = r \delta_{k_{\max}} + (1-r) \delta_{k_{\min}}$$

$$r = 1/N$$

$k_{\max}$ chosen to
maximize the
breakpoints





Salvatore Romano, Alberto Zancanaro, Enrico Lanza, Carlo Facchin

robustness of original network to positive node removal

