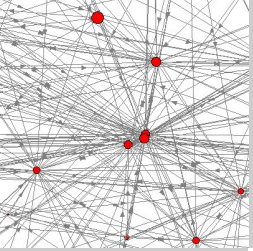

Modeling real networks through bipartite graphs

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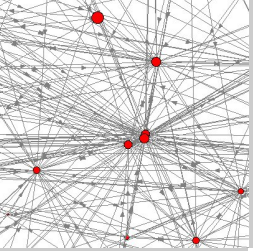
30.04.2008., MPIPKS, Dresden, Germany



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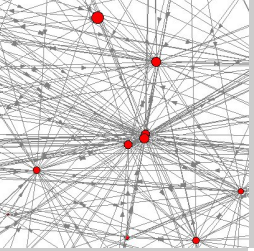

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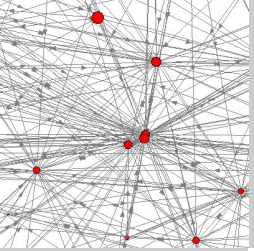
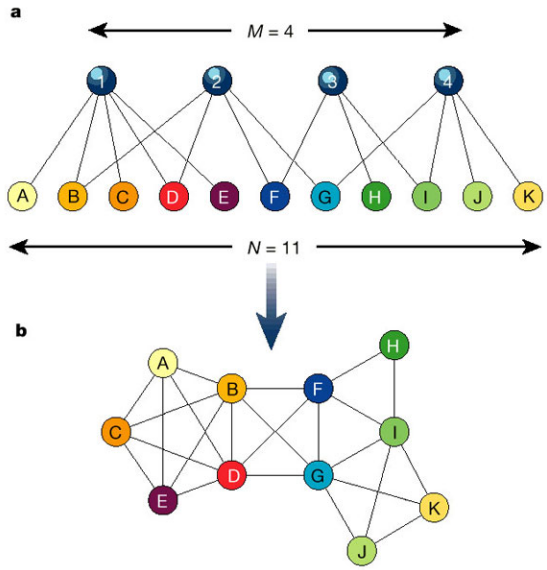
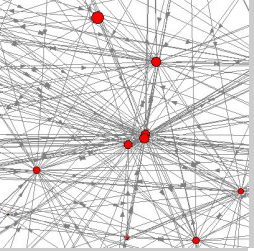


Bipartite Networks

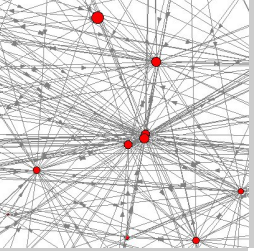
- Two types of nodes
- Links only between nodes of different type
- One-mode projections
- Why do we investigate them?





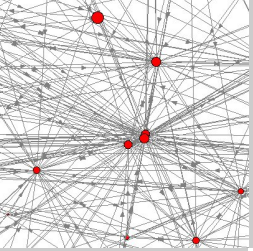
Examples

- Protein-protein interaction: bait and prey
- Gene regulation: regulators and genes
- Scientific publication networks: scientist and papers
- Actors network: actors and movies
- Corporate directors: boards and directors
- Economy networks: banks and companies
- Language networks: works and sentences



New input

- Two possible projected networks: top and bottom
- Trivial one-mode projection
- Many common nodes per pair
- Weighted one-mode projection
- Underlying bipartite structure



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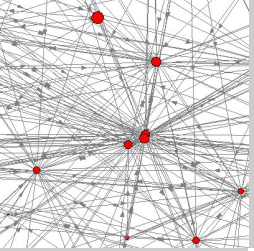
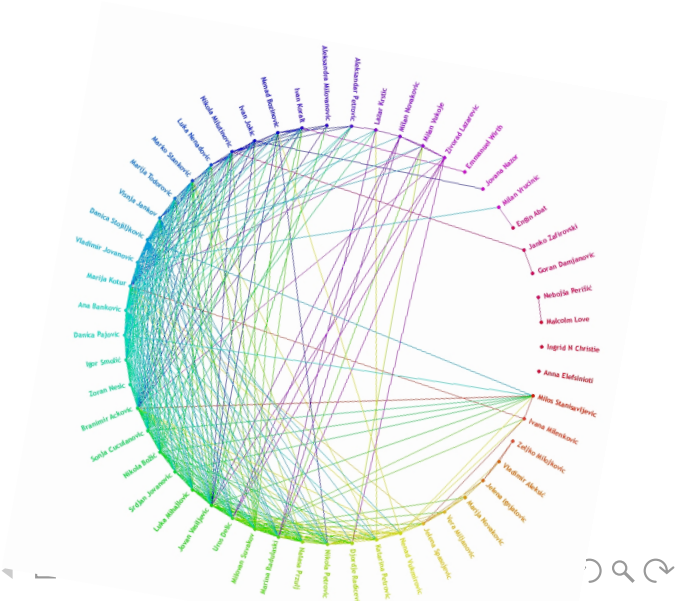
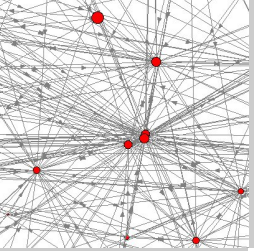


E-Social Networks

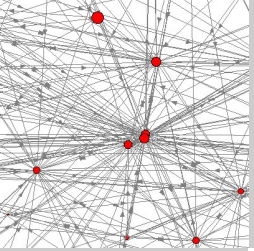
- Interactions between humans or groups over the internet
- E-mail, chats, forums, facebook,...
- Recommendations networks
- Goal 1: Get to know social structure
- Goal 2: Use that knowledge to develop recommendation system
- Here: Example of bipartite networks
- Movies recommendations





The Internet Movie Database

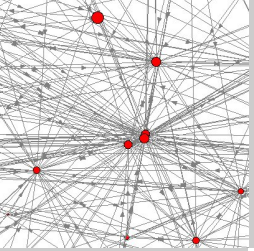
- On-line database about films, TV products, direct to video products and video games
- Launched 1990., “Movie rating system” and “Those Eyes”
- Commercial 1995., Amazon.com 1998.
- Today: Titles 1,039,447
- Movies released theatrically: 379,871
- Users: votes, comments, message boards etc.
- Recommendations lists
- USA movies, more than 10 votes, excluded TV, straight to video and video games, around 43,000 titles, 350,000 users



Investigated networks

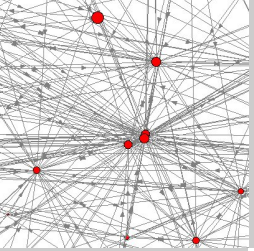
- **IMDb recommendations**
  - From recommendation lists on the site. User votes, genre, title, keywords, and, most importantly, user recommendations themselves
- **UD-BP - User Driven Bipartite networks**
  - Movie and user are linked if specific user left a comment on the web page of specific movie.
- **WOmP - Weighted One-mode projections**
  - Recommendation list - ten movies with highest value of *Cosine*.

$$\mu_i = (\ldots, 1, \ldots, 0, \ldots, 0, \ldots, 1, \ldots) \qquad Cosine_{ij} = \frac{\overrightarrow{\mu_i} \cdot \overrightarrow{\mu_j}}{|\mu_i||\mu_j|}$$



Examples - IMDb

- **The Lord of the Rings: The Fellowship of the Ring (2001)**
  The Lord of the Rings: The Return of the King (2003) The Lord of the Rings: The Two Towers (2002) The Chronicles of Narnia: The Lion, the Witch and the Wardrobe (2005) Stardust (2007) Willow (1988) Indiana Jones and the Temple of Doom (1984) Beowulf (2007) Details Cinema Showtimes Star Wars: Episode III - Revenge of the Sith (2005) The Lord of the Rings (1978) The Return of the King (1980) (TV)
- **Donnie Darko (2001)**
  The Butterfly Effect (2004) The Living and the Dead (2006) The Basketball Diaries (1995) Disturbia (2007) Vana espuma (1998) Blue Velvet (1986) Requiem for a Dream (2000) Twin Peaks: Fire Walk with Me (1992 Trick or Treat (1986) Vanilla Sky (2001)

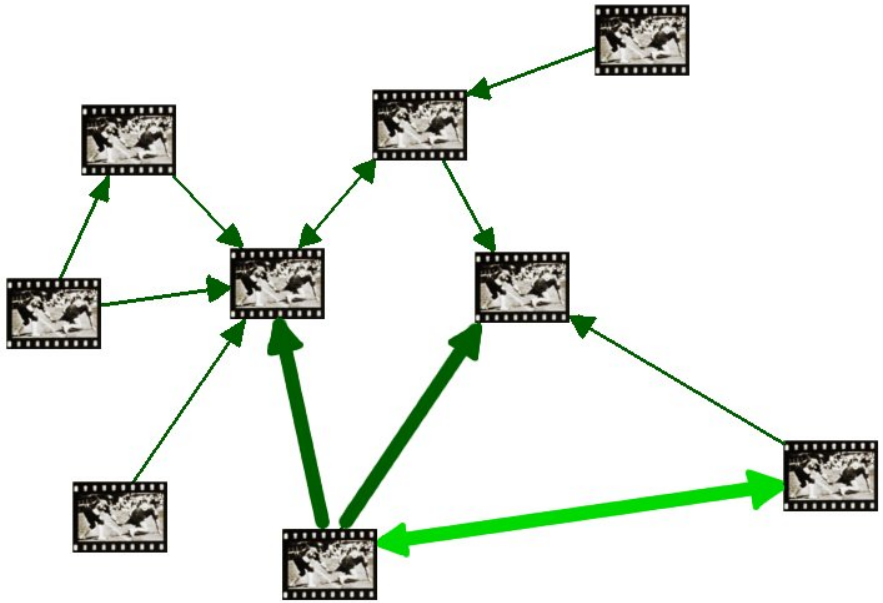


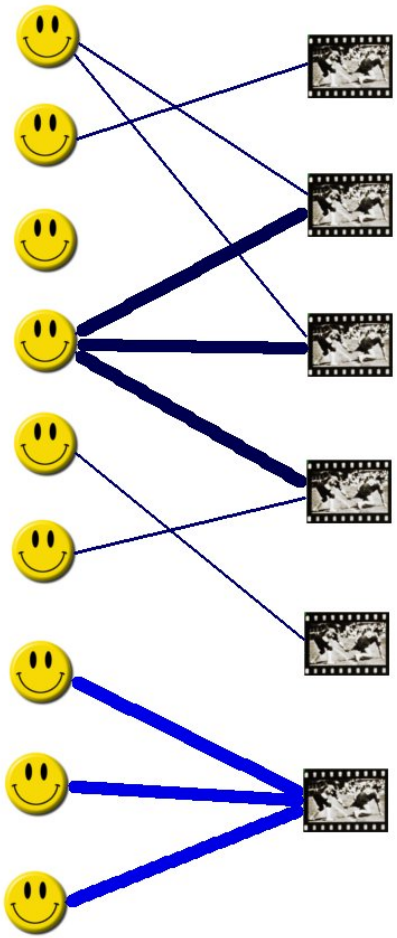
Examples - WOmP

- **The Lord of the Rings: The Fellowship of the Ring (2001)** The Lord of the Rings: The Return of the King (2003) The Lord of the Rings: The Two Towers (2002) Ocean's Eleven (2001) Shrek (2001) Spider-Man (2002) Star Wars (1977) Star Wars: Episode I - The Phantom Menace (1999) Star Wars: Episode II - Attack of the Clones (2002) Star Wars: Episode V - The Empire Strikes Back (1980) Star Wars: Episode VI - Return of the Jedi (1983)
- **Donnie Darko(2001)** Insomnia (2002/I) One Hour Photo (2002) The Others (2001) Out of Time (2003/I) Panic Room (2002) Phone Booth (2002) The Ring (2002) Road to Perdition (2002) Secretary (2002) Vanilla Sky (2001)

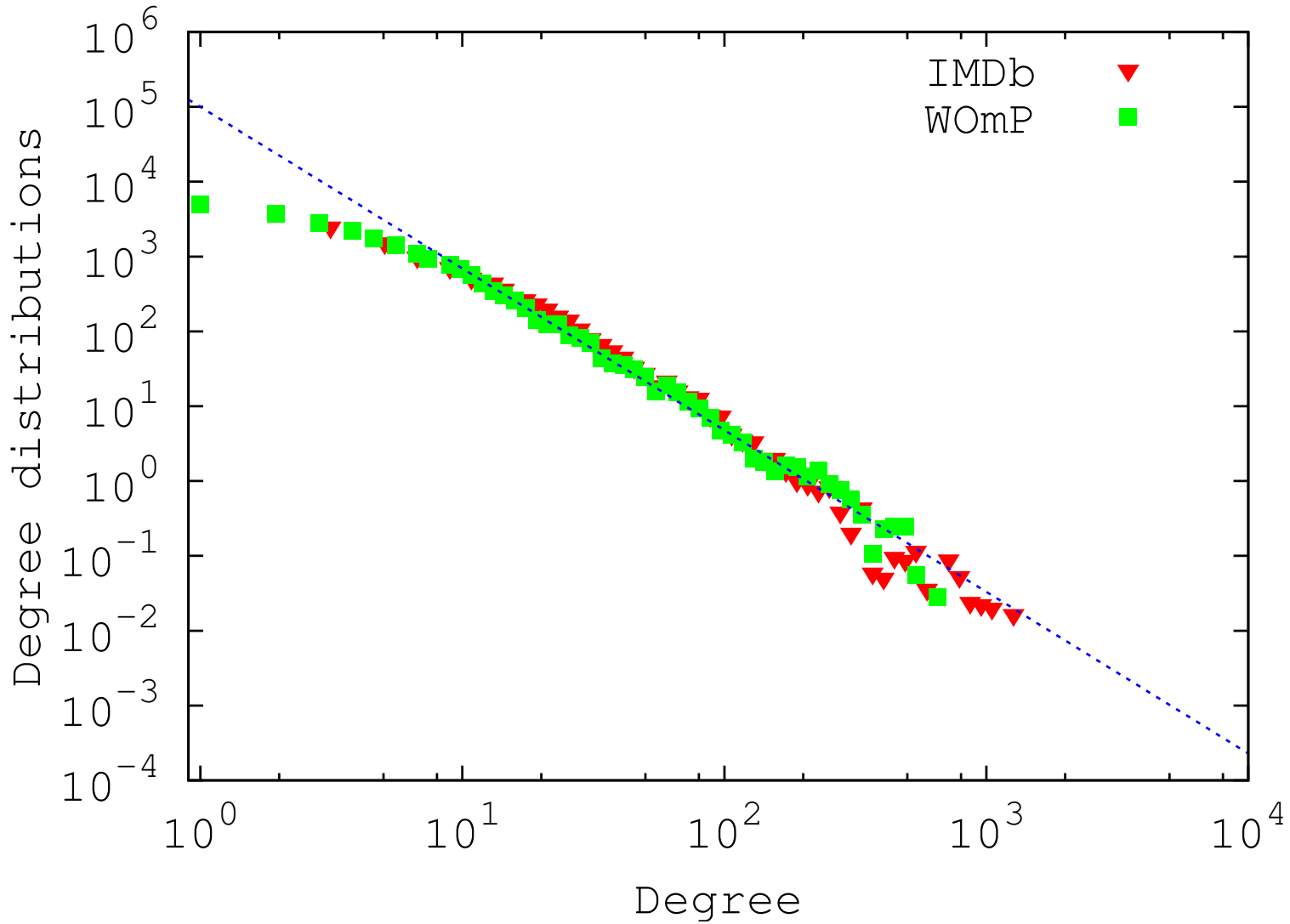
Degree distribution

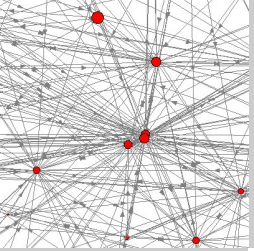
- Degree - number of neighbours
- Power law
- Per movie: $k_{max} = 4,763$, $\langle k \rangle = 27$
- Per user: $k_{max} = 3,040$, $\langle k \rangle = 3$



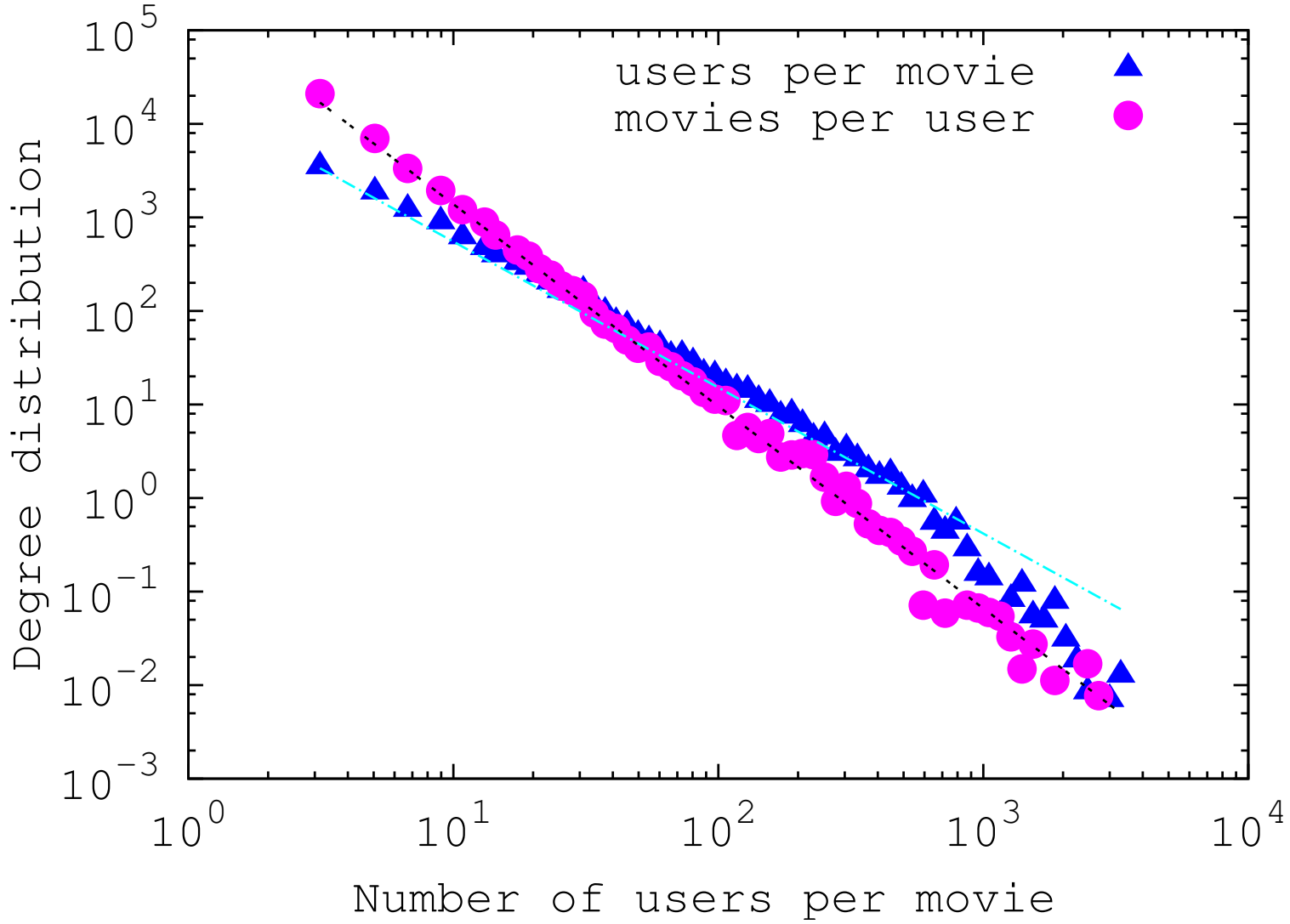


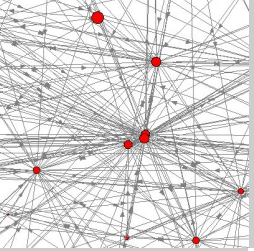
Degree distributions monopartite networks





Degree distributions bipartite networks

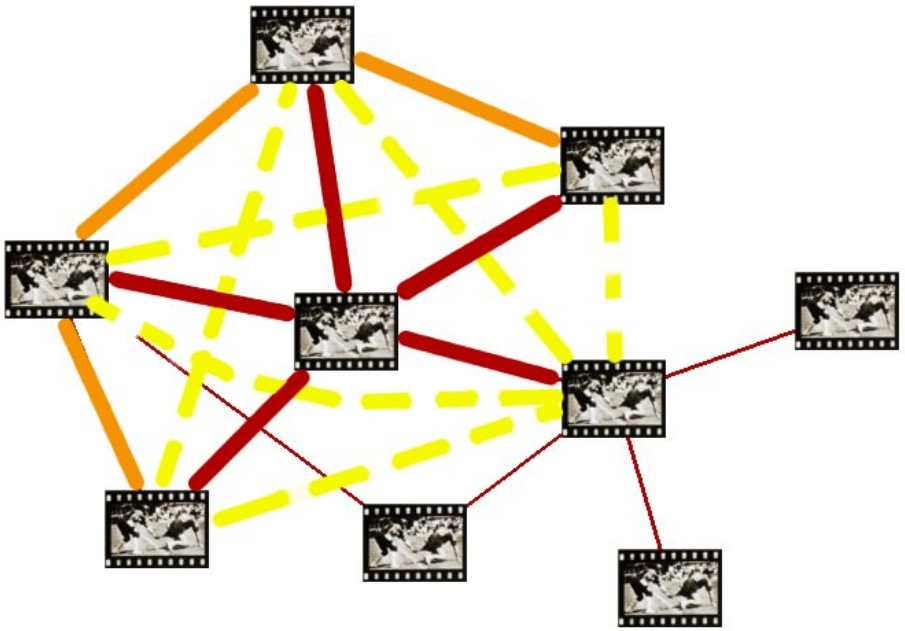




Clustering coefficient

- Clustering coefficient - how connected are the neighbours
- Social networks - high clustering

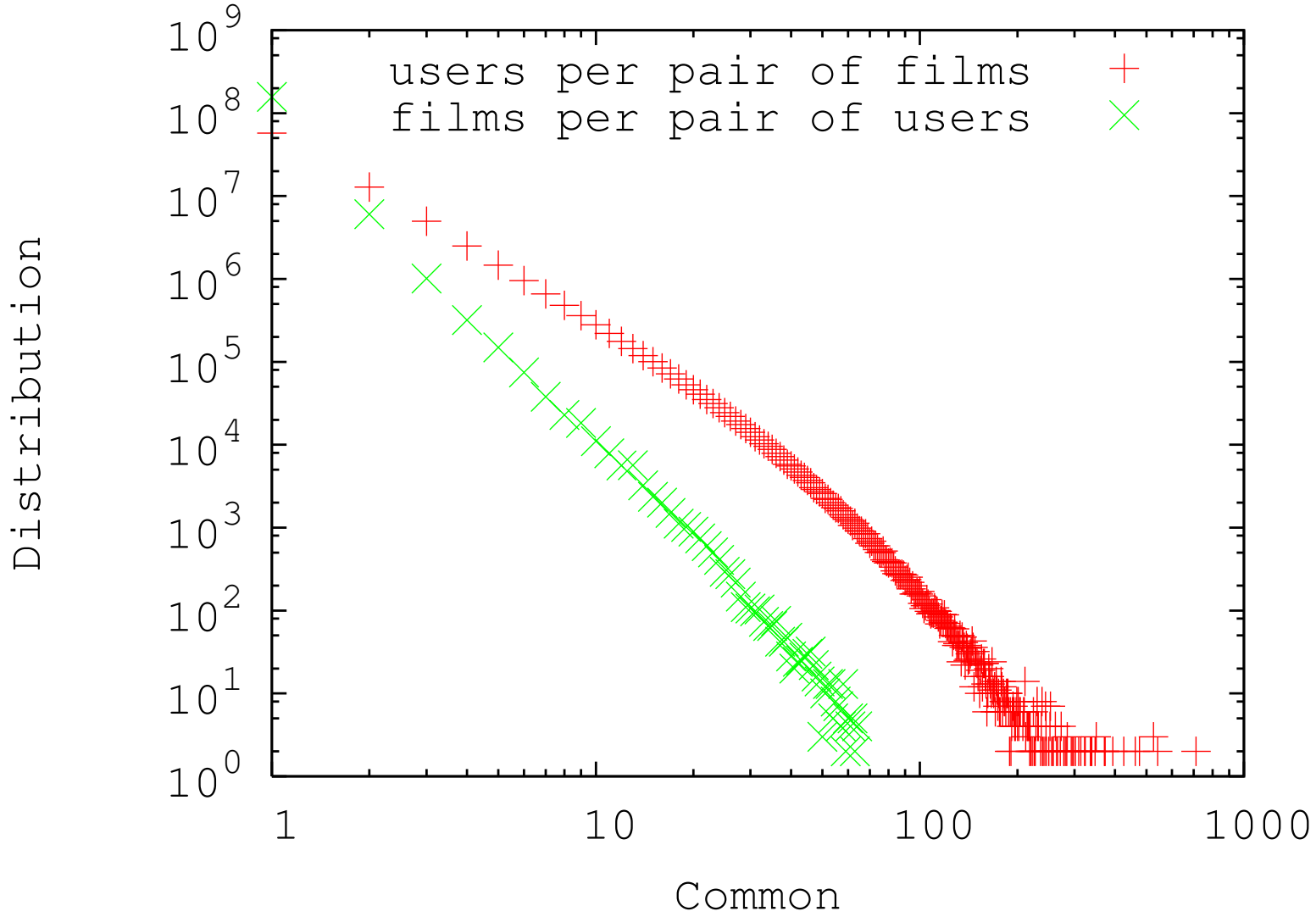
$$c_i = \frac{2e_i}{k_i(k_i-1)} = \frac{2 \cdot 3}{5 \cdot 4} = 0.3$$



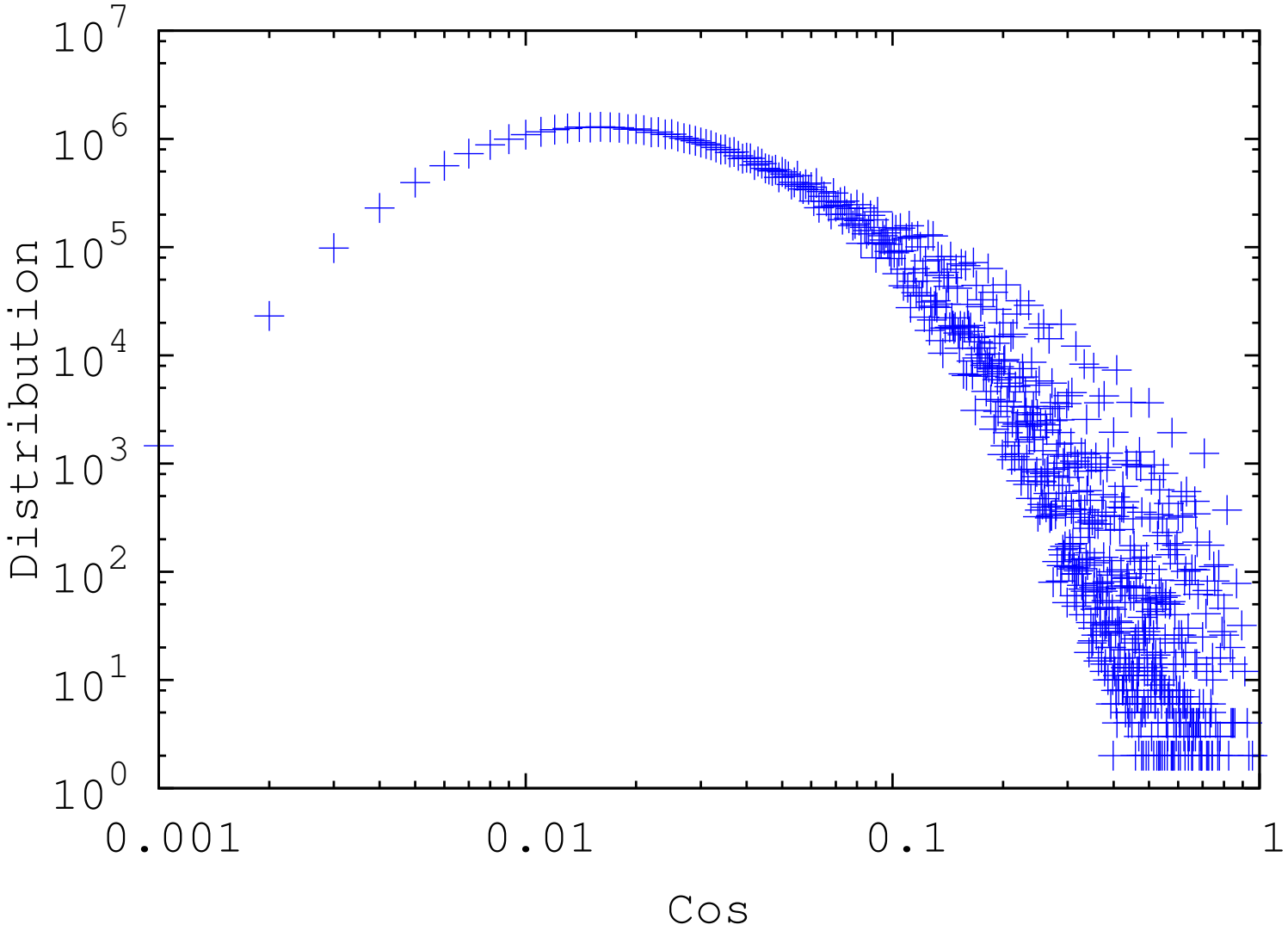
$$C_{IMDb} = 0.19$$

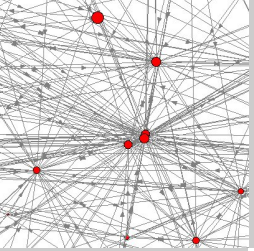
$$C_{WOmP} = 0.54$$

Distribution of Commons - bipartite clustering



Distribution of Cosines





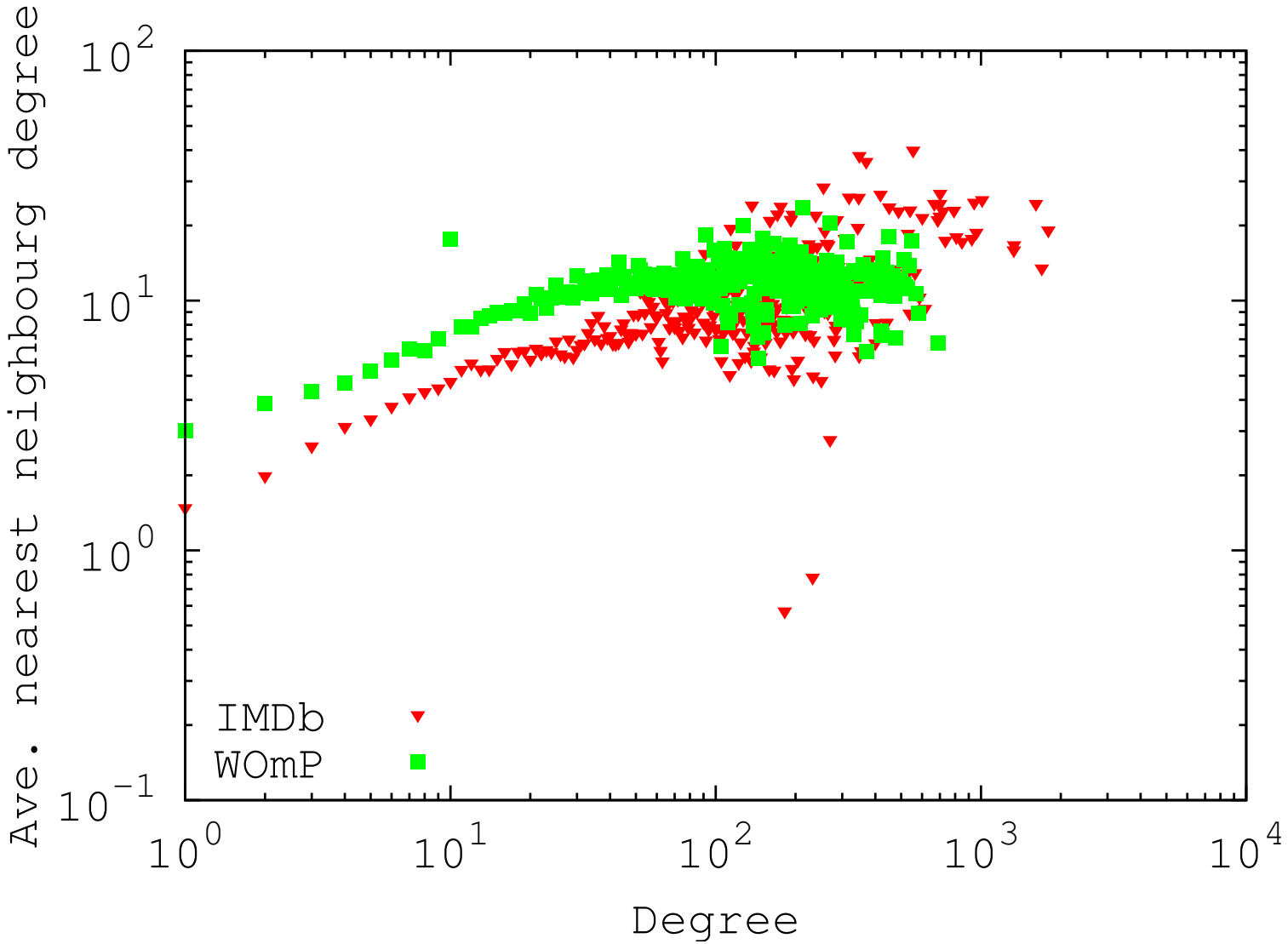
Assortativity

- Average nearest neighbours degree

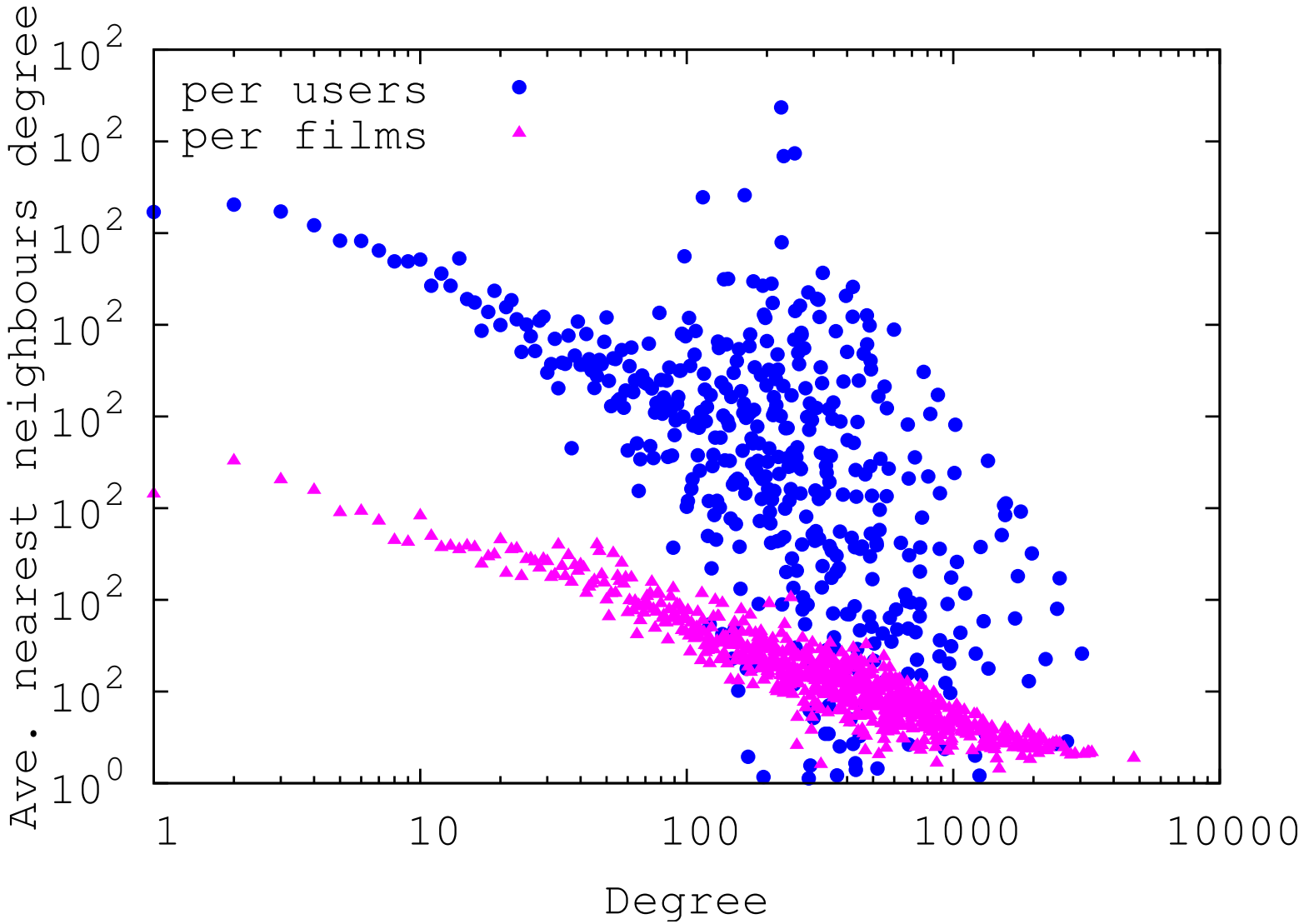
$$k_{nn,i} = \frac{1}{k_i} \sum_{j=1}^{N} a_{ij} k_j$$

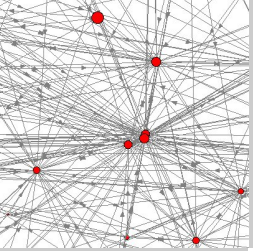
- Assortative connect to similar - social, biological
- Disassortative connect to different - technological

Assortativity monopartite networks

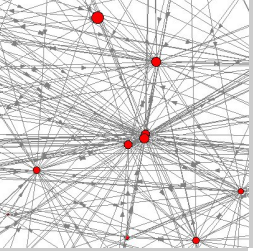


Assortativity bipartite networks





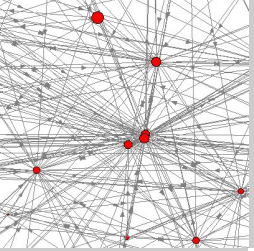
Outline



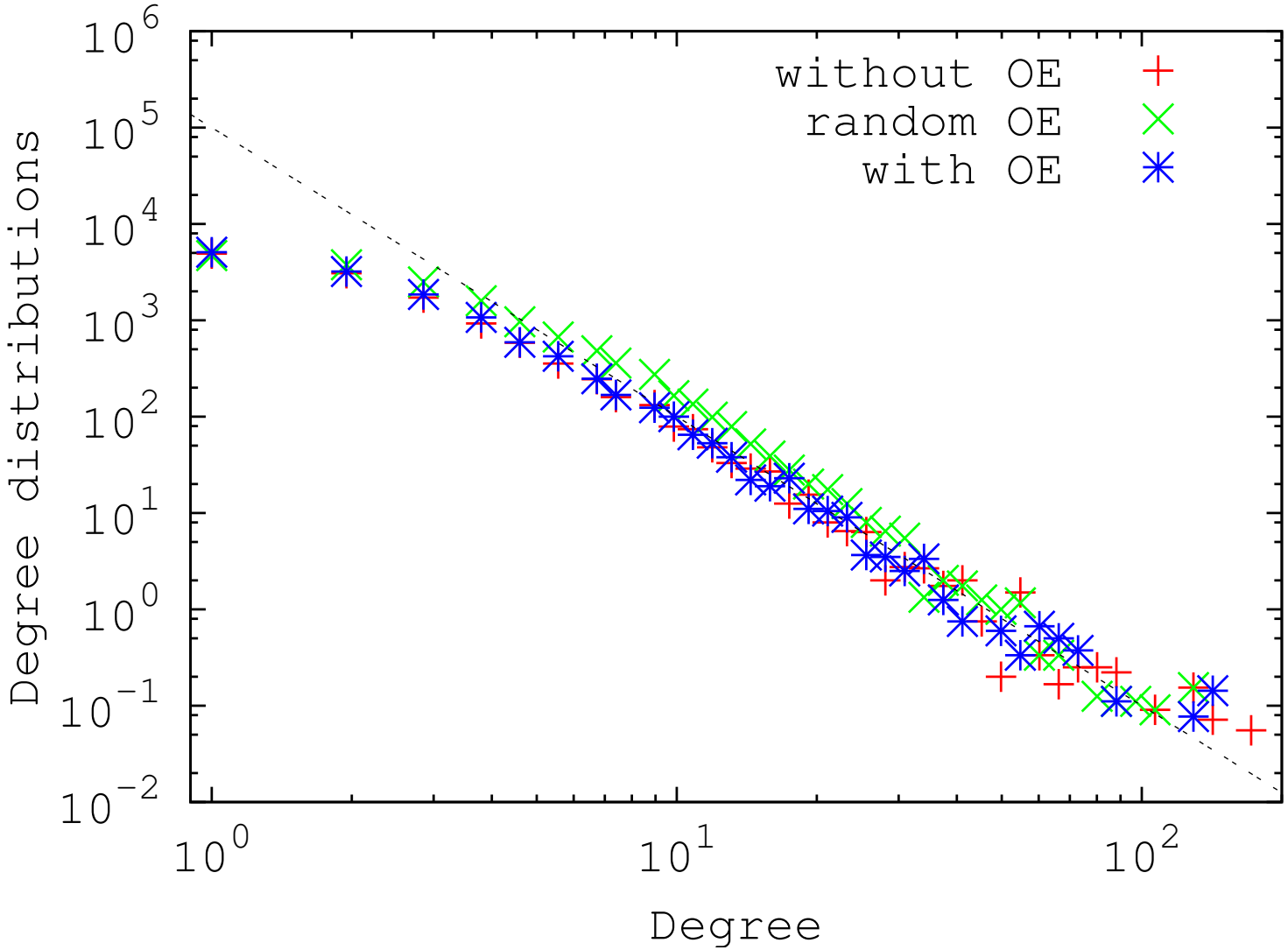
Model

- Analytical and numerical approach
- Guillaume, Latapy, Informational Processing Letters (2004)
- Degree distribution, Clustering
- High number of commons
- Model: Preferential growth + Exchange of opinion

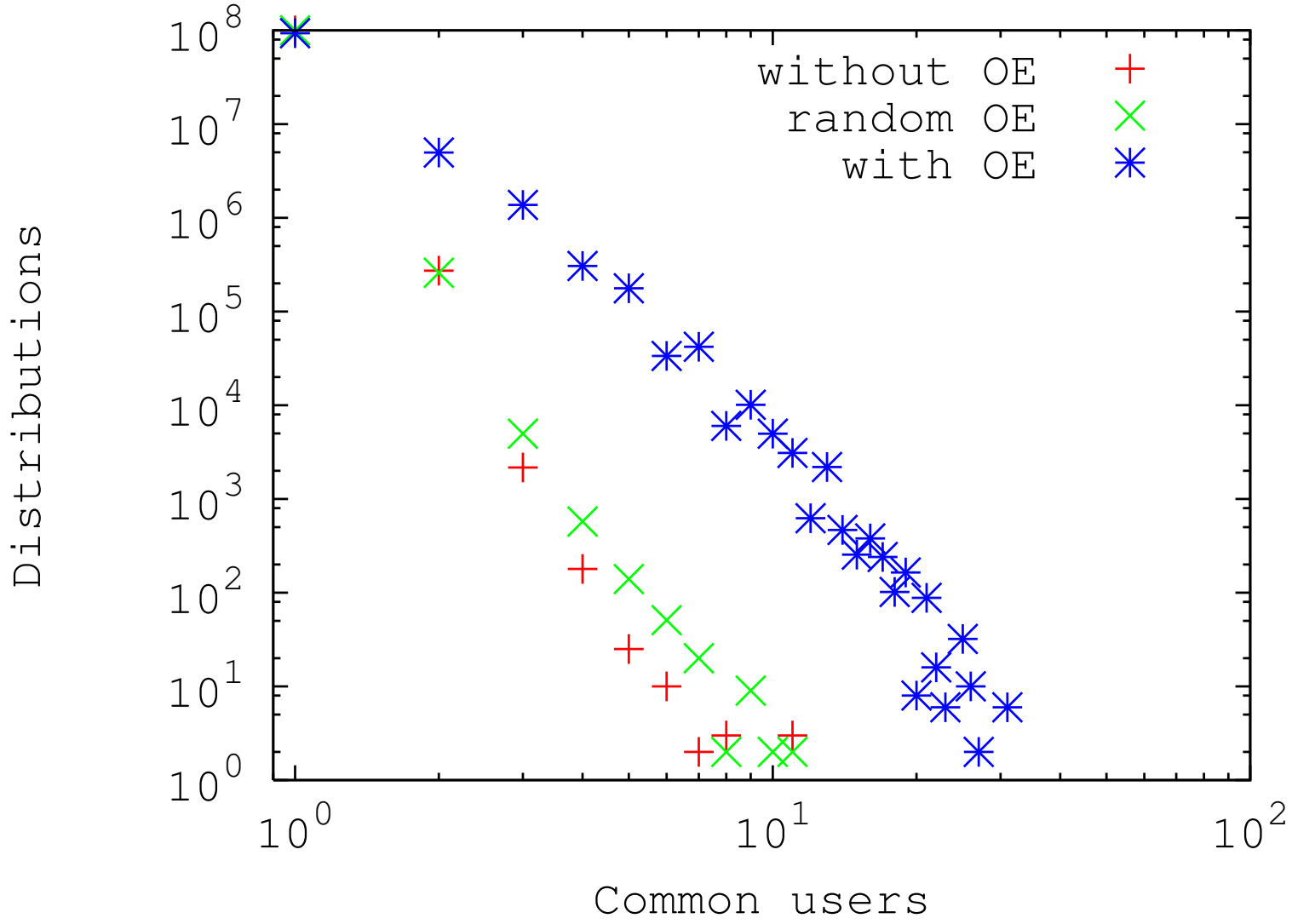
$$\frac{c_{ij}+1}{\sum_{a\neq i} c_{ia}+1}$$

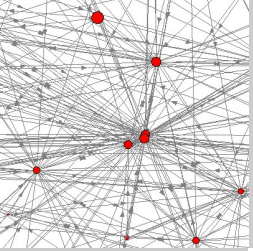


Degree distribution



Distribution of Commons





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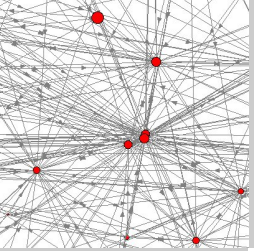
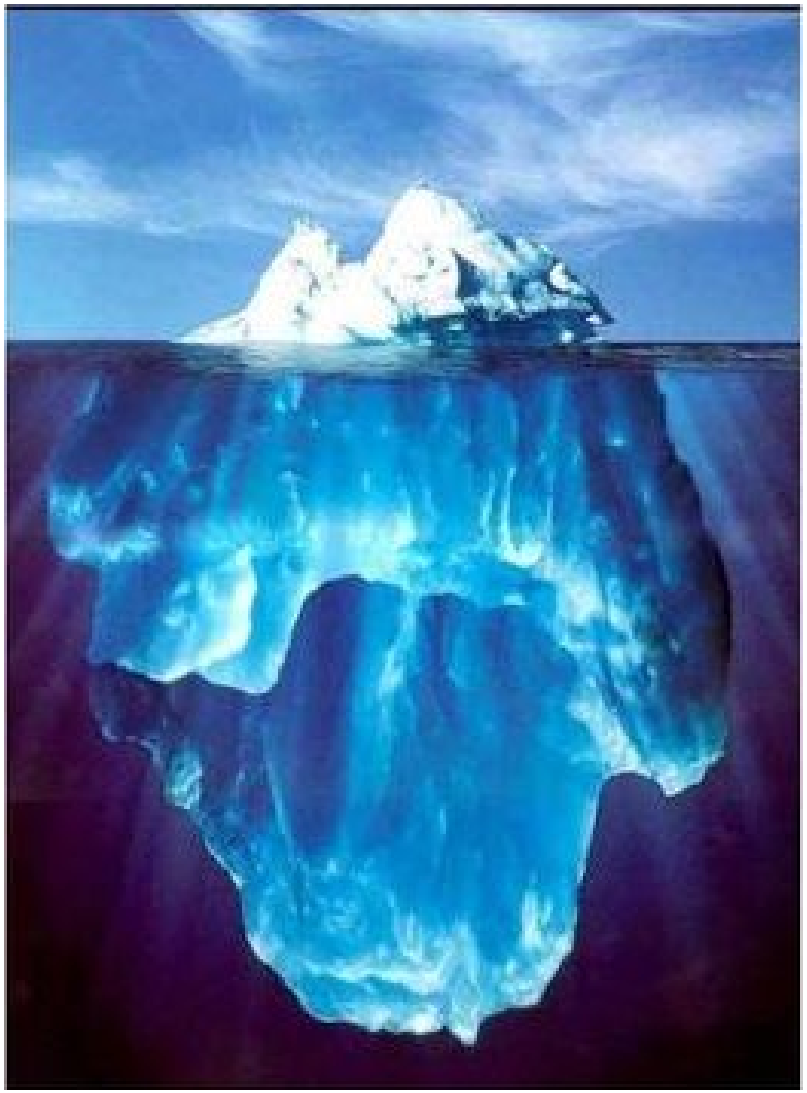


Conclusion

- Two type of networks considered: monopartite and bipartite
- Monopartite: power law degree distribution, high clustering, assoratative mixing, similar properties
- Bipartite: power law degreedistributions, high number of commons, dissassortative mixing
- Scale free degree distribution $\longrightarrow$ Scale free degree distribution
- Disassortative mixing $\longrightarrow$ Assortative mixing
- Model with exchange of opinion

Future works

- Analytical solution of the model
- Fine tune model
- Assorativity model
- Modular structure



Acknowledgments

- Author thanks Bosiljka Tadić for numerous useful comments and suggestions.