SYMPOSIUM on the Occasion of Angela Bracco and Adam Maj 60th Birthday

Complexity characteristics of Nuclear Physics

Scientific Collaboration Network

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Kraków, September 14, 2015

Complexity ⟷ „More is different”

(P.W. Anderson, Science 177 (1972) 393-396)

The WHOLE is not a simple sum of constitutents ⟶ emergence

Appropriate framework to quantify complexity is in terms of

Networks

random

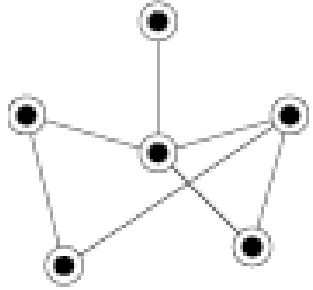
complex

small-world

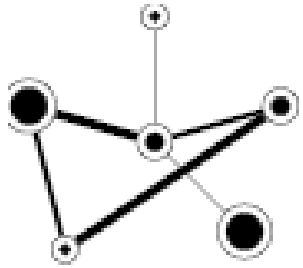
scale-free ⟷ hierarchical organization

Many real systems can be modeled as networks:

nodes + interactions (links or edges)



Dynamical processes on networks which are in turn affected by the dynamics



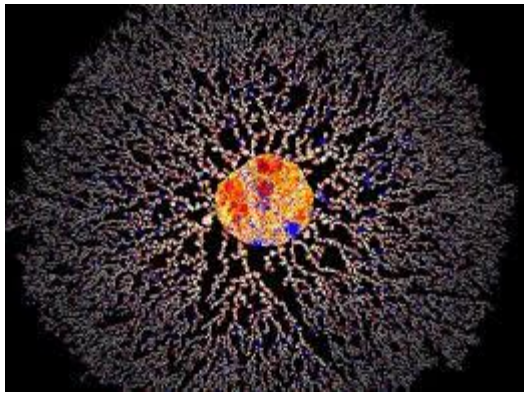
→ Networks represent the backbone of complexity

Networks permeate almost every conceivable discipline

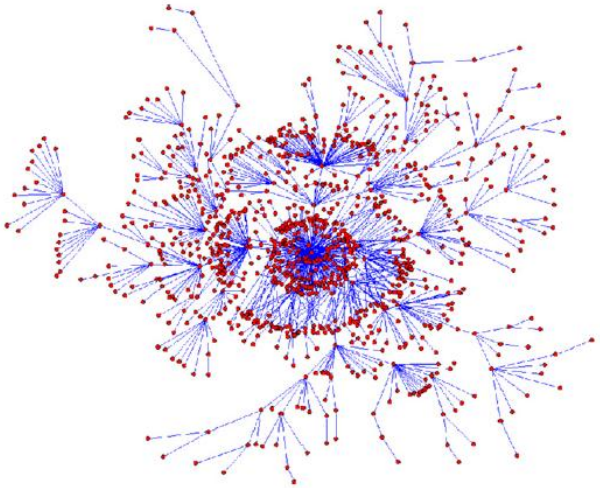
"network science" has thus become a crucial component of modern scientific education.

Examples of ‘real world’ networks

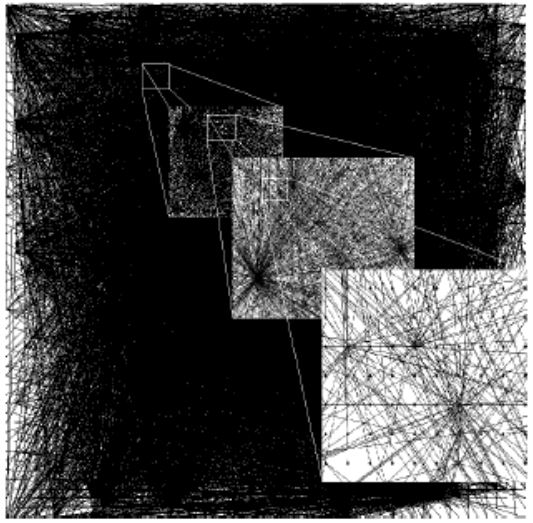
World transportation network



Protein homology network



Stock market companies network

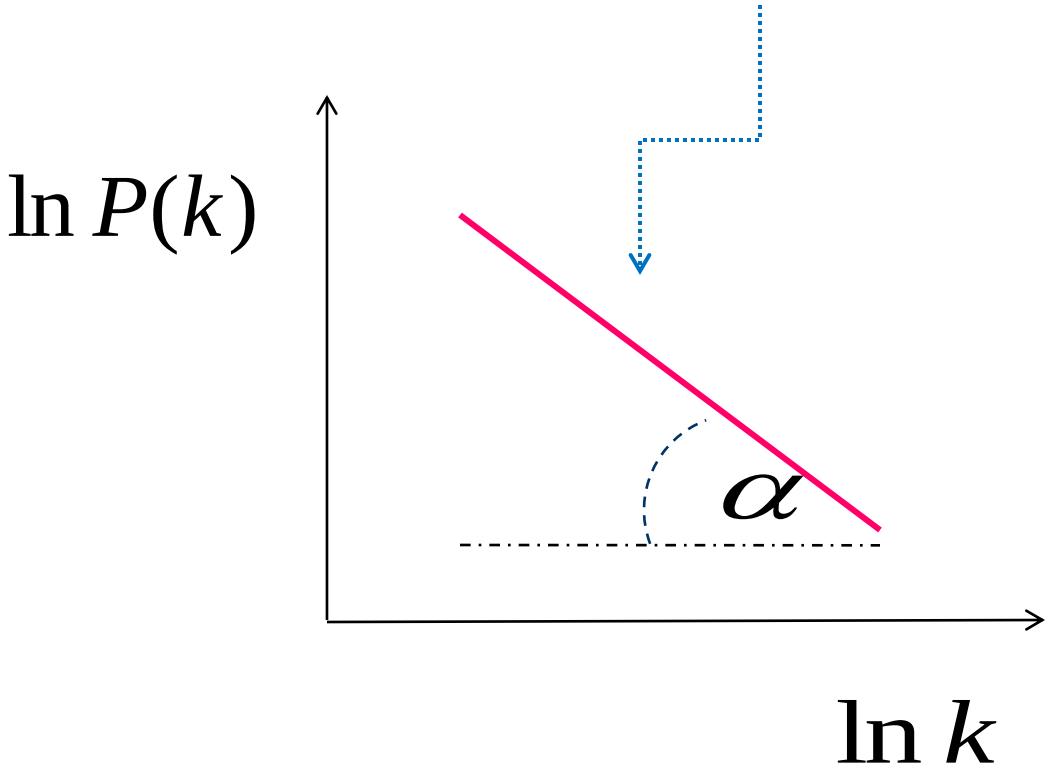


Linguistic: word adjacency network

Principal network characteristics:

degree k distribution

$$P(k) \propto k^{-\gamma}$$

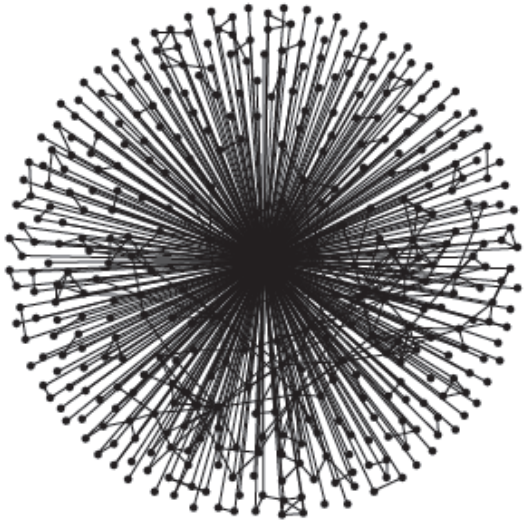


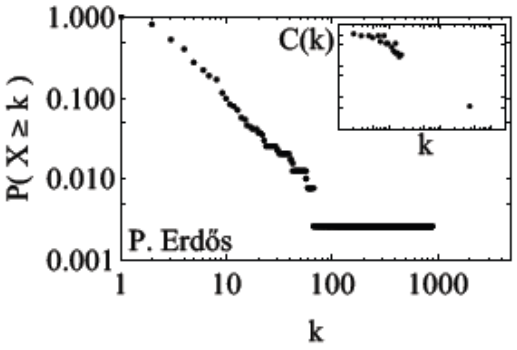
Scale-free
(hierarchical)

$$\gamma = tg\,\alpha$$

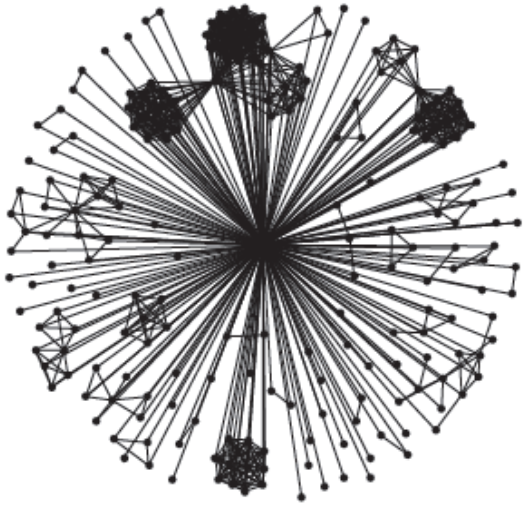
Scientific collaboration networks

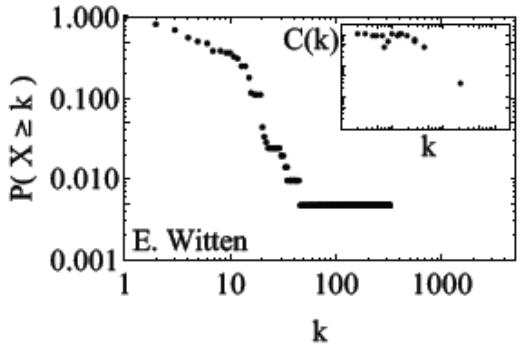
Erdos # = 1



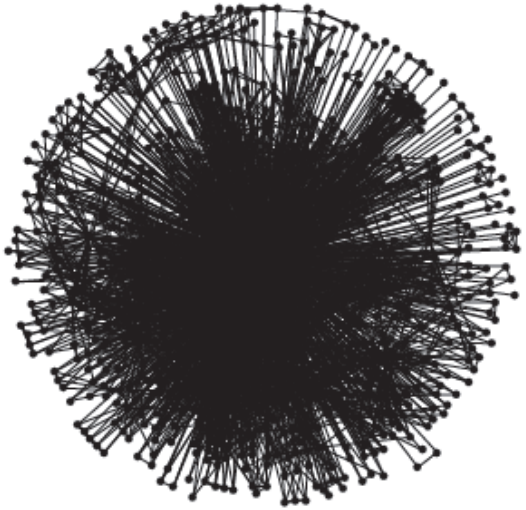


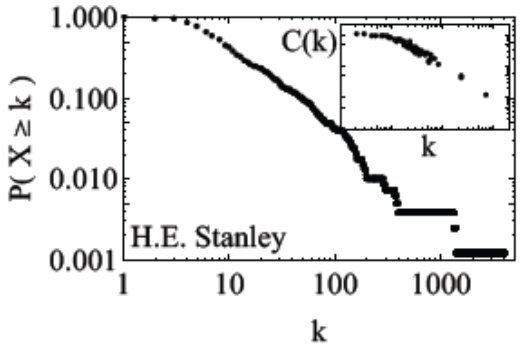
Witten # = 1





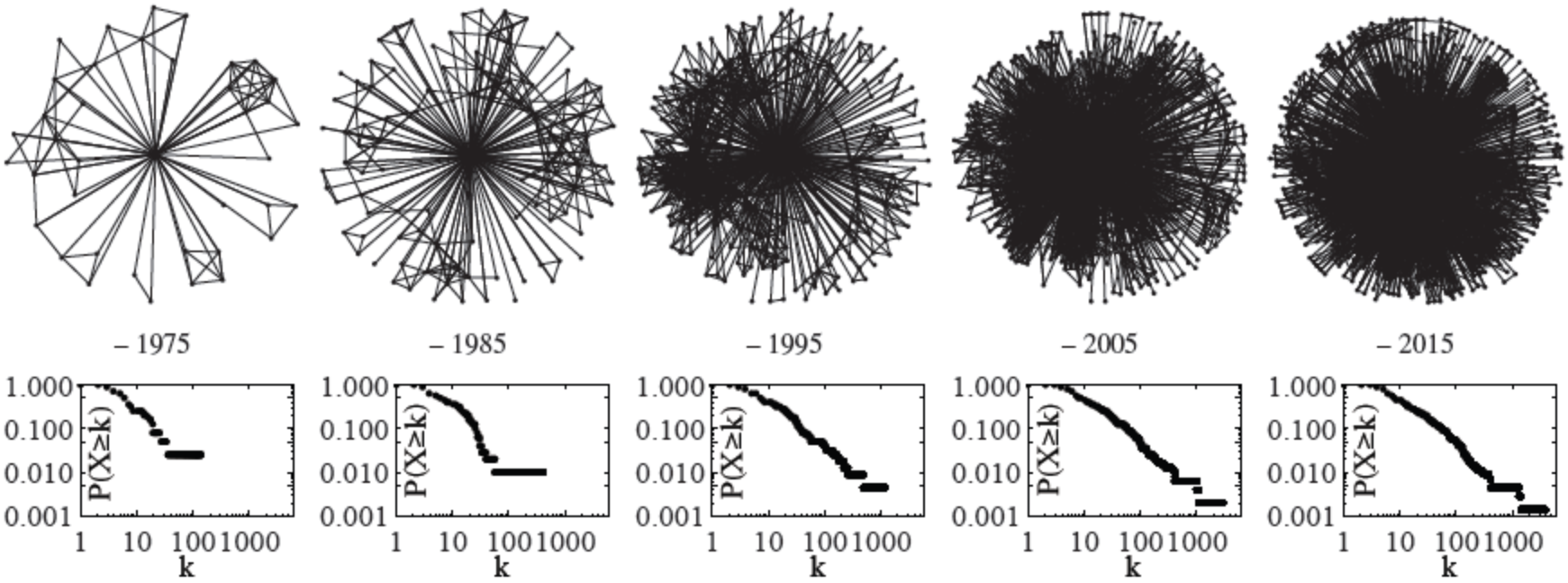
Stanley # = 1





* Based on *Web of Science*	P. Erdős	E. Witten	H.E. Stanley
Number of articles	750	319	1177
Number of collaborators	392	145	683
h–index	60	131	123

Time evolution of Stanley's collaboration network



Scientometric parameters

	A.Bracco	A.Maj
Number of articles	363	288
Number of co-authors	1429	1143
Number of common articles	173	
Number of common co-workers	883	

AGATA-Advanced Gamma Tracking Array, 354 Authors

Nuclear Instruments and Methods in Physics Research A 668 (2012) 26–58

Number of authors (descending order) in Bracco's publications

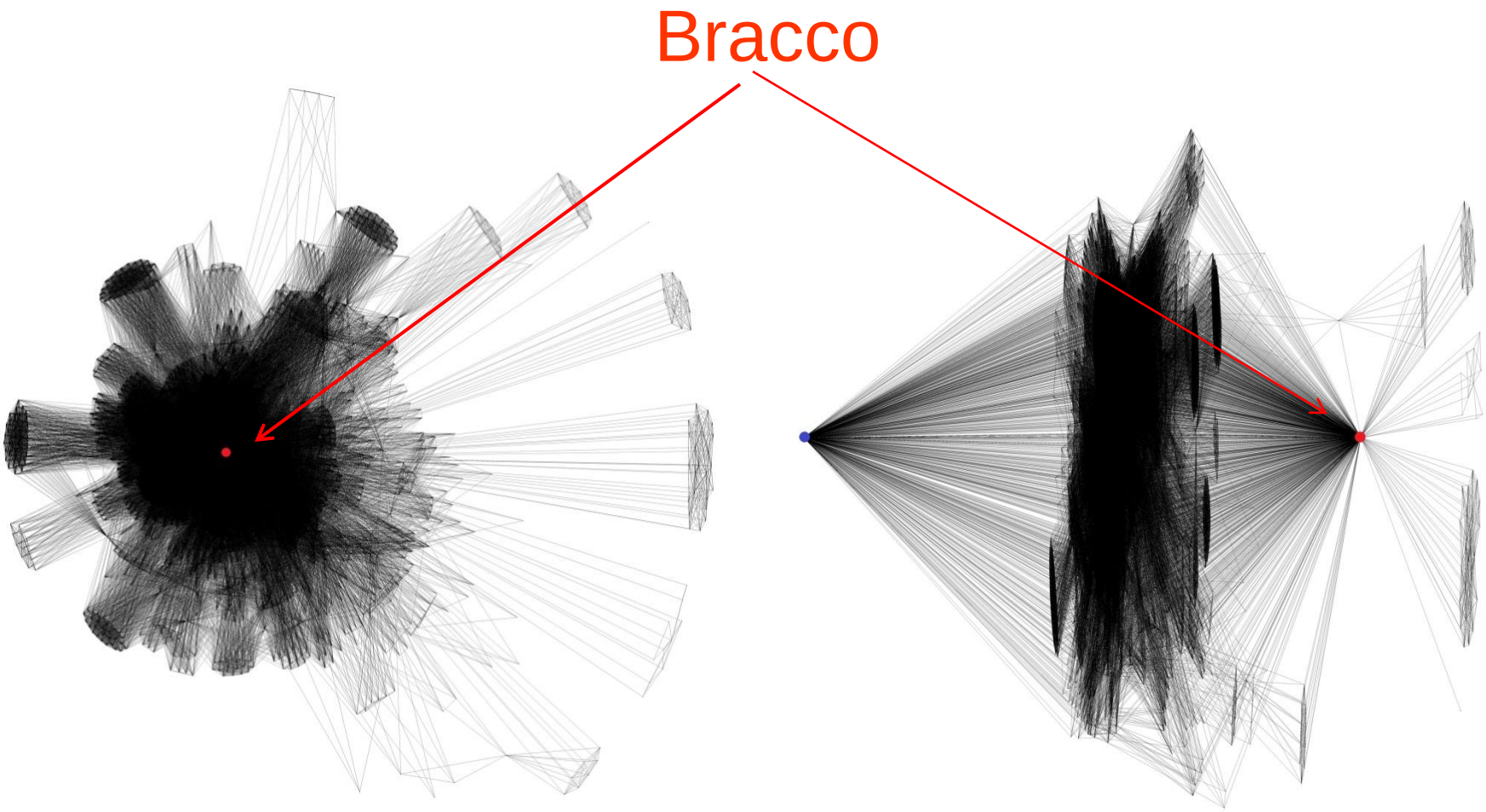
Bracco = {354, 110, 105, 84, 83, 83, 81, 80, 78, 78, 77, 76, 76, 76, 75, 74, 72, 70, 69, 69, 69, 68, 68, 68, 67, 66, 65, 64, 62, 60, 58, 58, 58, 56, 56, 54, 54, 53, 53, 53, 53, 52, 52, 52, 51, 51, 50, 49, 49, 49, 48, 48, 48, 48, 47, 47, 47, 46, 46, 46, 46, 46, 45, 45, 45, 45, 44, 44, 43, 43, 43, 43, 43, 43, 42, 42, 42, 42, 42, 42, 42, 42, 41, 41, 41, 41, 41, 41, 41, 41, 39, 39, 39, 38, 38, 38, 37, 37, 37, 37, 37, 36, 34, 34, 33, 33, 33, 33, 32, 32, 31, 31, 31, 31, 31, 30, 29, 29, 29, 29, 28, 28, 28, 28, 28, 27, 27, 27, 27, 27, 27, 27, 27, 27, 27, 27, 27, 27, 26, 26, 26, 26, 26, 26, 26, 26, 26, 26, 26, 25, 25, 25, 25, 25, 25, 25, 25, 25, 25, 25, 24, 24, 24, 24, 24, 23, 23, 23, 22, 22, 22, 22, 22, 22, 21, 21, 21, 21, 21, 21, 21, 20, 20, 20, 20, 20, 20, 20, 20, 20, 20, 20, 20, 20, 20, 19, 19, 19, 19, 19, 18, 18, 18, 18, 16, 16, 16, 15, 15, 15, 15, 14, 14, 14, 14, 14, 14, 14, 14, 13, 13, 13, 13, 13, 13, 13, 13, 13, 13, 13, 13, 13, 13, 13, 13, 13, 13, 13, 13, 12, 12, 12, 12, 12, 12, 11, 11, 11, 11, 11, 11, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 6, 6, 6, 6, 6, 6, 6, 6, 6, 6, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 3, 3, 3, 3, 3, 3, 3, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 1, 1, 1, 1, 1}

Number of authors (descending order) in Maj's publications

Maj={354, 105, 101, 78, 78, 77, 76, 75, 74, 72, 72, 69, 69, 69, 68, 68, 67, 66, 65, 64, 63, 63, 63, 63, 62, 62, 62, 58, 58, 58, 56, 56, 56, 56, 56, 55, 55, 55, 54, 54, 54, 54, 53, 53, 53, 53, 53, 52, 52, 52, 51, 51, 51, 50, 49, 49, 49, 48, 48, 48, 48, 48, 47, 47, 46, 46, 46, 46, 45, 45, 44, 44, 43, 43, 43, 42, 42, 42, 42, 41, 41, 41, 41, 41, 41, 41, 41, 41, 41, 39, 39, 38, 38, 37, 37, 37, 37, 36, 36, 34, 34, 33, 31, 31, 31, 31, 31, 31, 31, 29, 29, 29, 28, 28, 28, 28, 28, 27, 27, 27, 27, 27, 26, 26, 26, 26, 26, 26, 26, 26, 25, 25, 25, 25, 25, 25, 24, 24, 23, 23, 23, 23, 22, 22, 22, 22, 21, 21, 21, 20, 20, 20, 20, 20, 20, 20, 20, 20, 20, 19, 19, 19, 18, 18, 18, 18, 18, 18, 17, 17, 17, 17, 17, 16, 16, 16, 16, 16, 16, 16, 15, 15, 14, 14, 14, 13, 13, 13, 13, 13, 13, 13, 13, 13, 12, 12, 12, 12, 12, 12, 11, 11, 11, 11, 11, 11, 11, 11, 11, 11, 11, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 7, 7, 7, 7, 7, 7, 7, 7, 7, 6, 6, 6, 6, 6, 6, 6, 6, 6, 5, 5, 5, 5, 5, 4, 4, 4, 3, 3, 2, 2, 1, 1, 1}

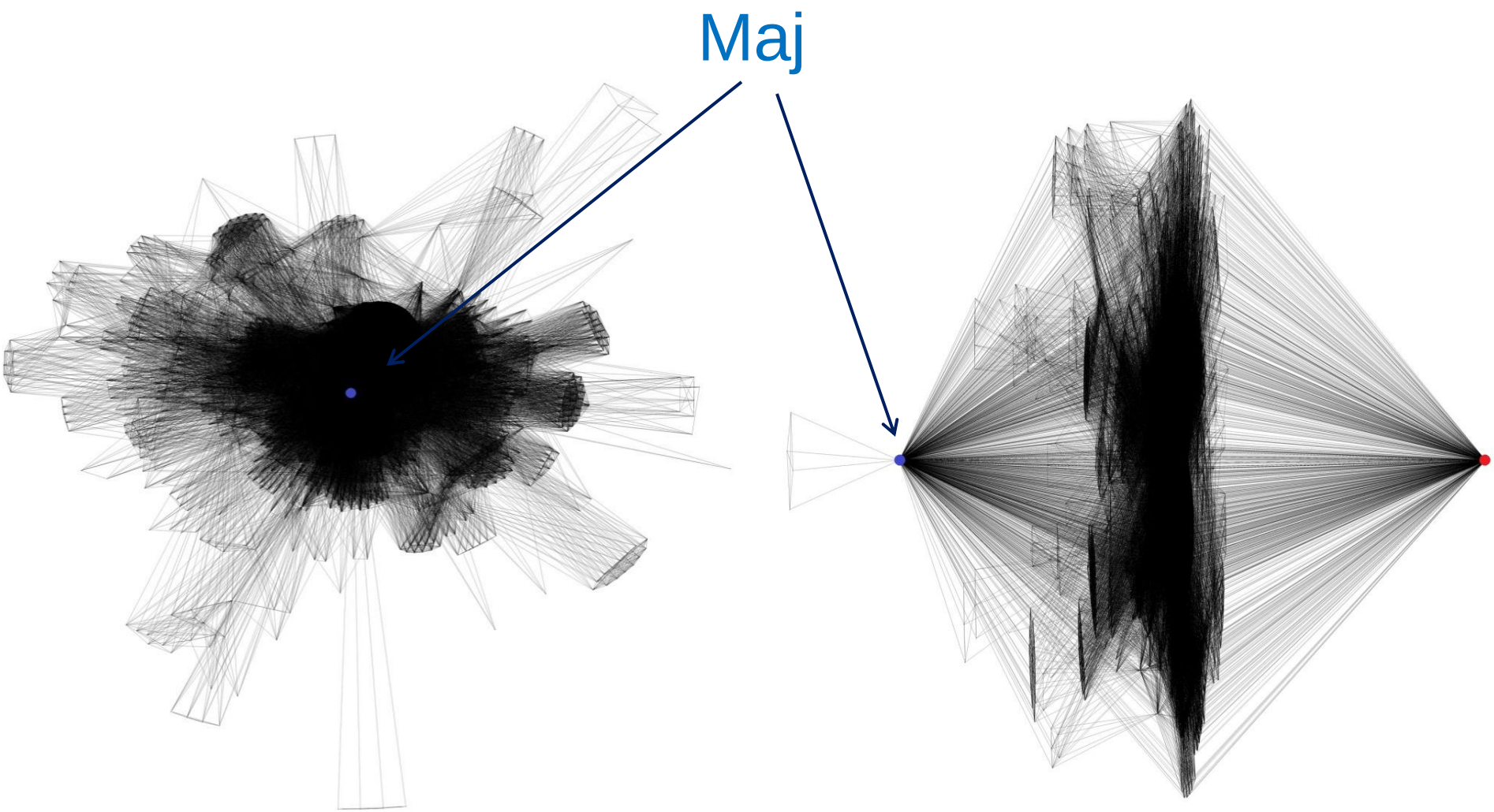
Bracco's scientific collaboration network

(Bracco # = 1)



Maj's scientific collaboration network

(Maj # = 1)



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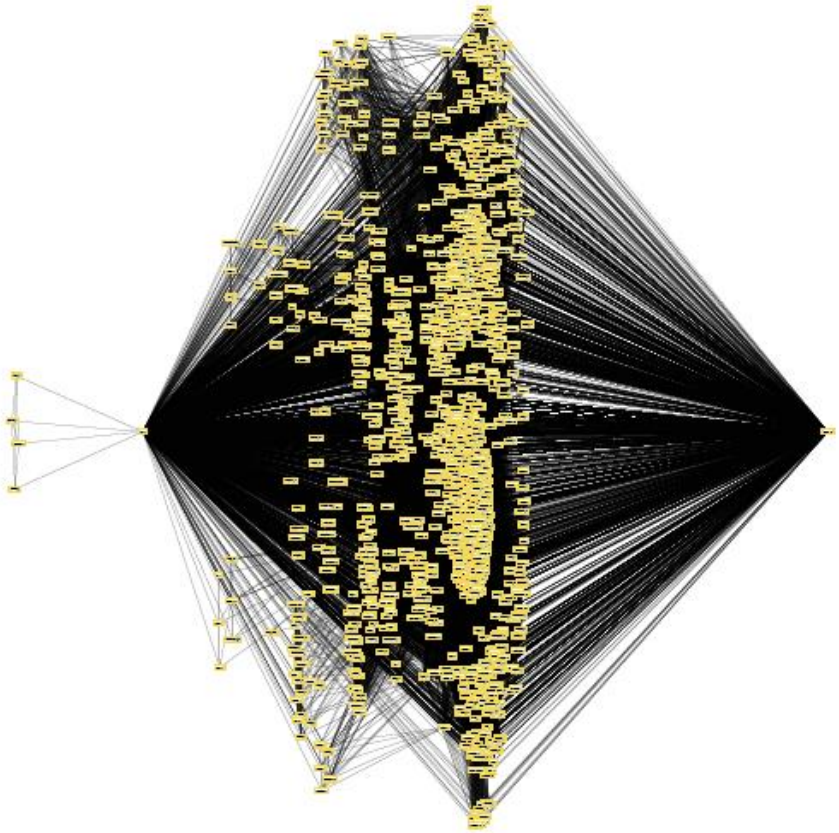

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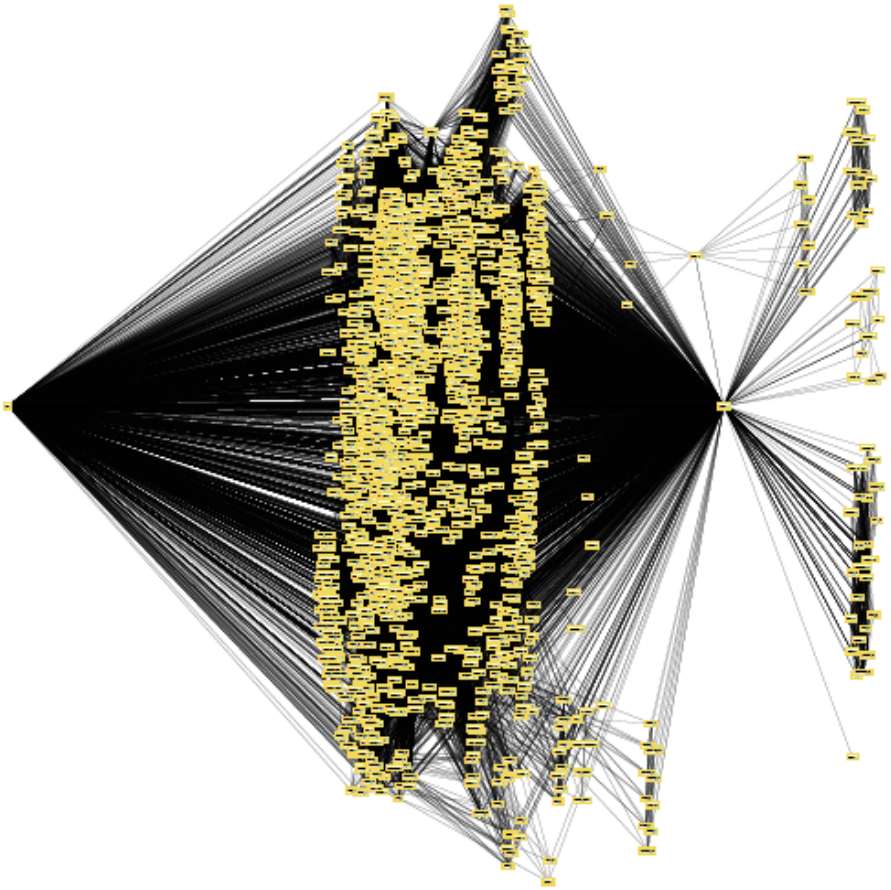
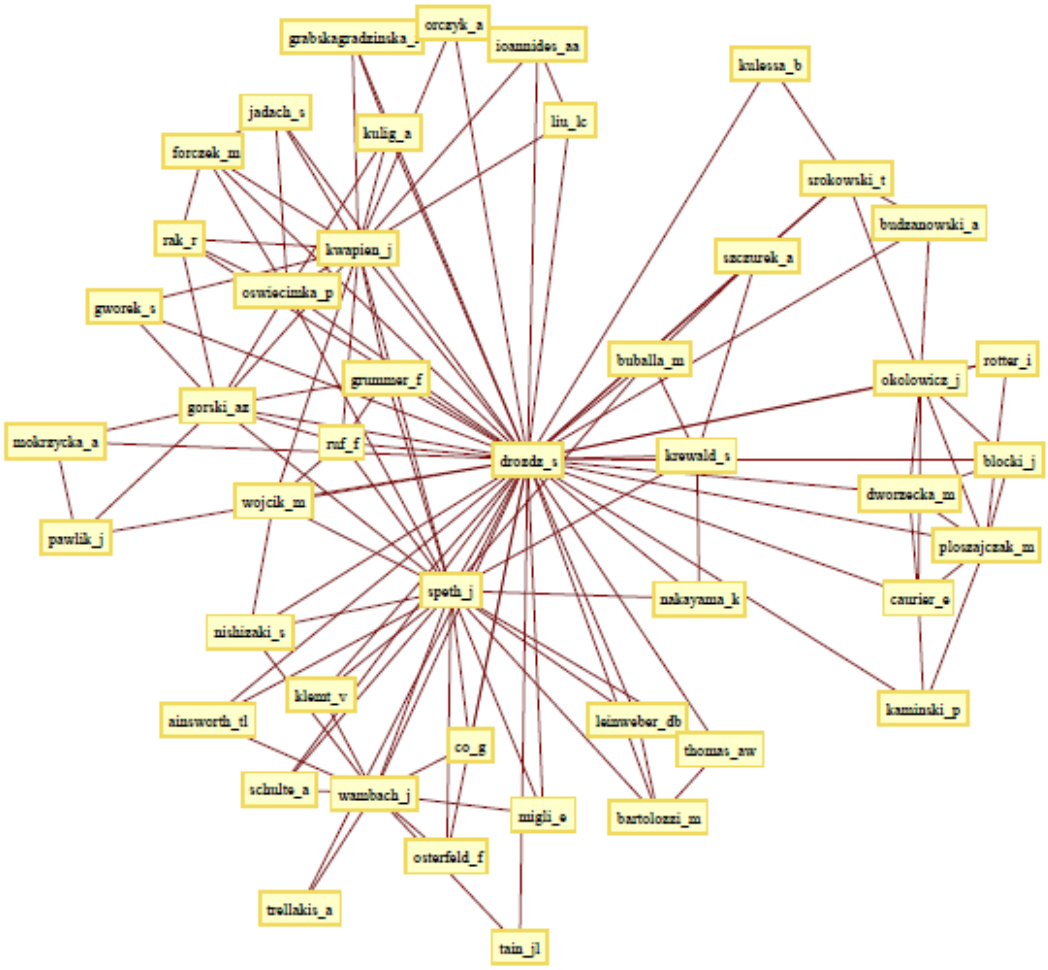
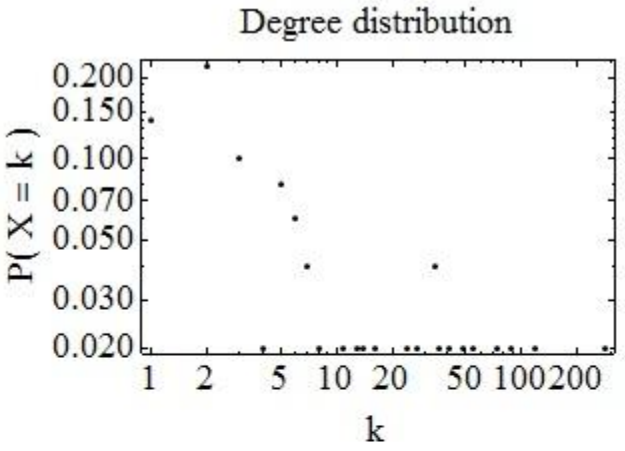
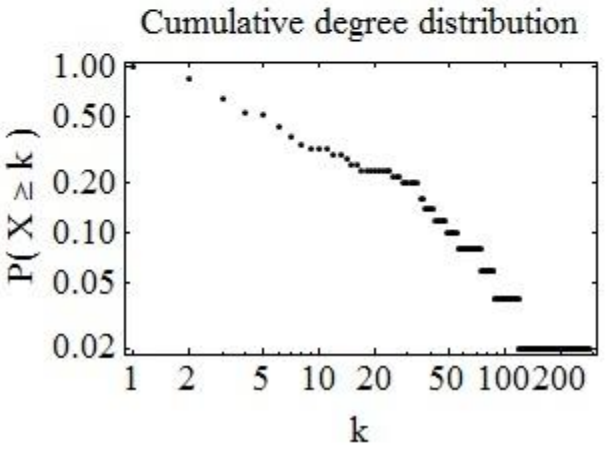


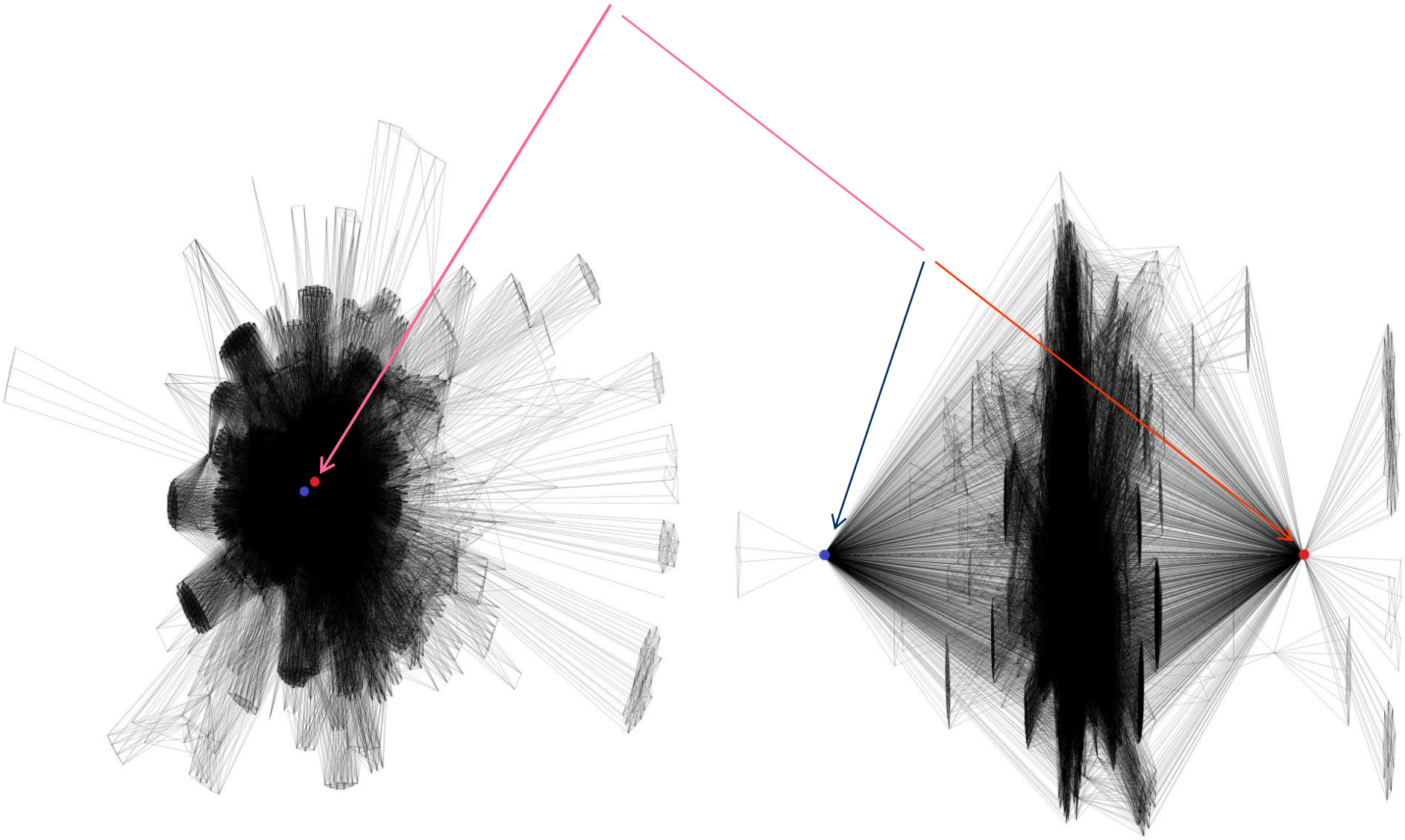
S. Drożdż's scientific collaboration network





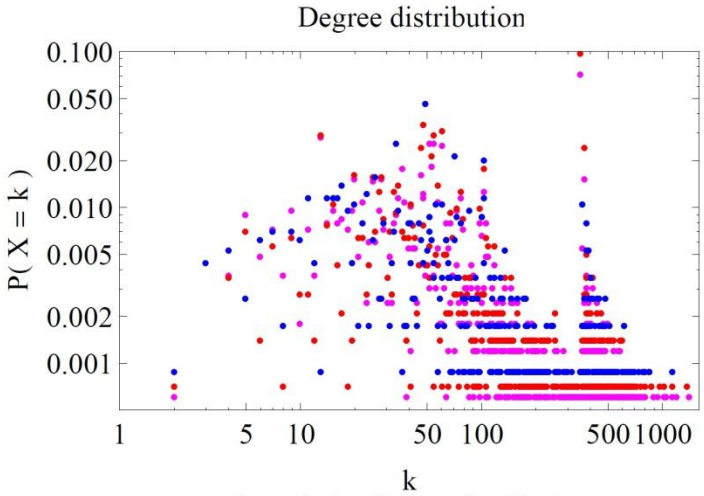


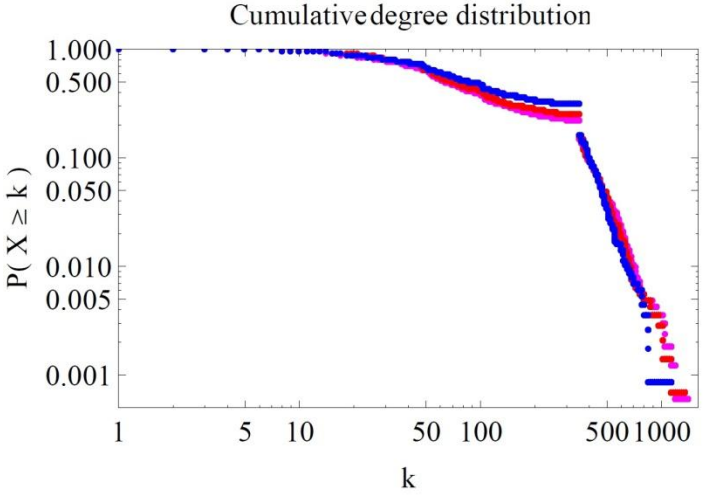
Bracco & Maj # = 1



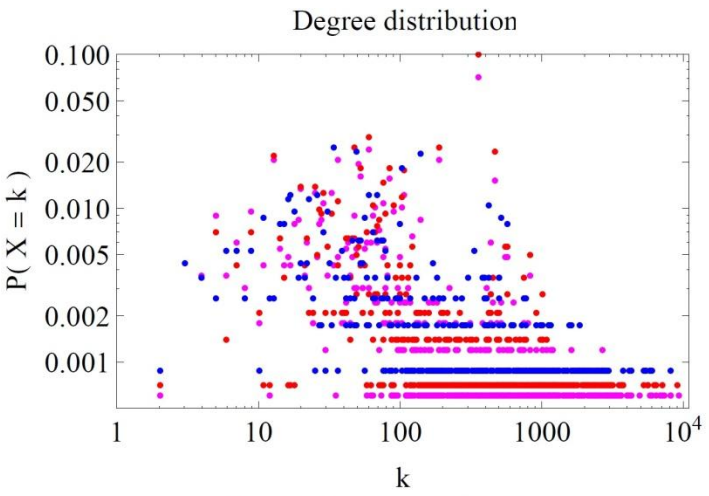
(i) Bracco, (ii) Maj and (iii) Bracco & Maj degree distribution

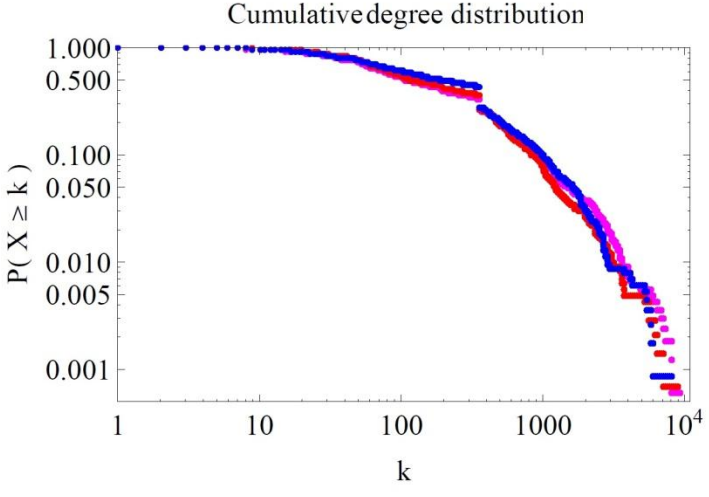
unweighted





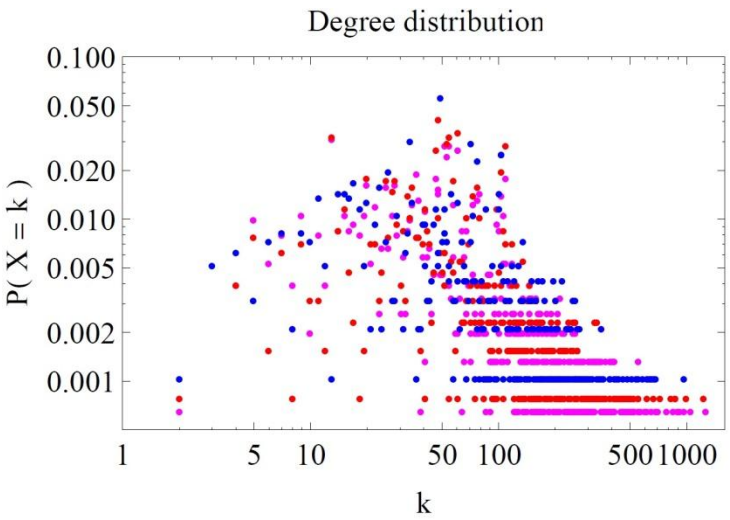
weighted

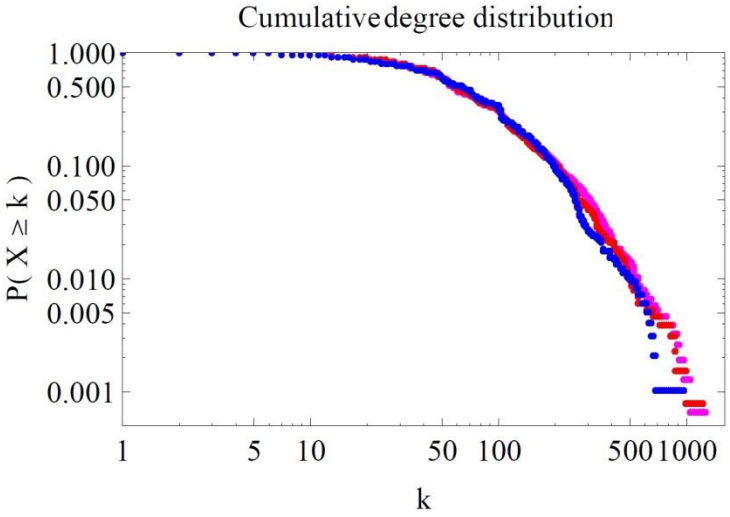




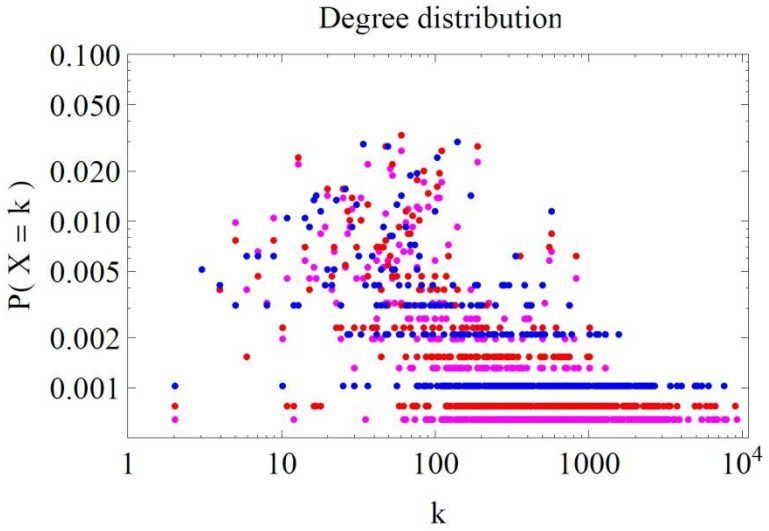
(i) Bracco, (ii) Maj and (iii) Bracco & Maj
354 authors paper removed degree distribution

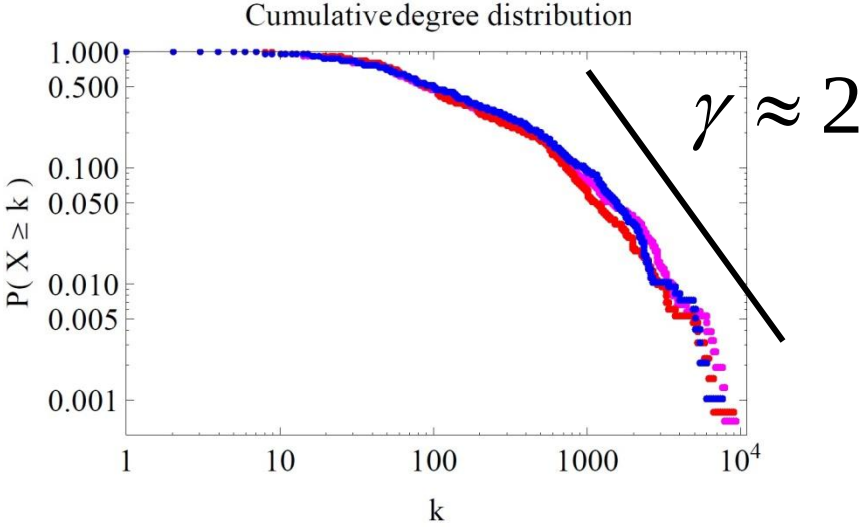
unweighted





weighted

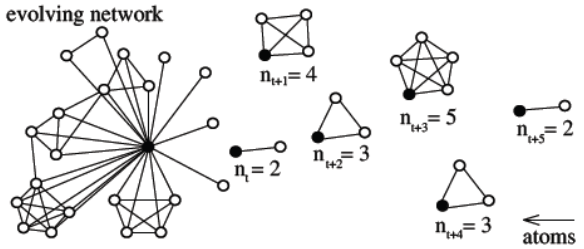




Modeling dynamics of collaboration network growth

Assume (Matthew effect)
preferential attachment:

Visualizing growth:



$$\frac{\partial \bar{k}(\tau,t)}{\partial t} = \delta \frac{\bar{k}(\tau,t)}{\sum_j k_j} \quad \text{and} \quad \sum_j k_j = ct^{\alpha}$$

$$\delta = \frac{d}{dt}\sum_j k_j = c\alpha t^{\alpha-1} \qquad \bar{k}(\tau,t) = \left(\frac{\tau}{t}\right)^{-\alpha}$$

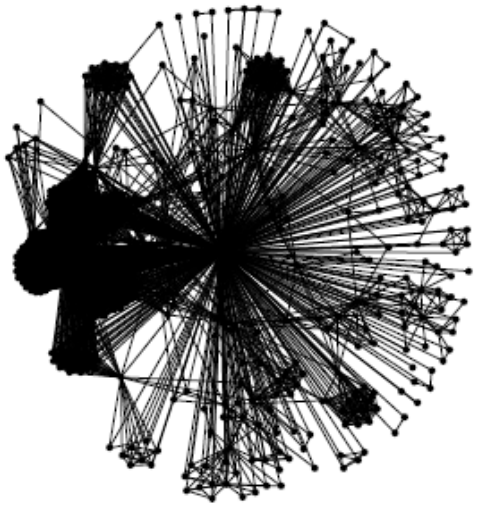
$$P(k,t) = \frac{1}{t}\int_0^t \delta(k-\bar{k}(\tau,t))d\tau = -\frac{1}{t}\left(\frac{\partial \bar{k}(\tau,t)}{\partial \tau}\right)^{-1}_{\tau=k(\tau,t)}$$

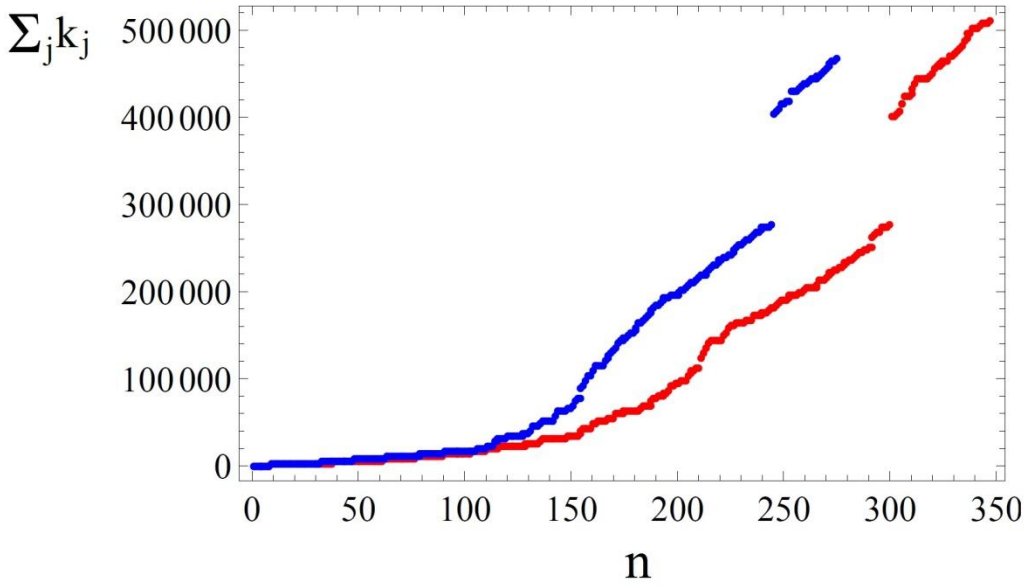
$$P(k) \sim k^{-\gamma} \quad \text{with} \quad \gamma = 1+\frac{1}{\alpha}$$

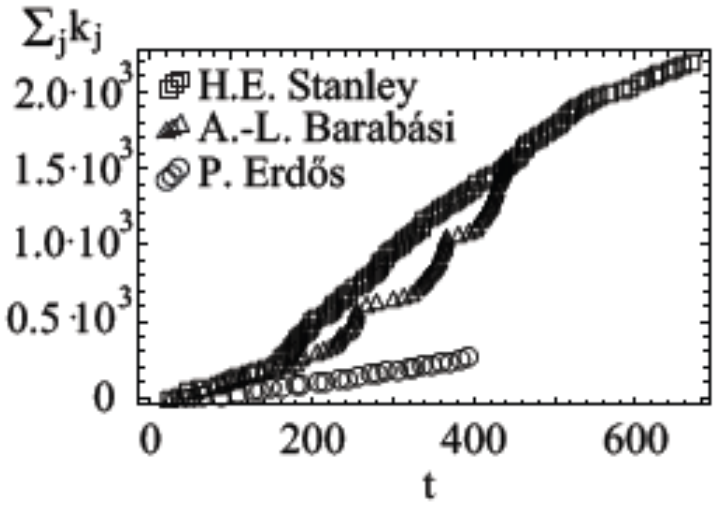
$$\gamma \approx 2 \quad \text{corresponds to} \quad \alpha \approx 1$$

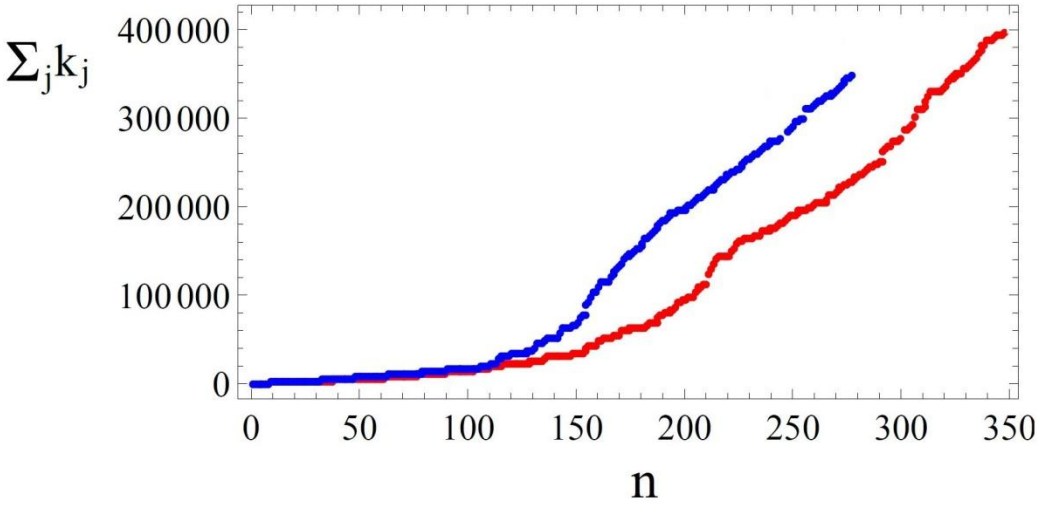
which implies linear growth of $\sum_j k_j = k_{tot}$

Bracco & Maj


1.000
0.100
0.010
0.001
P(X ≥ k)
C(k)
k
A.-L. Barabási
1
10
100
1000
k


Σ_j k_j
500 000
400 000
300 000
200 000
100 000
0
0
50
100
150
200
250
300
350
n


Σ_j k_j
2.0·10^3
1.5·10^3
1.0·10^3
0.5·10^3
0
H.E. Stanley
A.-L. Barabási
P. Erdős
0
200
400
600
t


Σ_j k_j
400 000
300 000
200 000
100 000
0
0
50
100
150
200
250
300
350
n

Conclusion:

Angela Bracco and Adam Maj's

Scientific Collaboration Networks

contain a sizeable component belonging to

$\gamma = 2$ (scale free) Universality Class

Complex Systems Theory Department of IFJ PAN

wishes them that their k_{tot} keeps increasing linearly

for many decades to come !