Ciência das redes e suas aplicações

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Indiana University

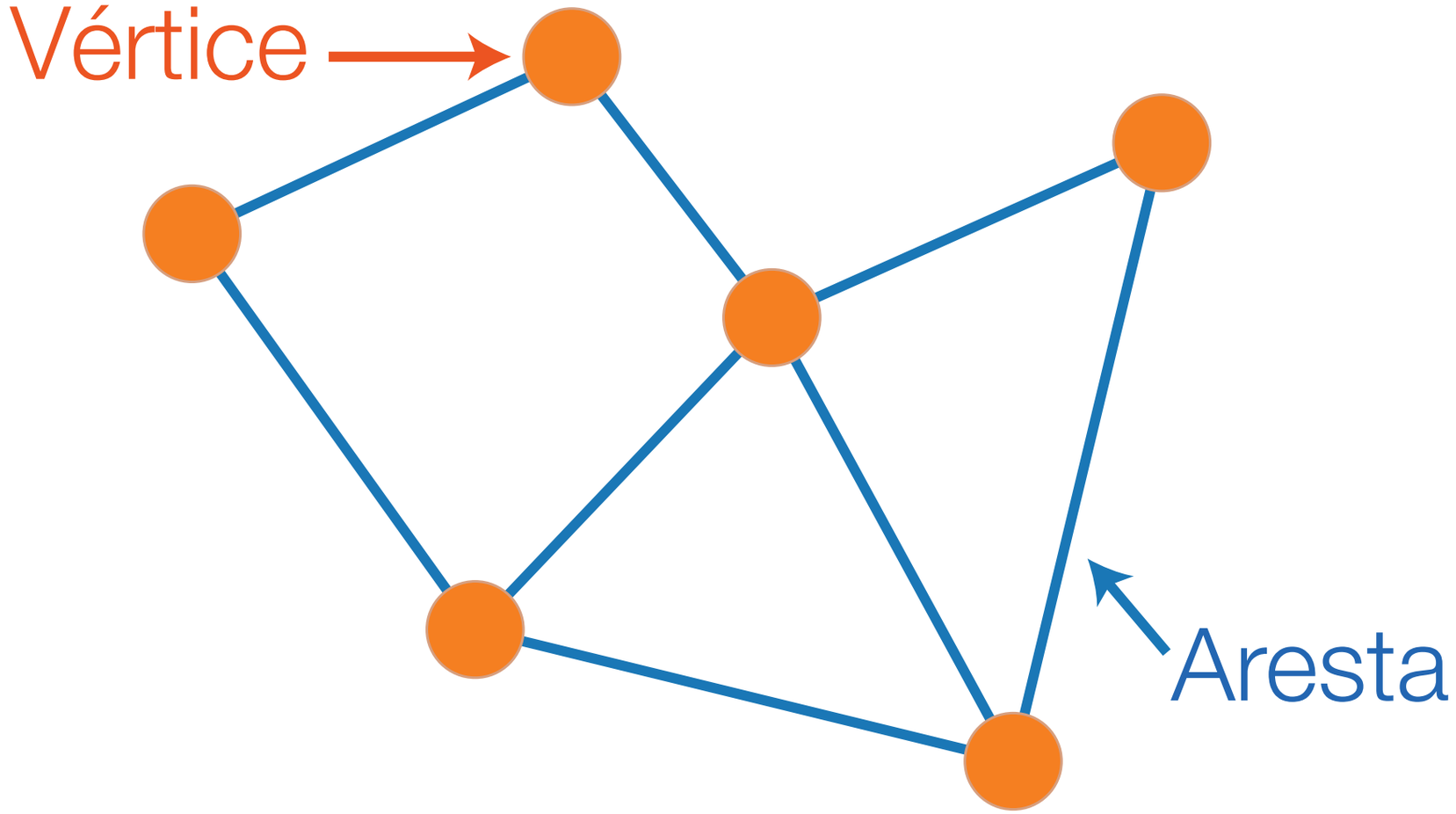
Network Science Institute

(IUNI)

Resumo

- Redes Complexas
  - Grafos
  - Exemplos
  - Propriedades
  - Visualização de redes
- Aplicações
  - Caracterização de cidades
  - Modelo de crises em redes
  - Análise de textos
  - Ciência da ciência
  - Redes Sociais
  - Modelos de epidemia
- Links

Grafos e redes complexas



Vértices podem representar

pesquisadores

pessoas

proteínas

partículas

Arestas podem representar

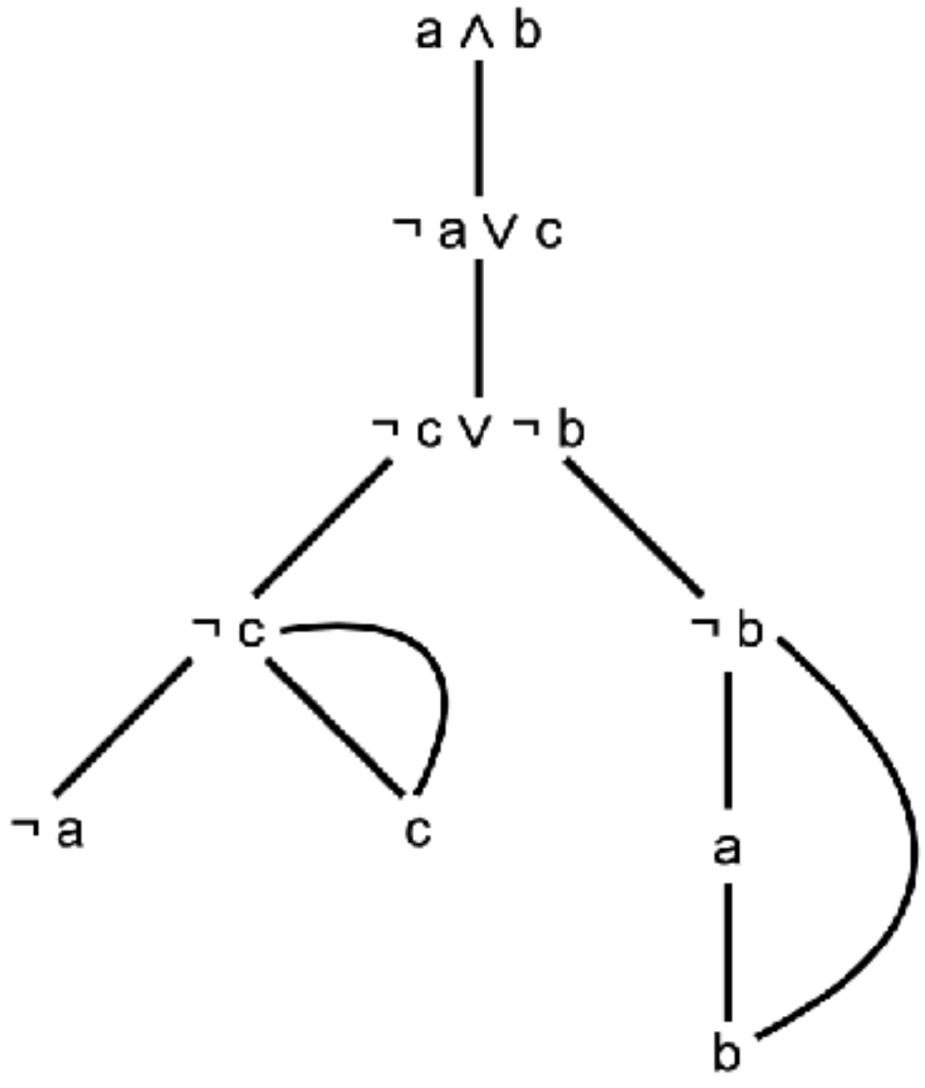
colaboração acadêmica

relações de amizade

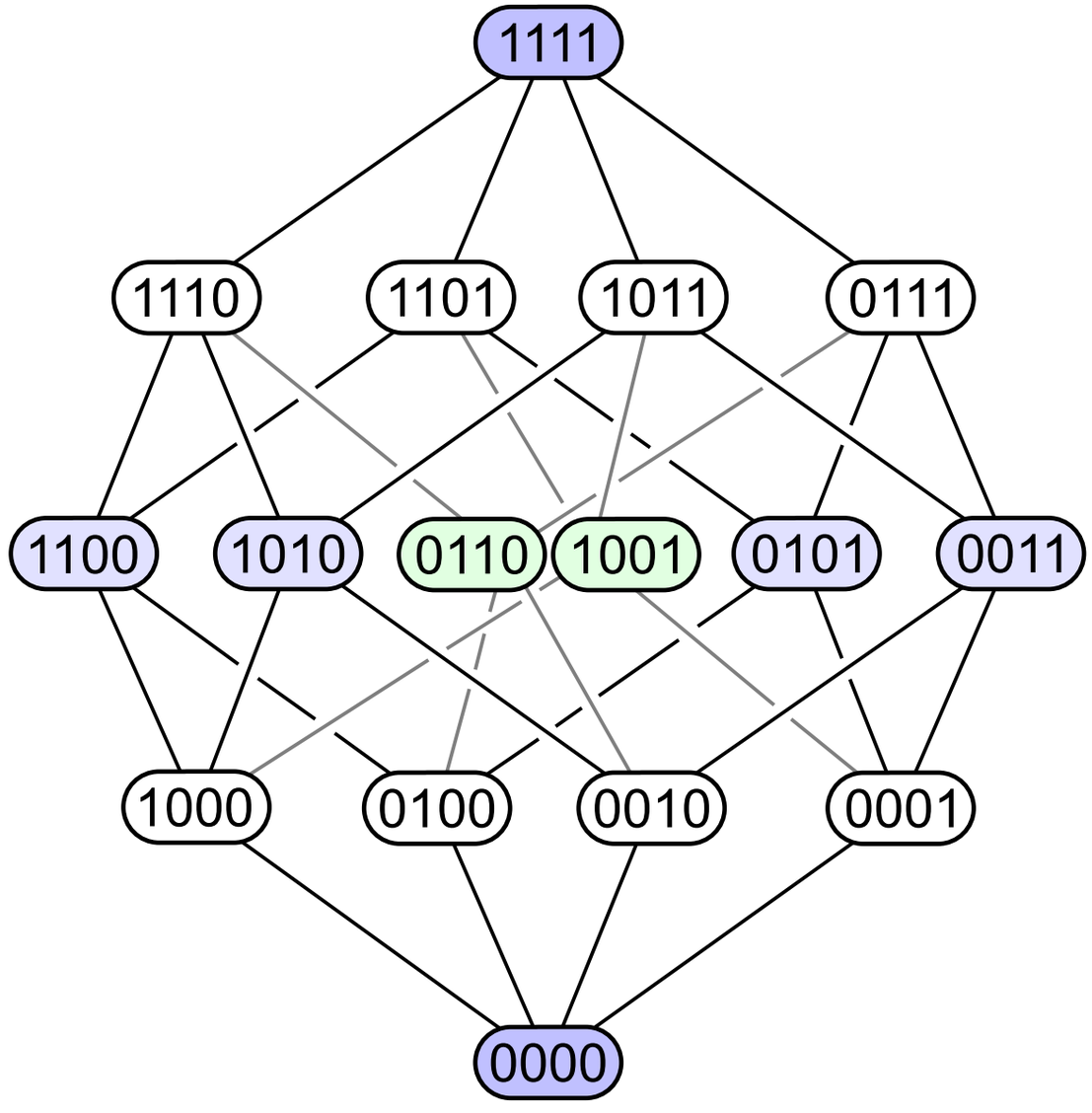
semelhança funcional

interações

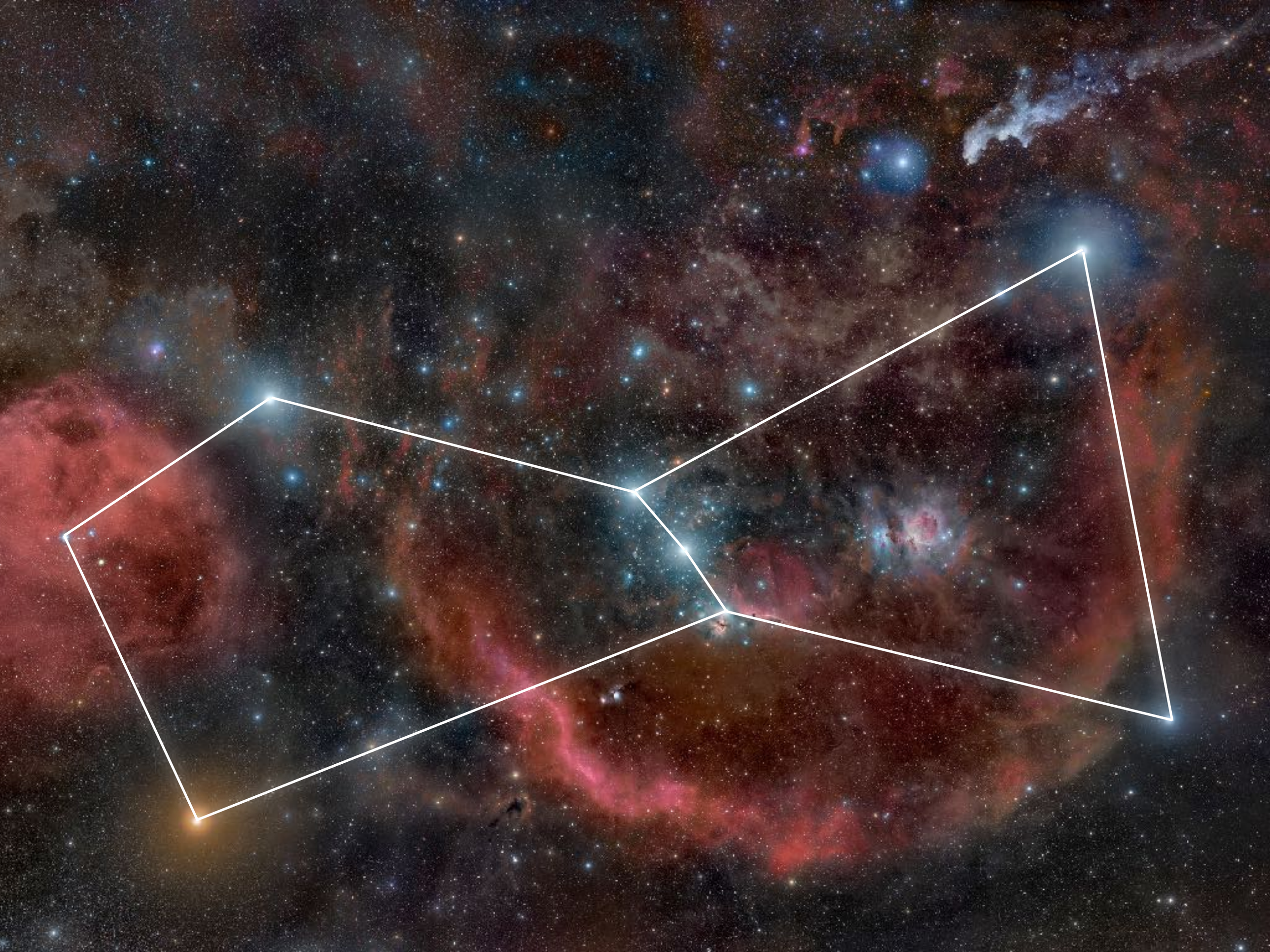
Grafos e redes complexas

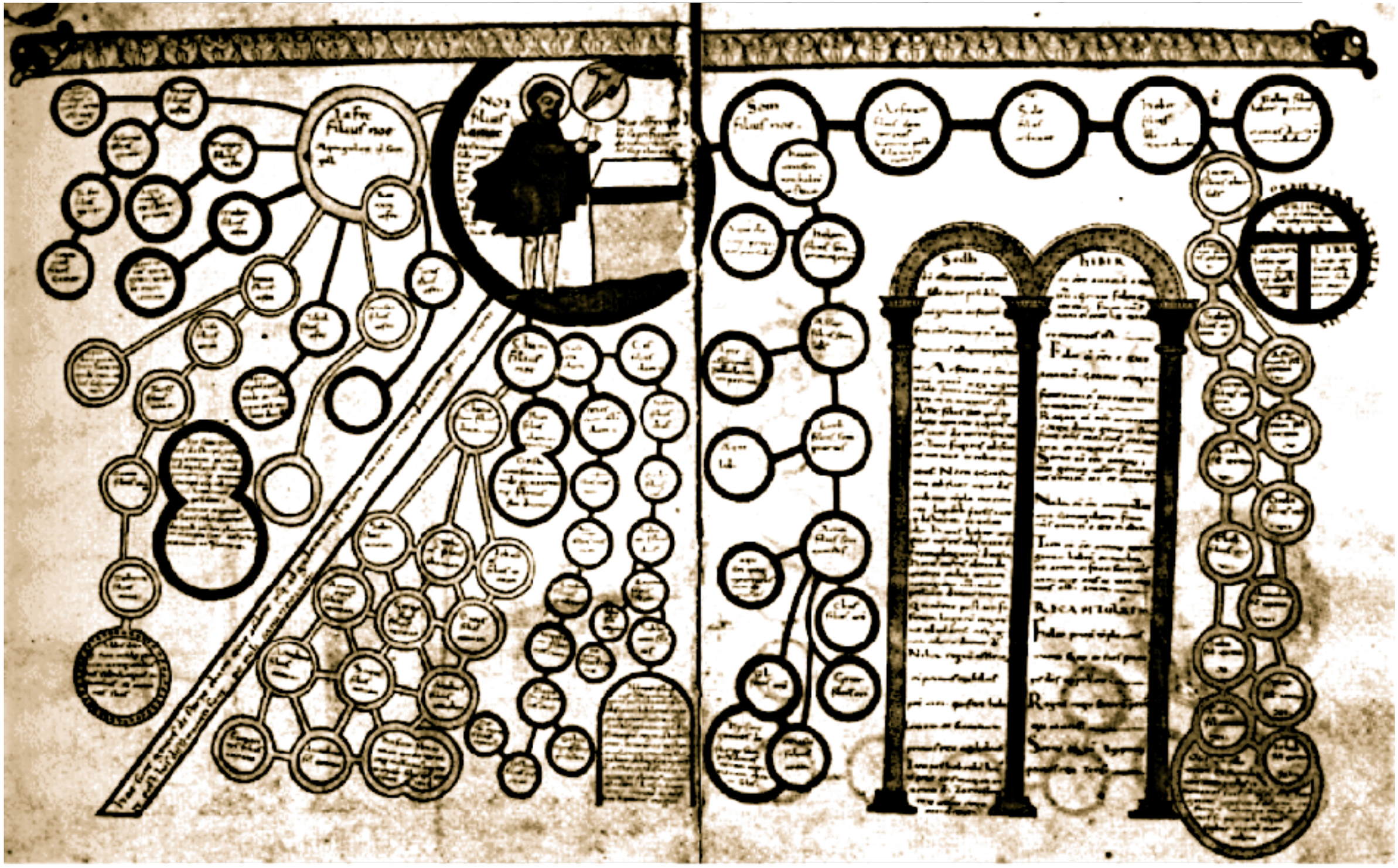


Matemática



Computação

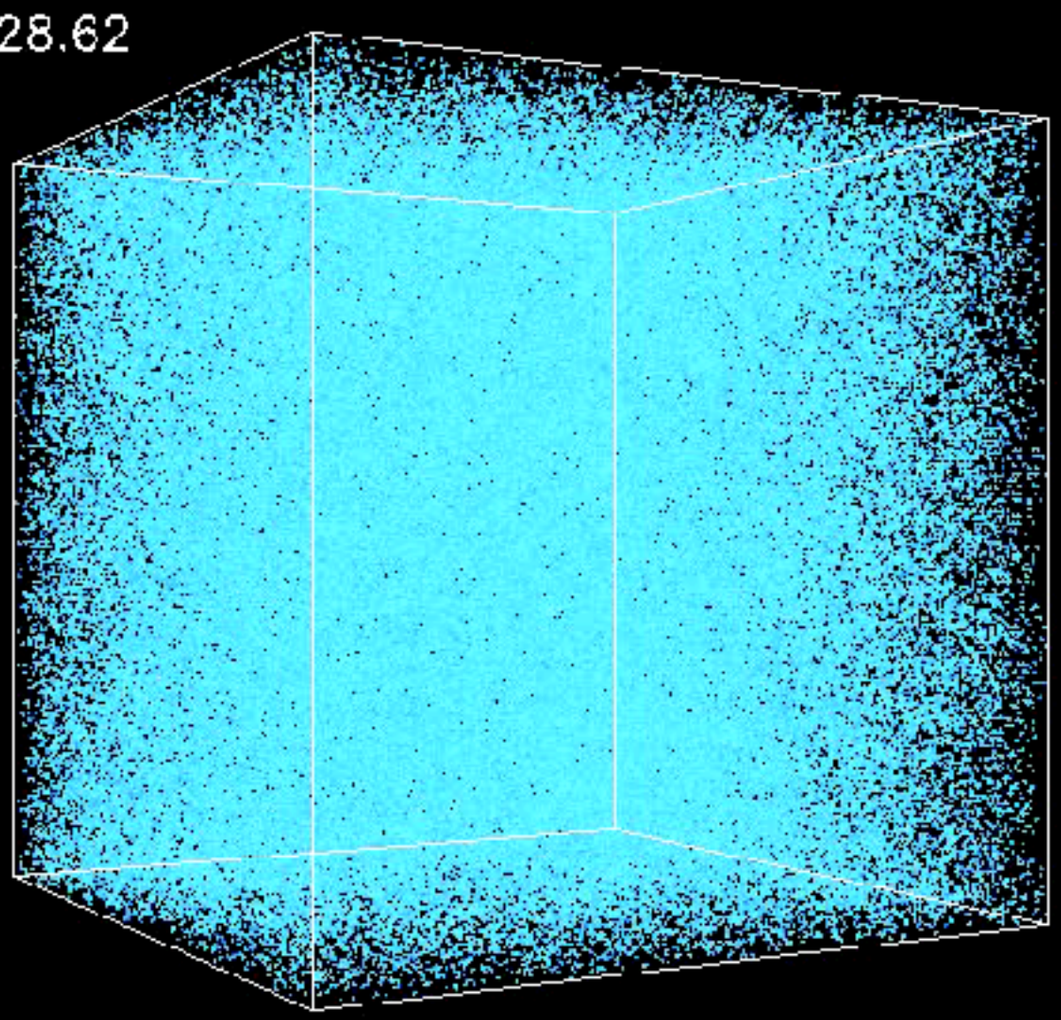




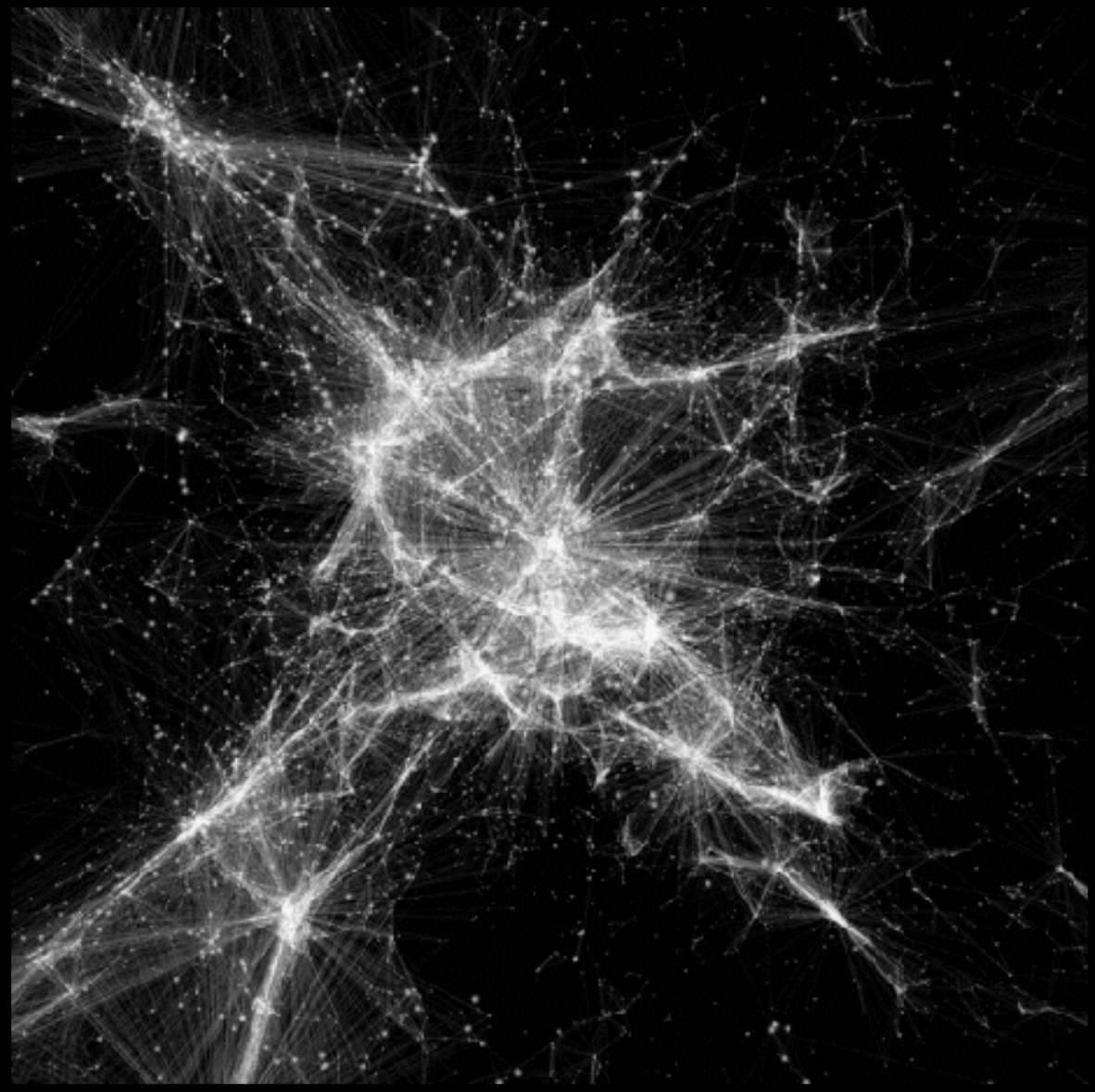
Descendentes de Noé - séc. XI *(domínio público)*

Kabbalah - séc. XVI *(domínio público)*

Exemplos de redes complexas



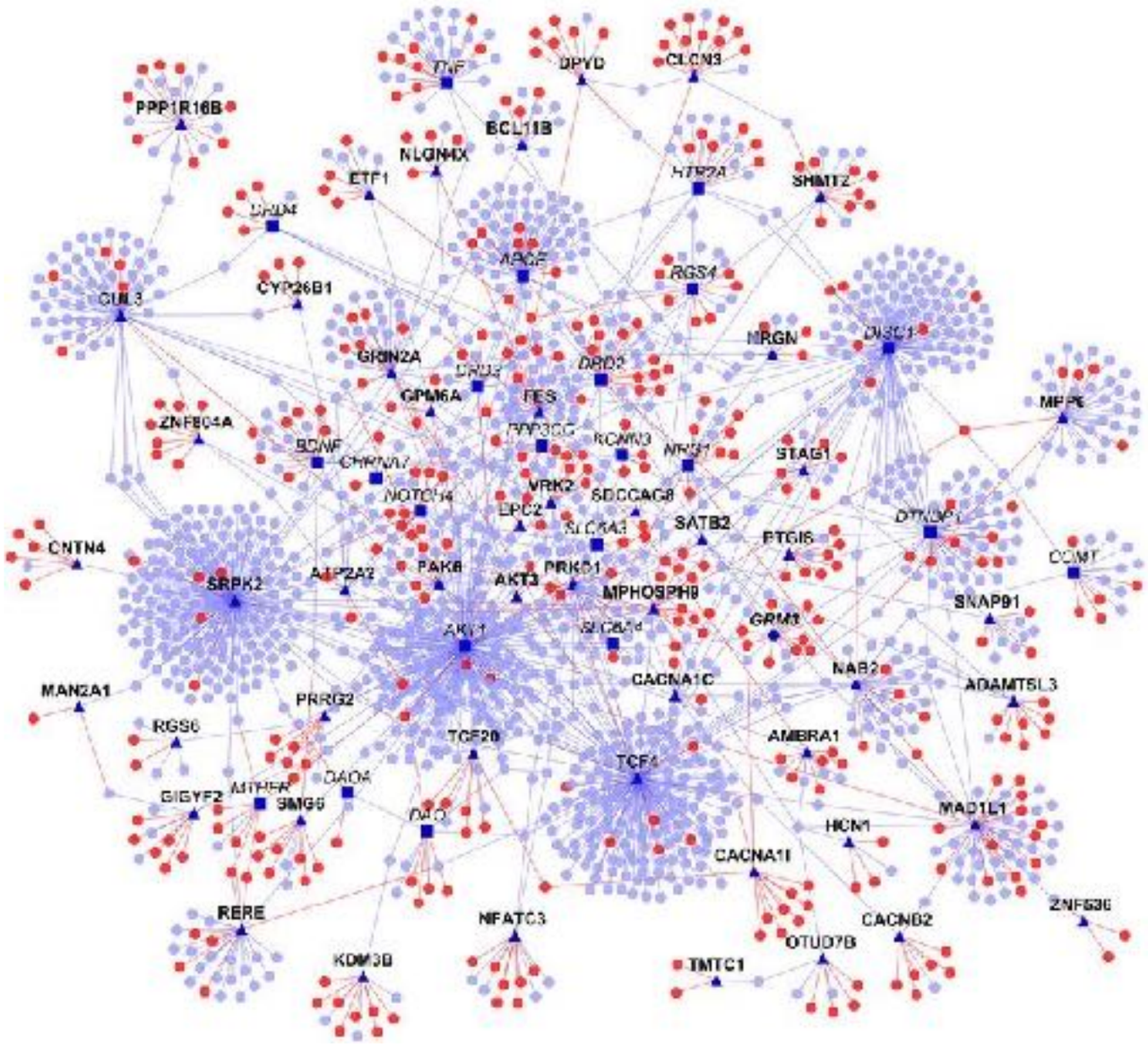
Simulação gerada por:
National Center for Supercomputer Applications
Andrey Kravtsov
(The University of Chicago)
e Anatoly Klypin
(New Mexico State University).



Coutinho, B. C., Hong, S., Albrecht, K., Dey, A., Barabási, A. L., Torrey, P., ... & Hernquist, L. (2016). The Network Behind the Cosmic Web. *arXiv preprint arXiv:1604.03236*.

Exemplos de redes complexas

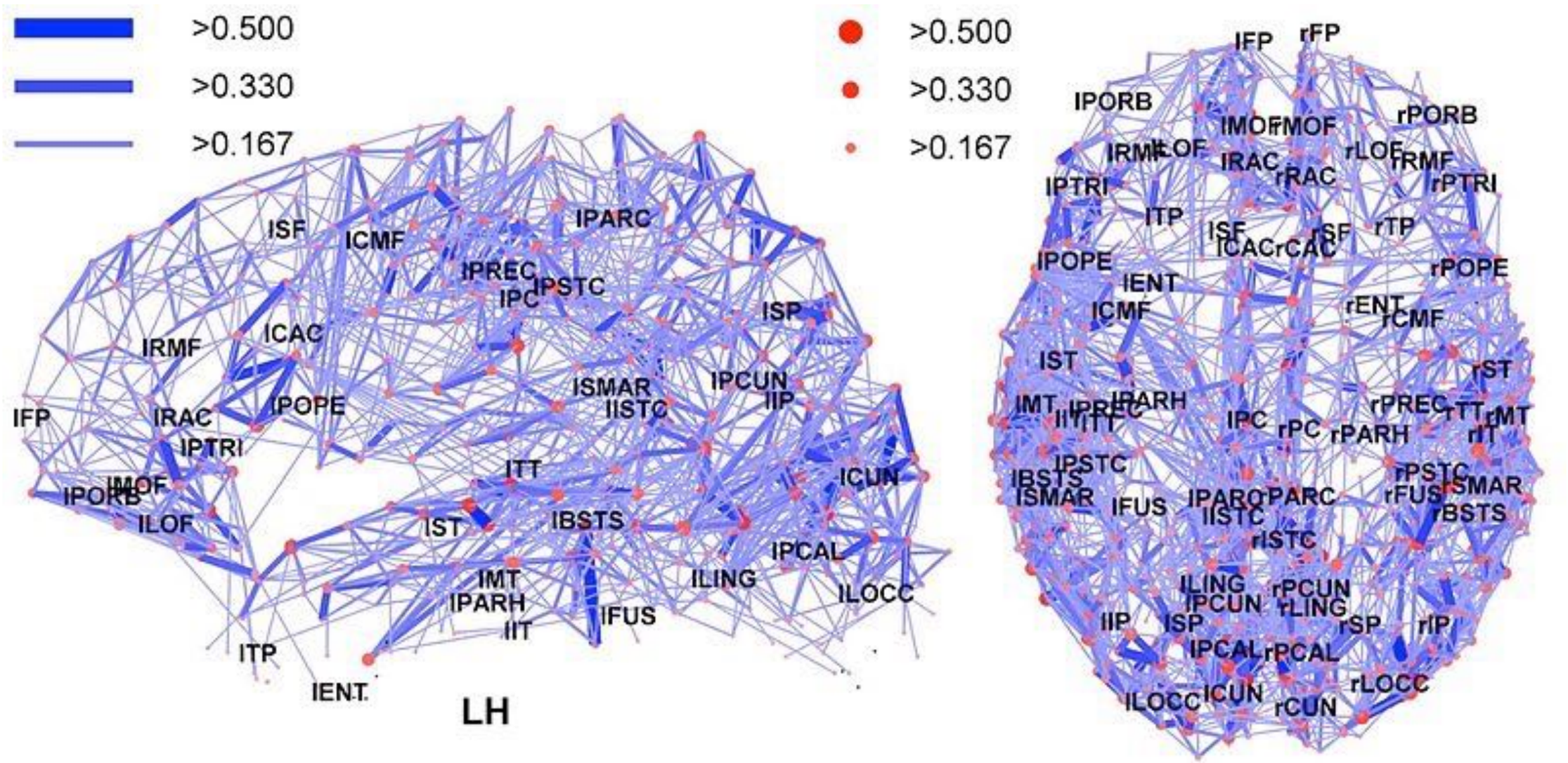
Interação entre proteínas



Ganapathiraju, Madhavi K., et al. "Schizophrenia interactome with 504 novel protein–protein interactions." npj Schizophrenia 2 (2016): 16012.

Exemplos de redes complexas

Relação entre regiões corticais



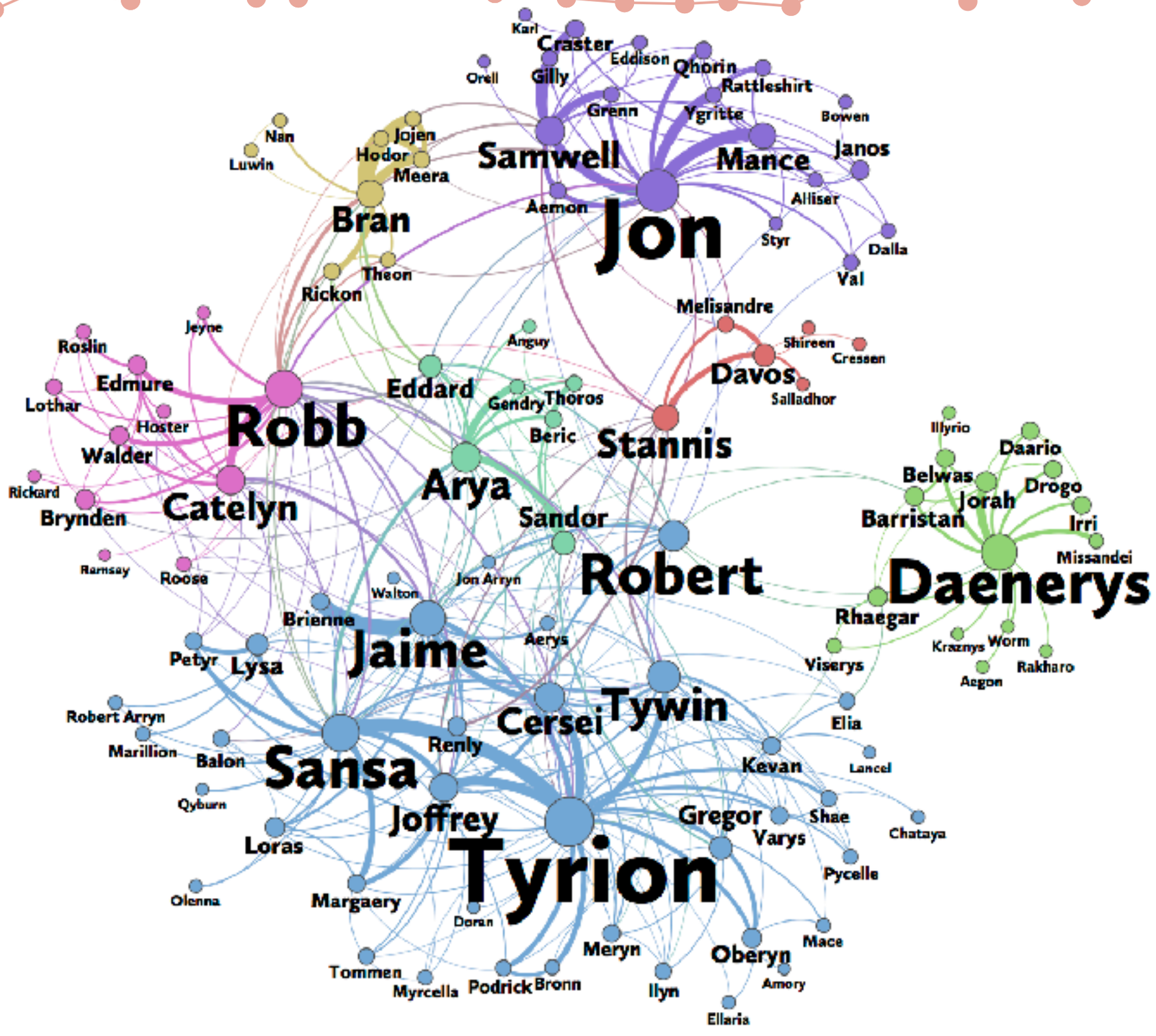
P. Hagmann *et al.* Mapping the structural core of human cerebral cortex. *PLoS Biology* 6(7), 2008.

Exemplos de redes complexas

The Internet

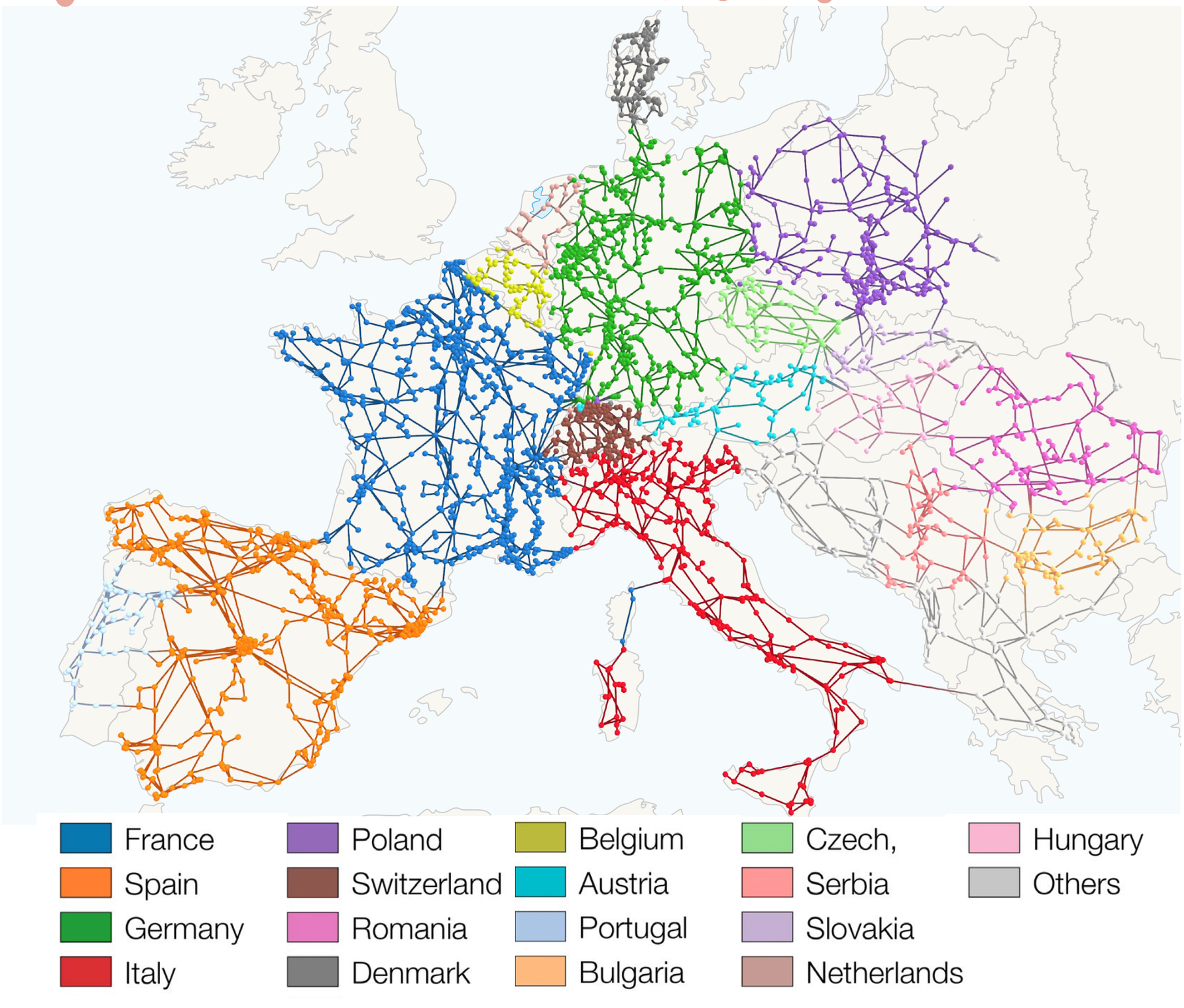
The opte project: http://opte.org/

Exemplos de redes complexas

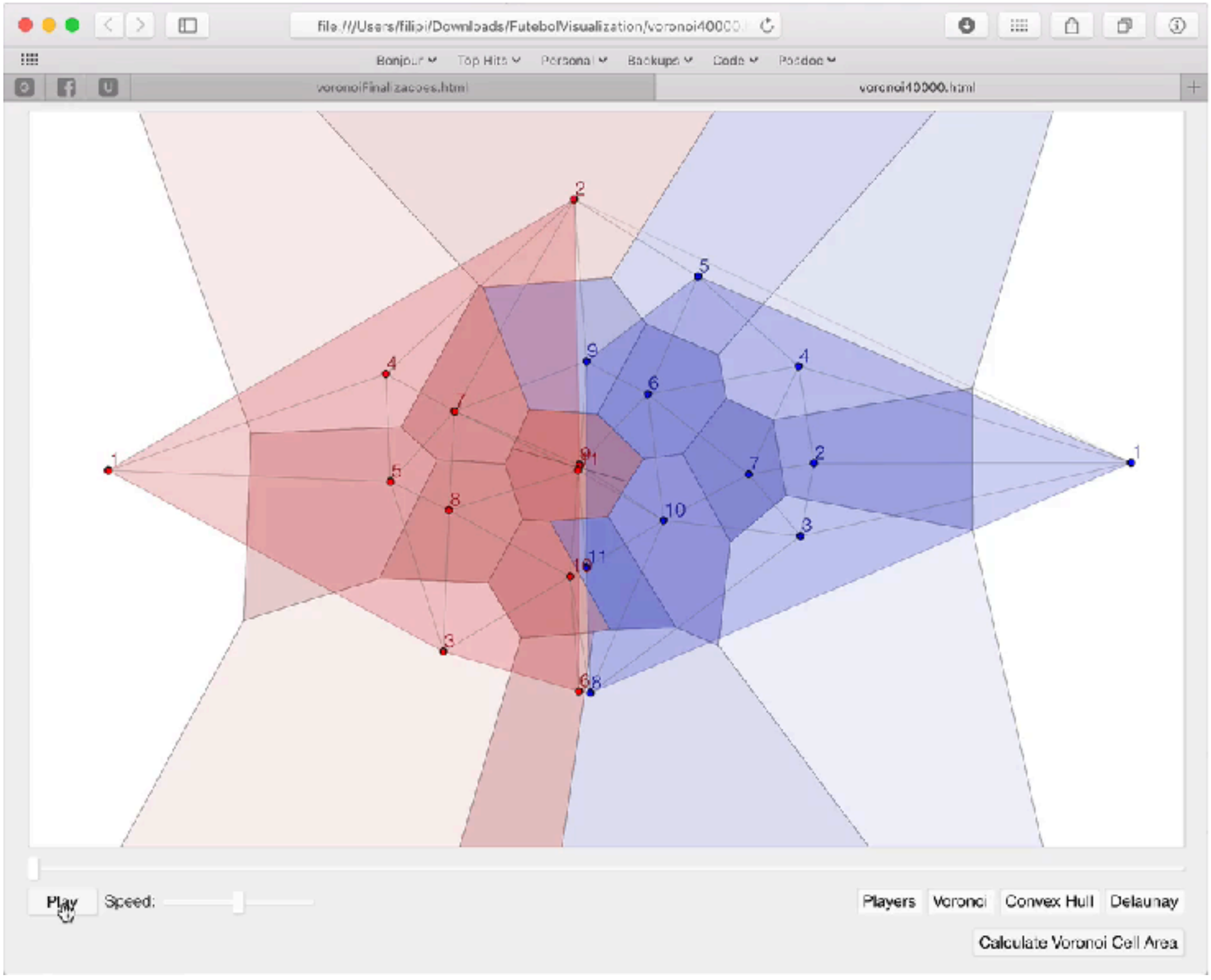


A. Beveridge and J. Shan, "Network of Thrones," Math Horizons Magazine , Vol. 23, No. 4 (2016), pp. 18-22.

Exemplos de redes complexas



Exemplos de redes complexas



internet

www

geologia

saúde

colaboração científica

estradas

biologia molecular

imagens

sociologia

aeroportos

ecologia

transmissão de doenças

música

telefonia celular

mercado financeiro

neurociência

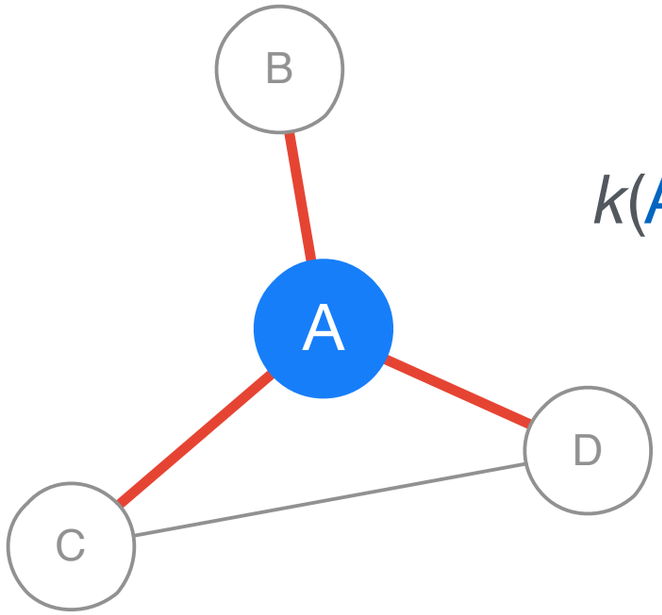
linguística

genética

proteínas

etc., etc., etc...

Propriedades básicas



Grau (ou conectividade)

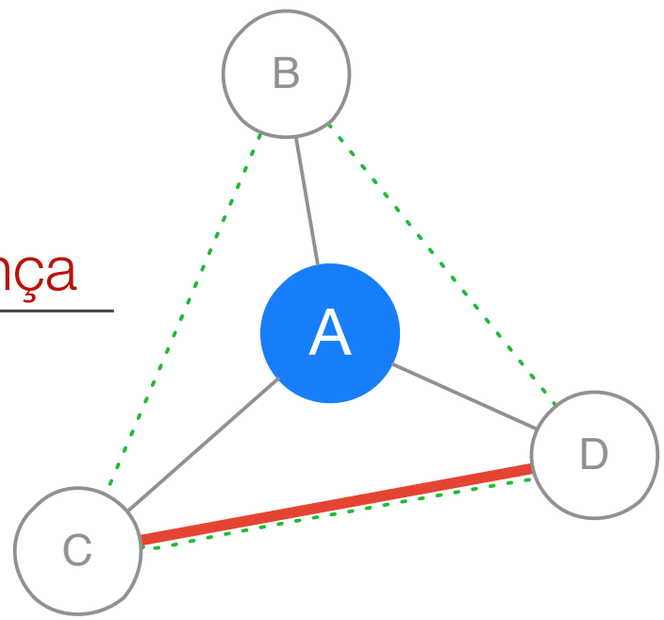
k(A) = *número de conexões do vértice A.*

$$k(A) = 3$$

Coeficiente de Aglomeração

$$Cc(A) = \frac{\text{número de conexões na vizinhança}}{\text{número de trios possíveis}}$$

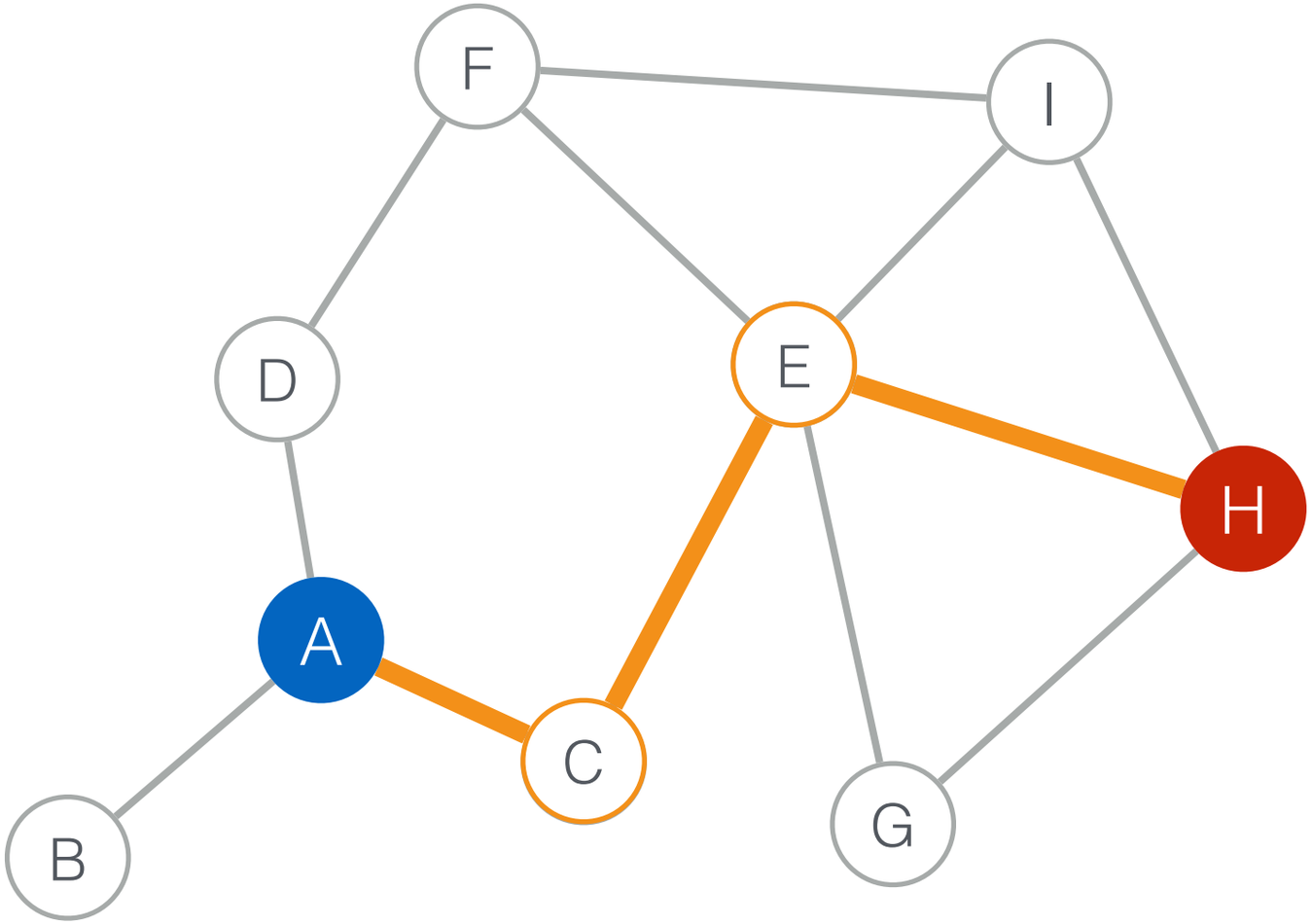
$$Cc(A) = 2\frac{1}{3(3-1)} = \frac{1}{3}$$



Caminhos mínimos ou geodésicas

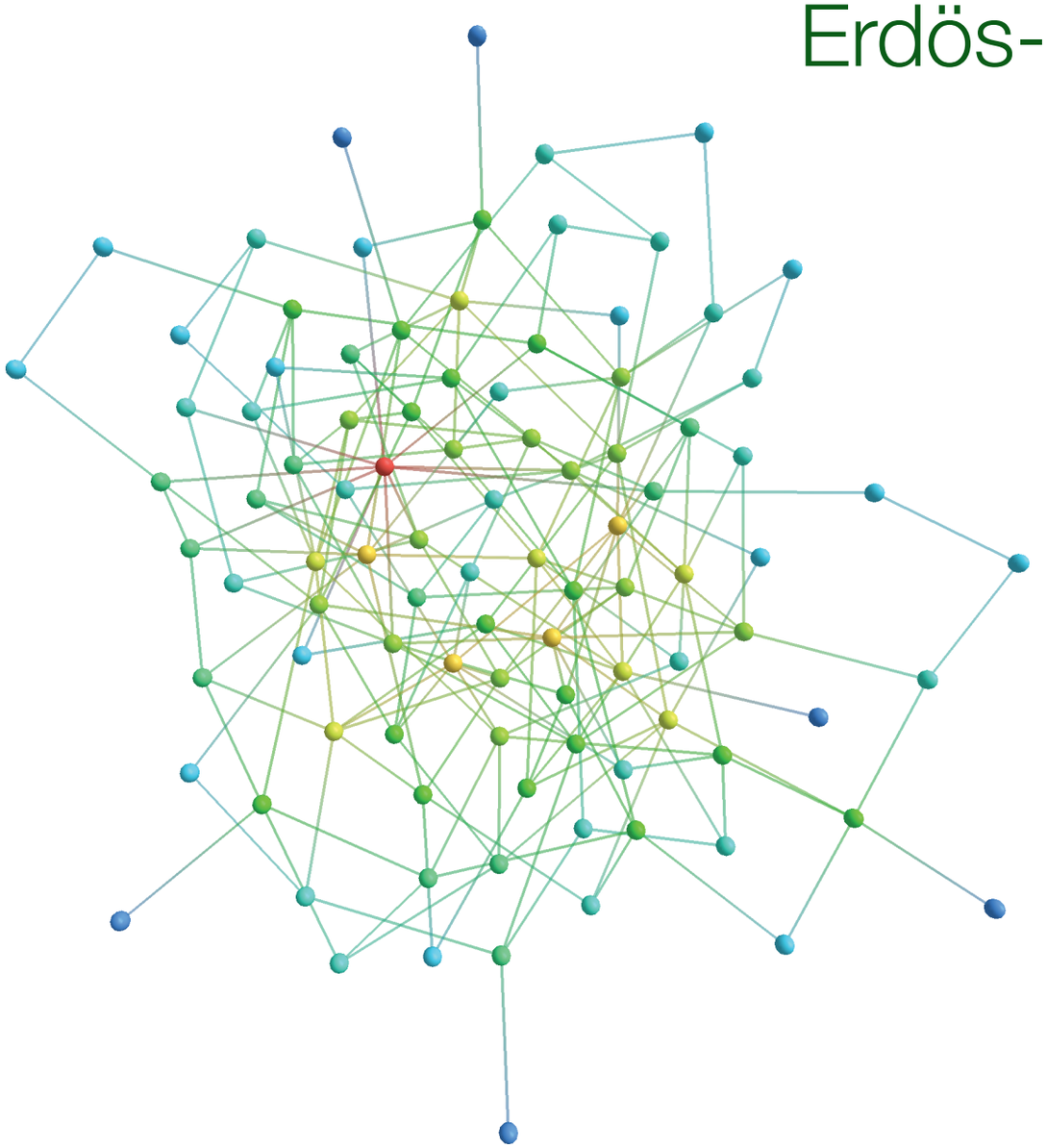
g(A,H) = distância mínima, em arestas, entre dois vértices

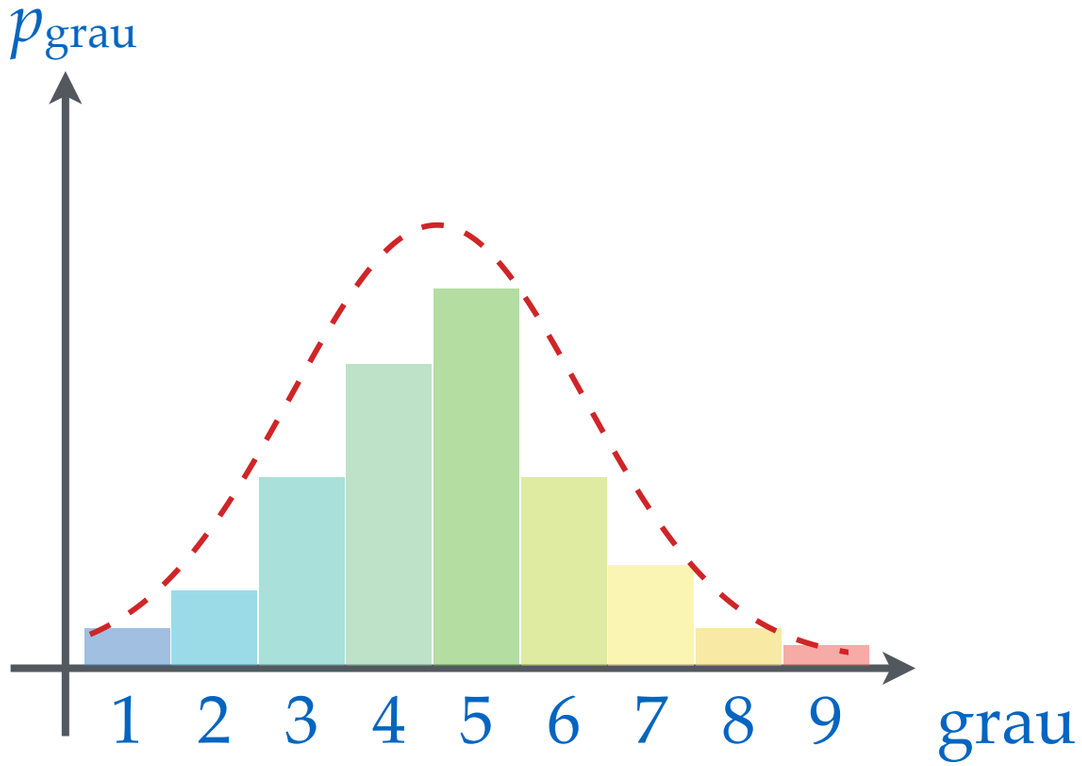
$$g(A, H) = 3$$



Modelo ER

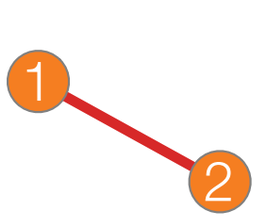
Erdös-Rényi (ER)



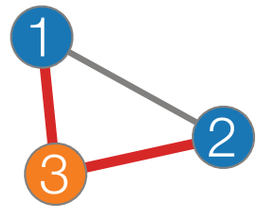


Modelo BA

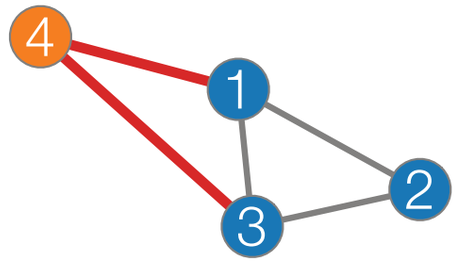
Barabási-Albert (BA)



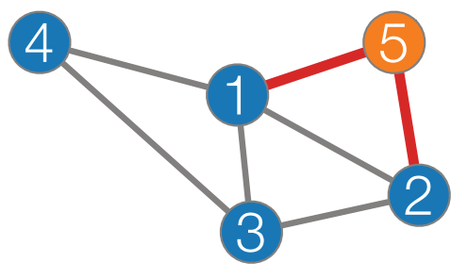
(a) t=0



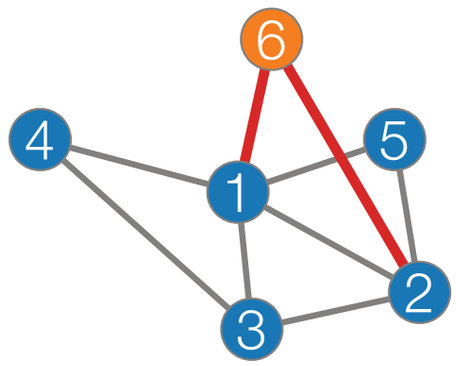
(b) t=1



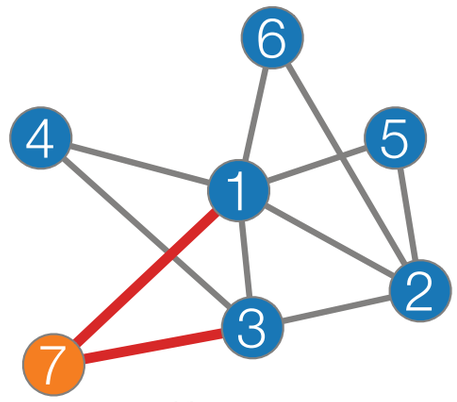
(c) t=2



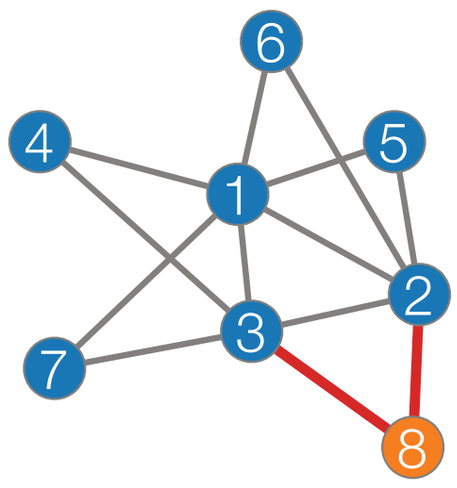
(d) t=3



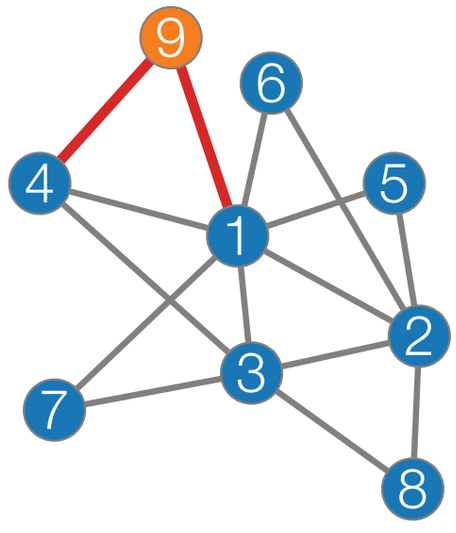
(e) t=4



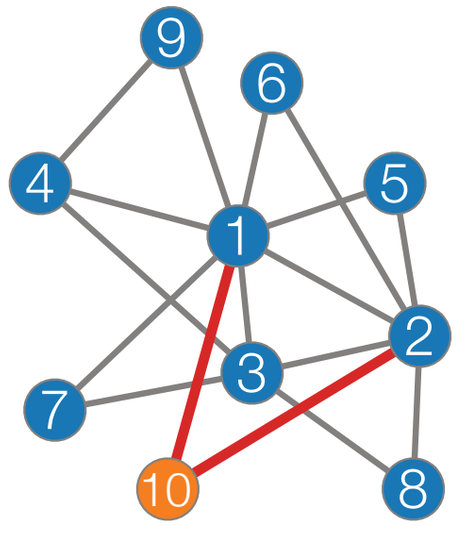
(f) t=5



(g) t=6



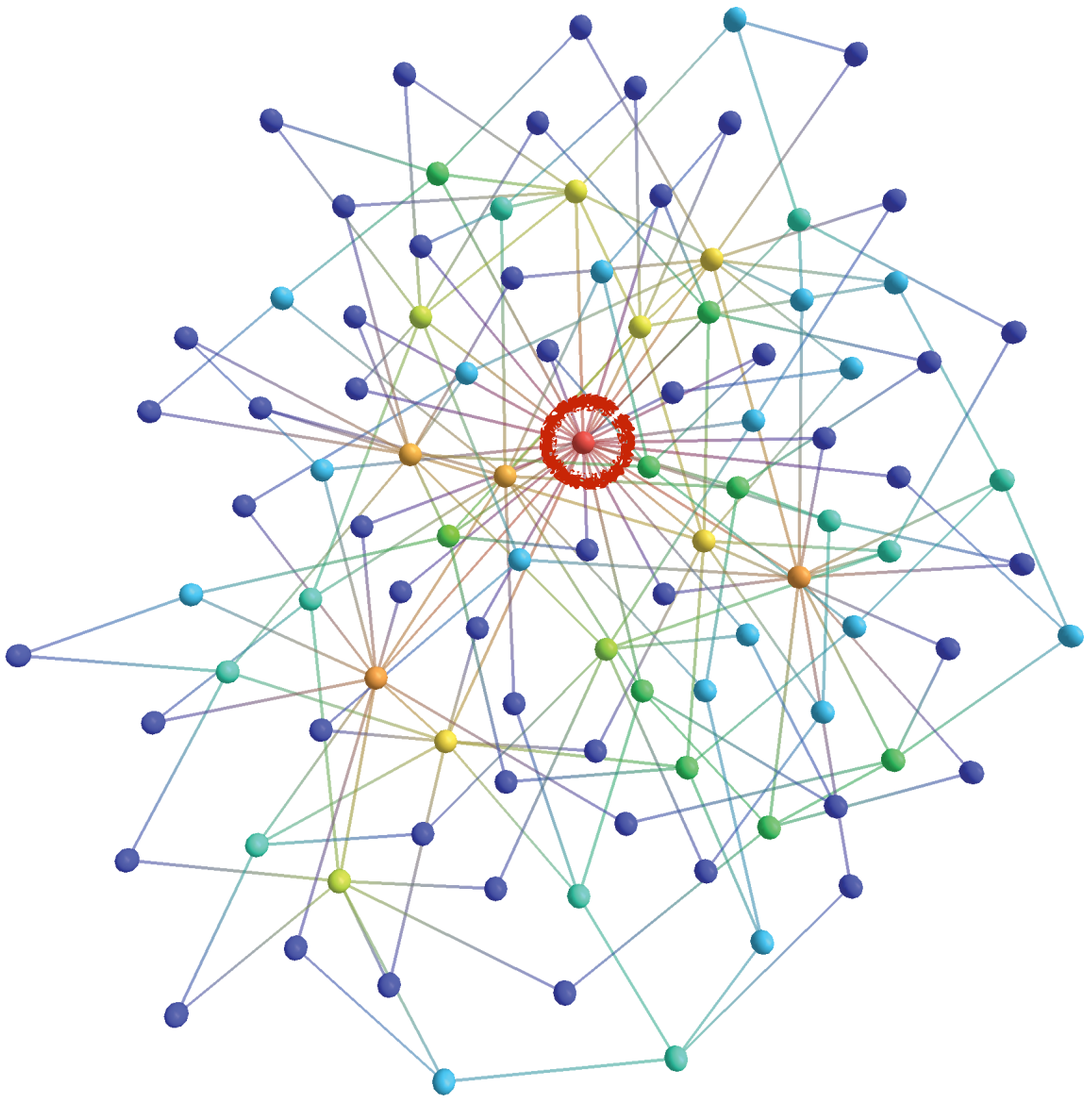
(h) t=7

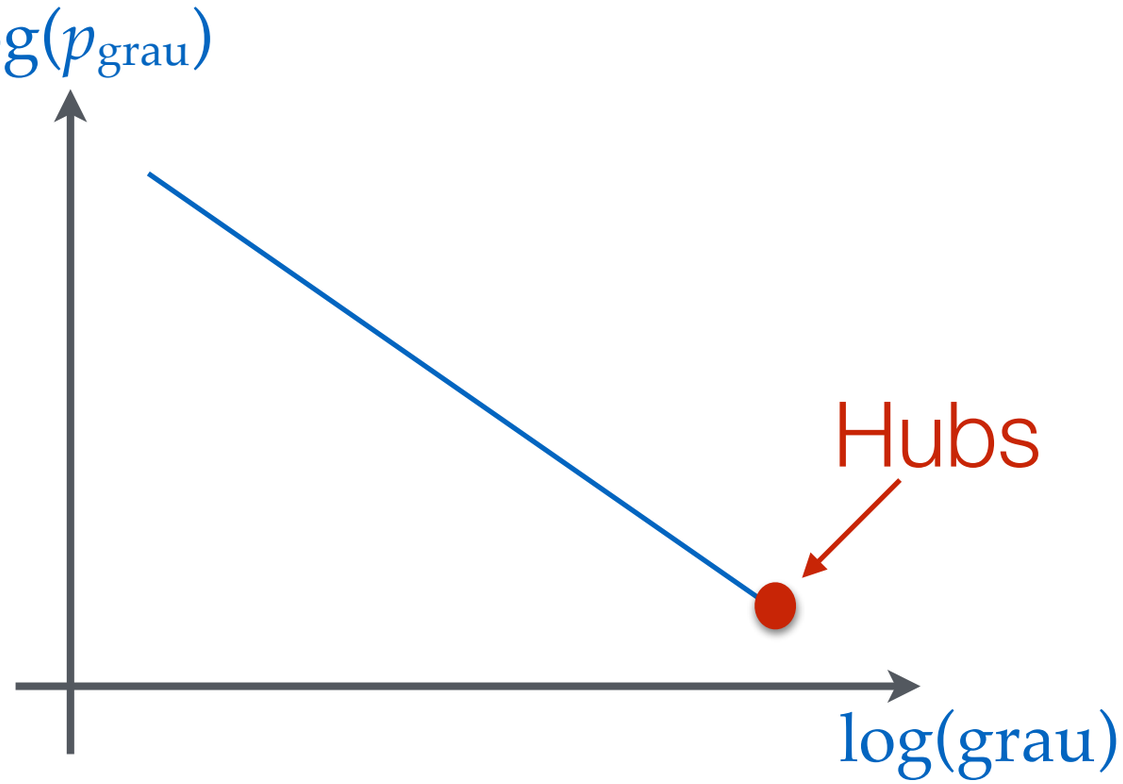


(i) t=8

Modelo BA

Barabási-Albert (BA)





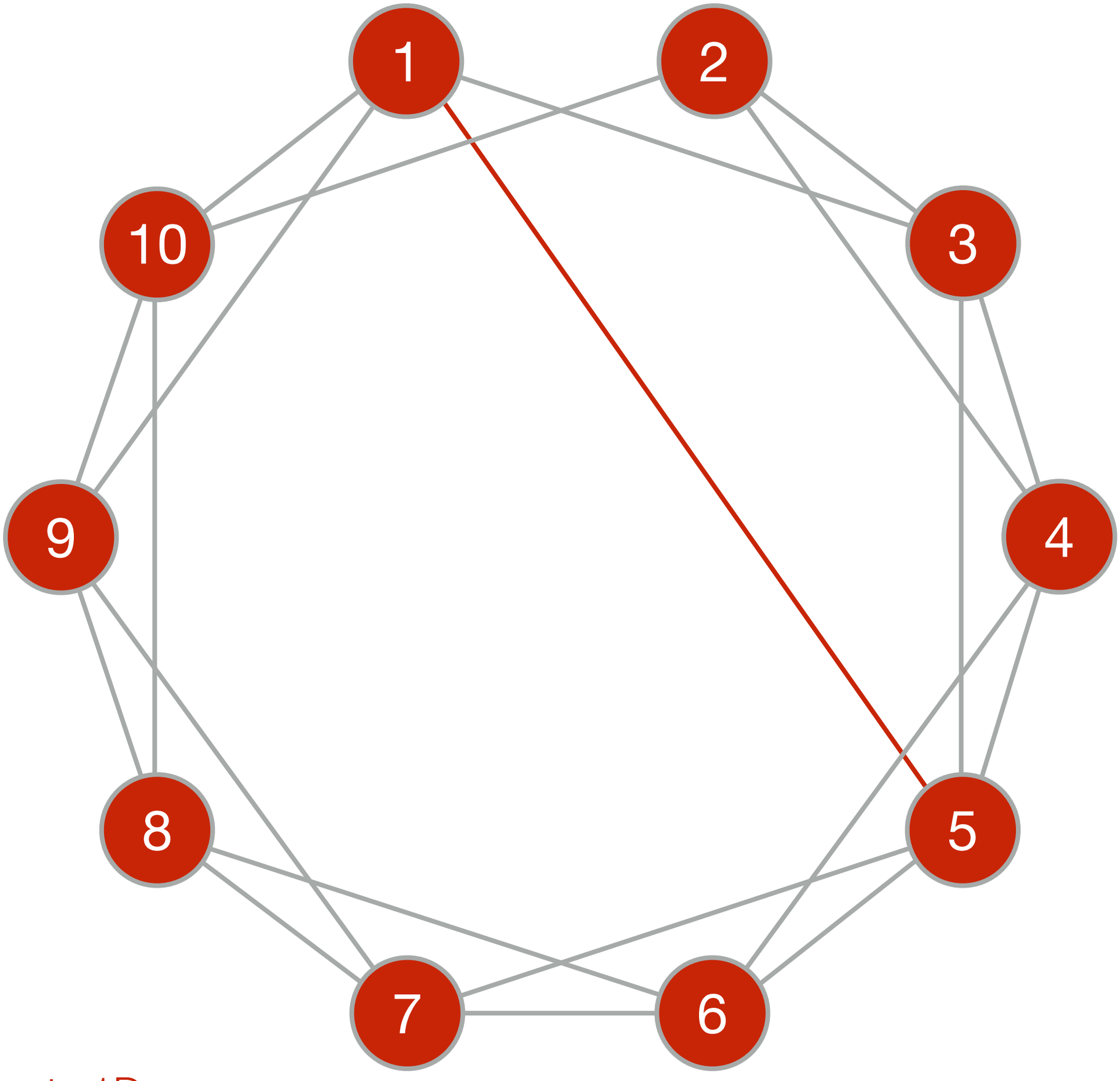
Fenômeno pequeno mundo

Número Erdös

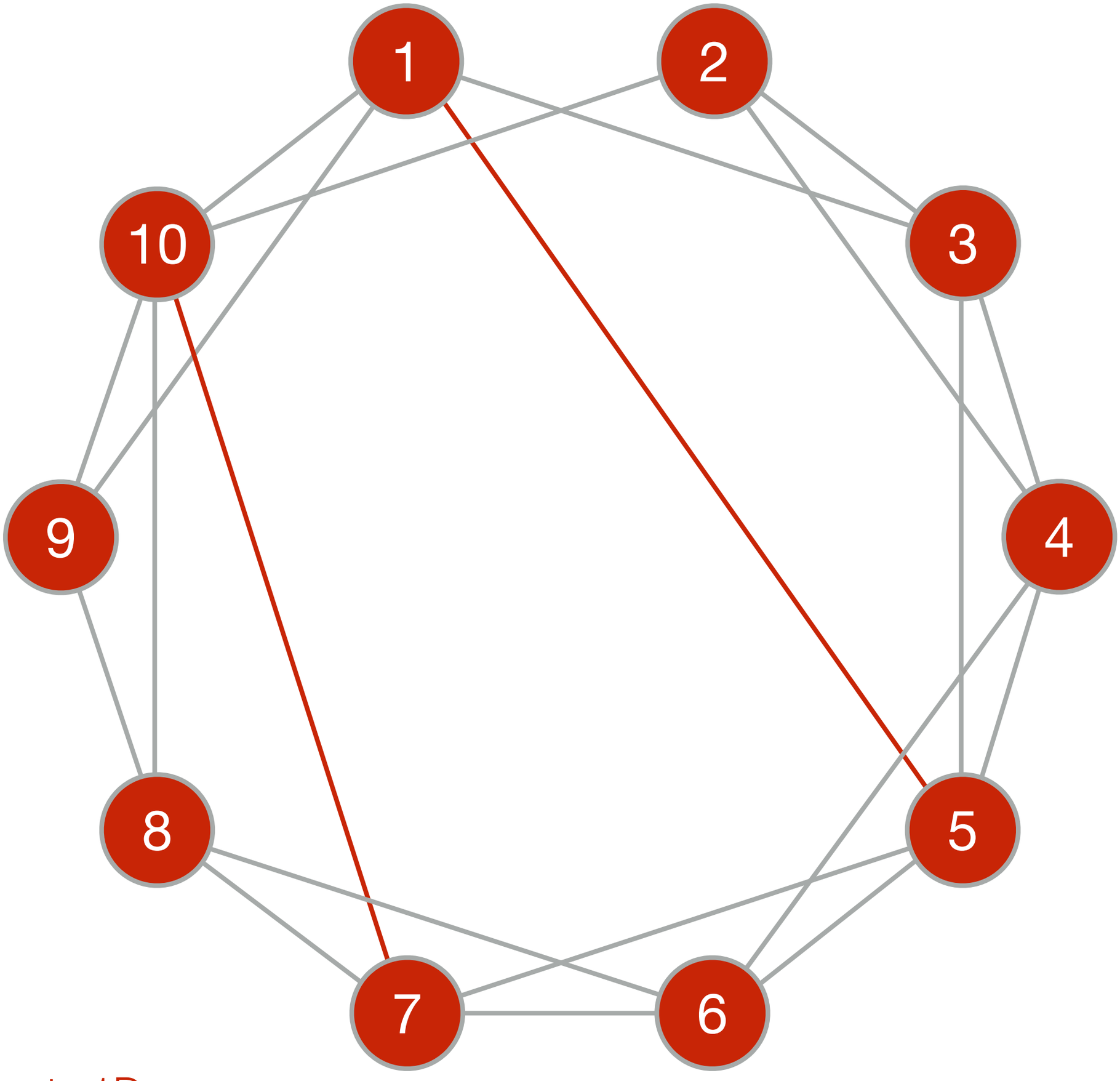
http://oracleofbacon.org/

Número Bacon

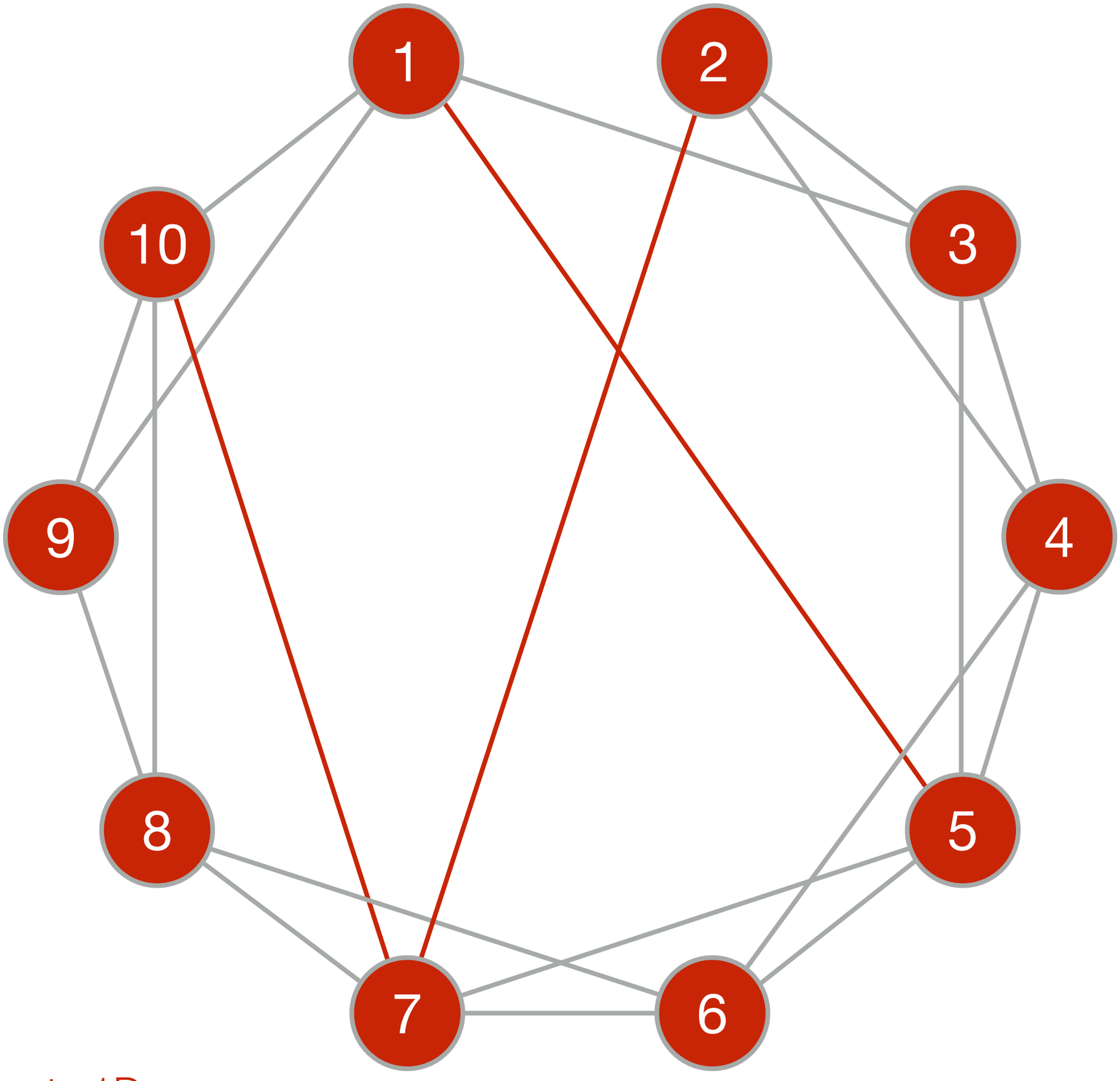
Adaptado de: http://explosm.net/comics/689/



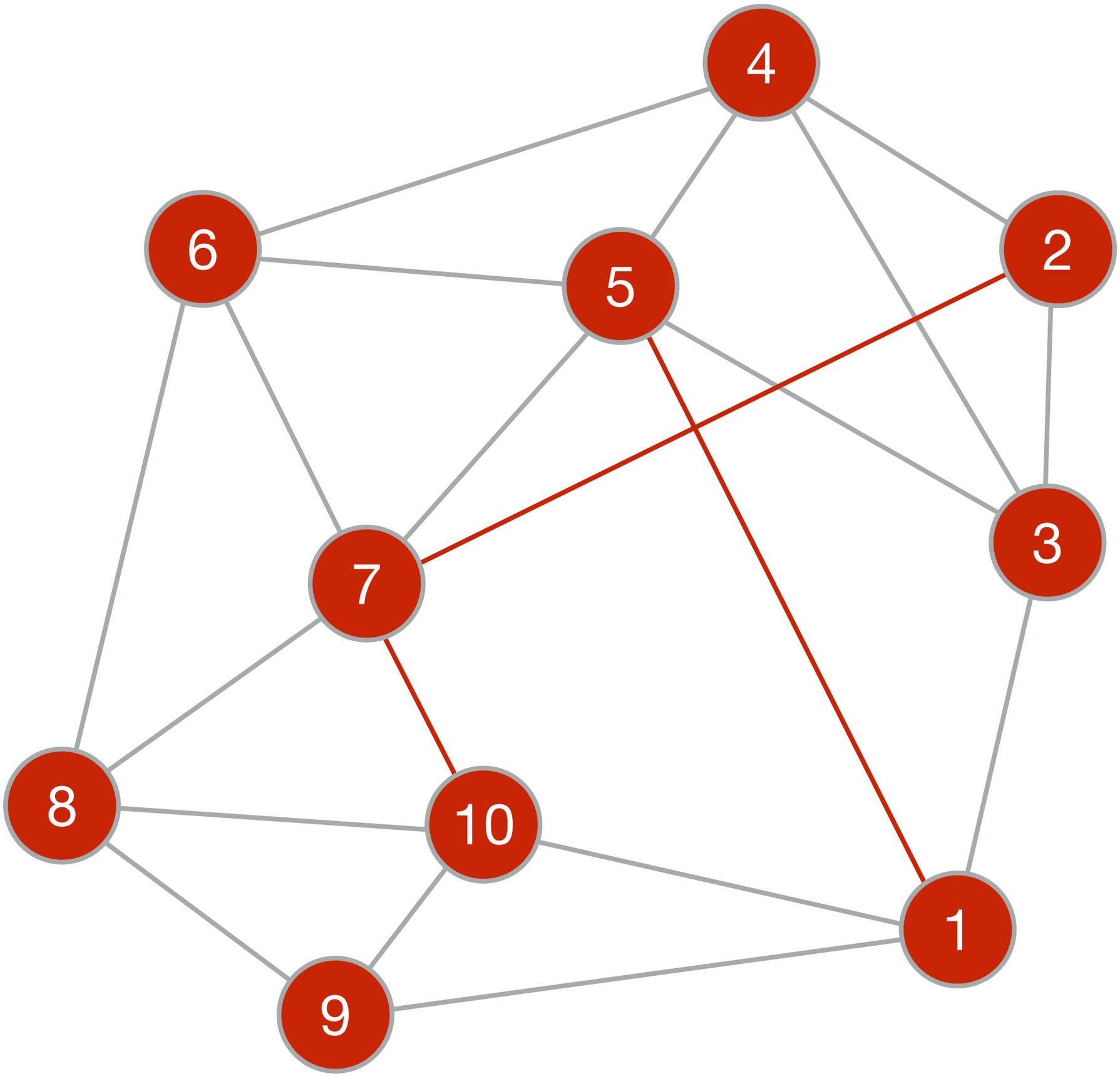
Watts-Strogatz 1D



Watts-Strogatz 1D

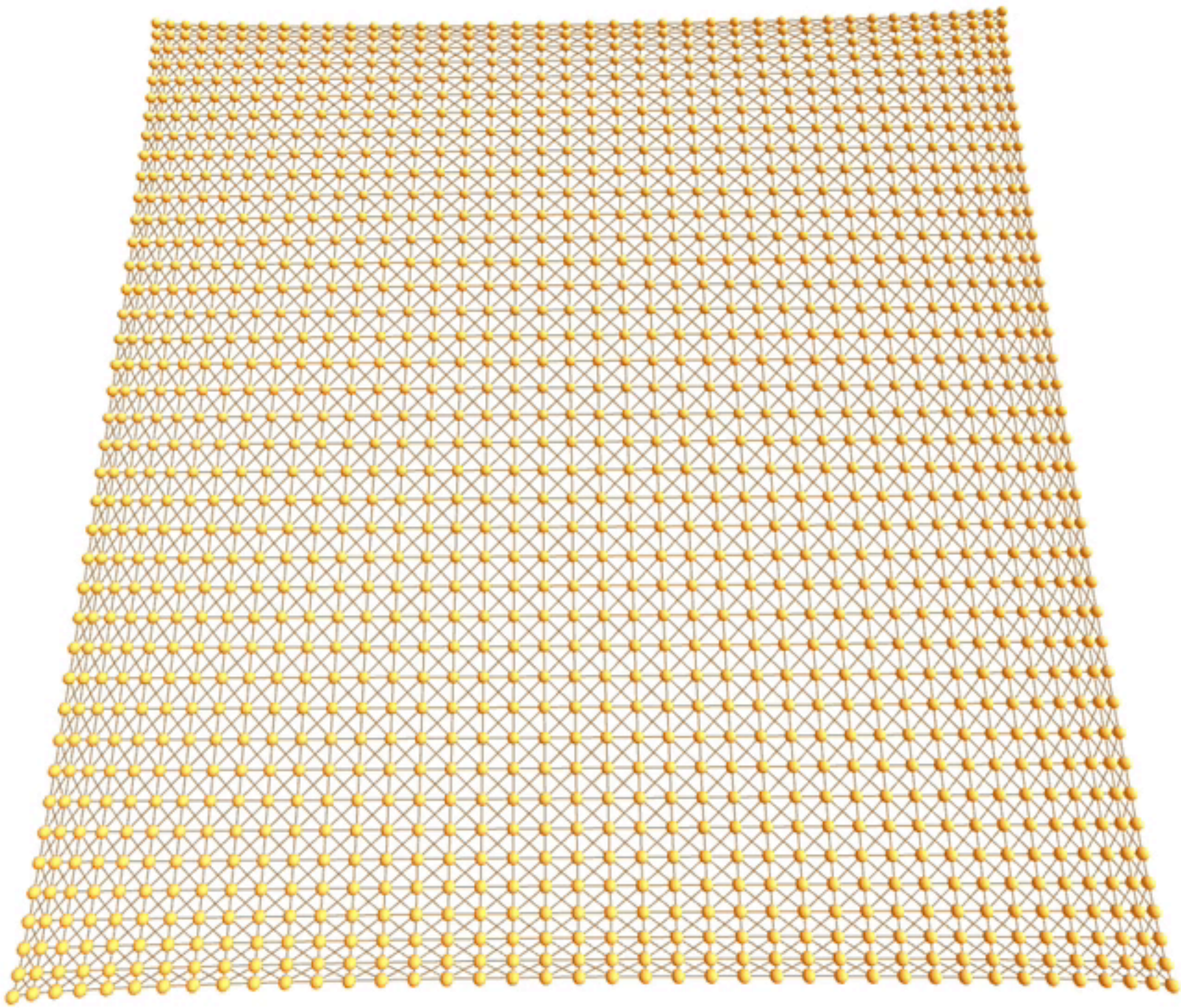


Watts-Strogatz 1D

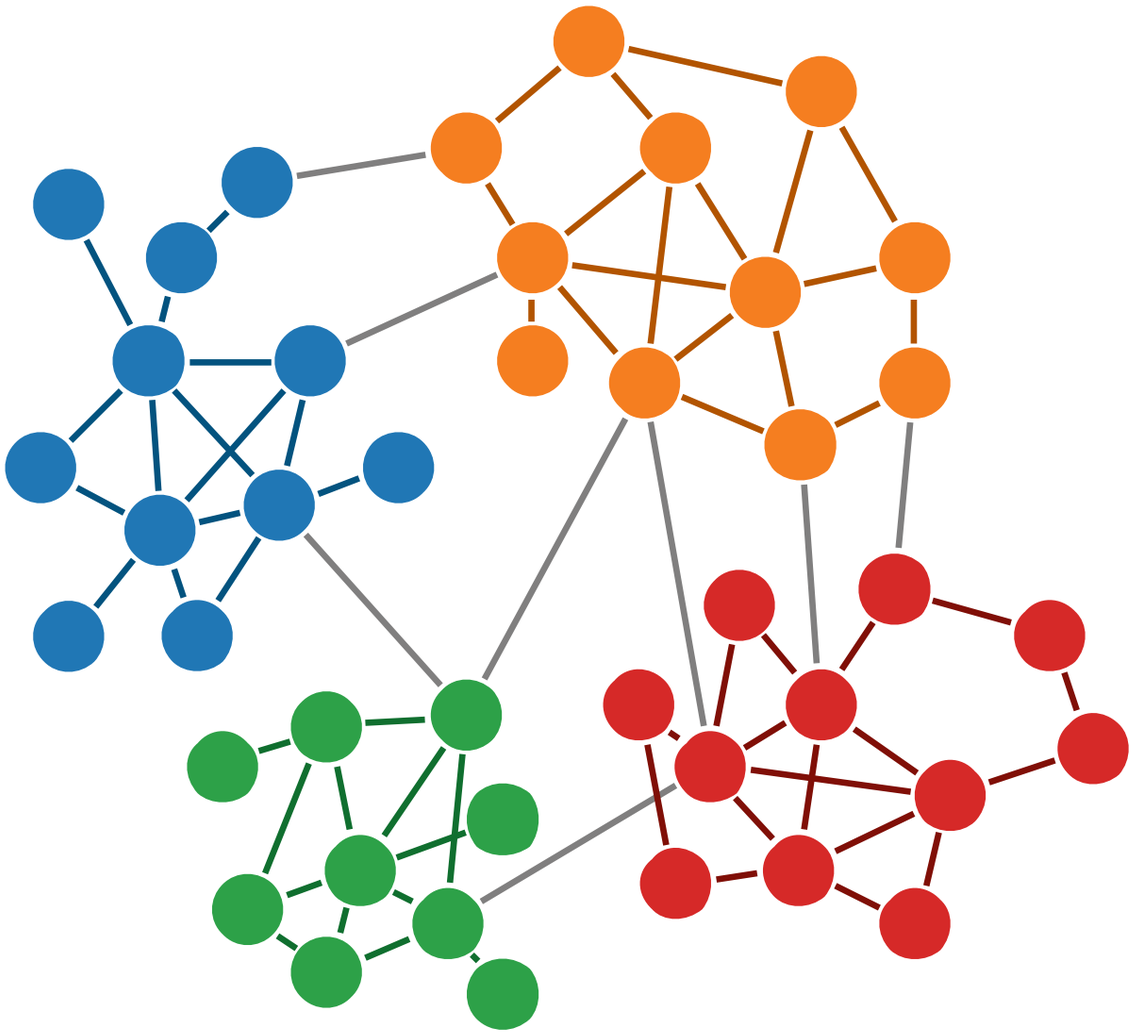


Watts-Strogatz 1D

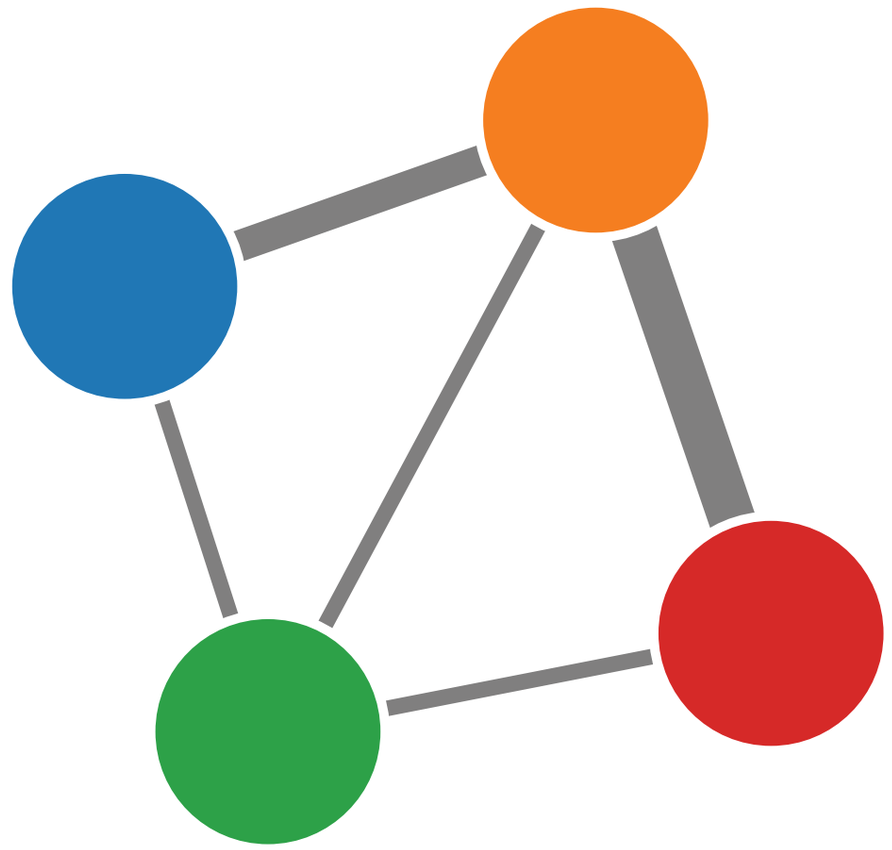
Modelo pequeno mundo Watts-Strogatz



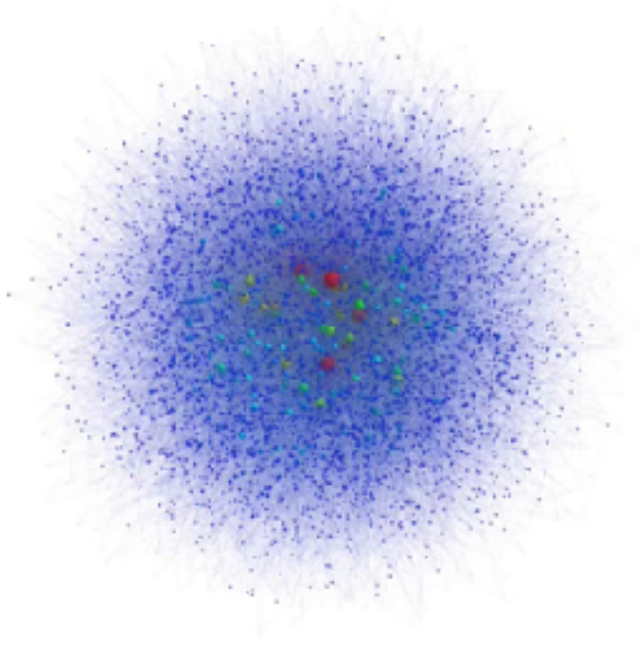
Comunidades

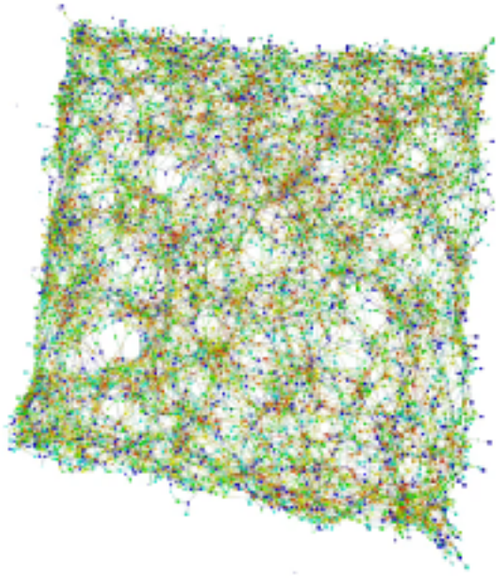


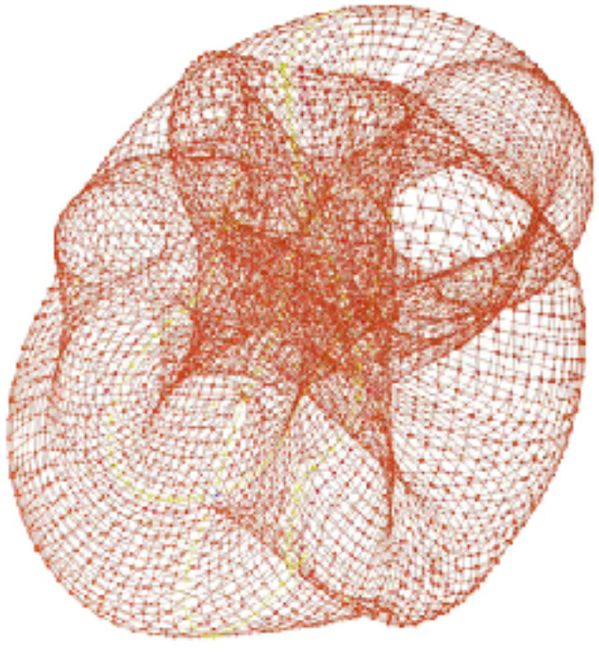
(a) Estrutura de comunidades

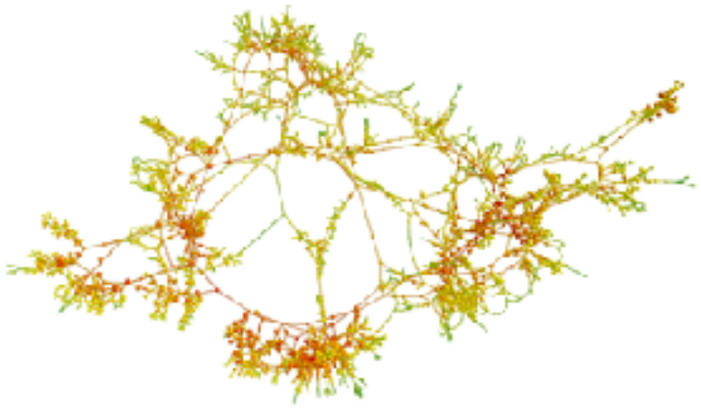


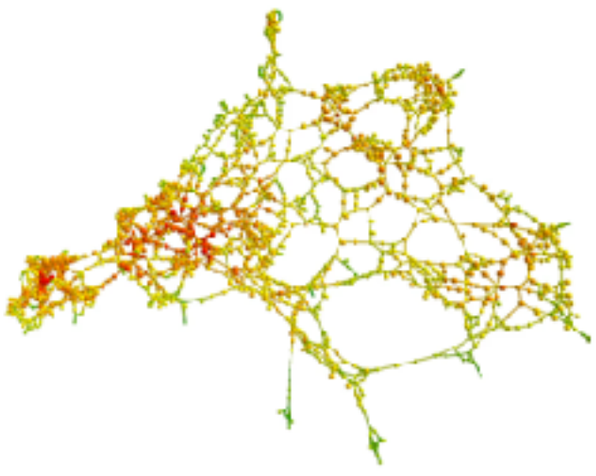
(b) Grafo reduzido de comunidades

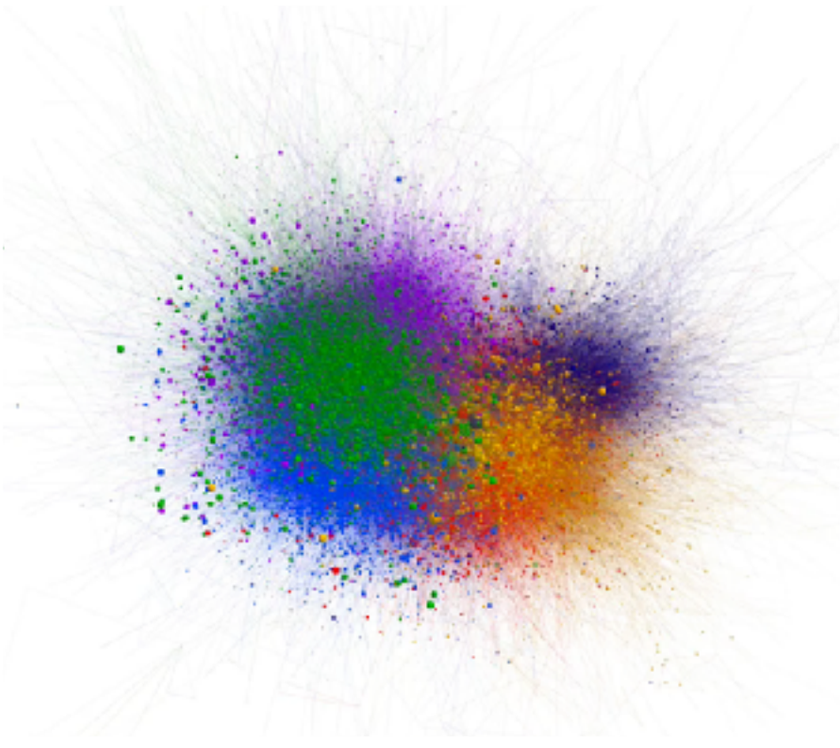




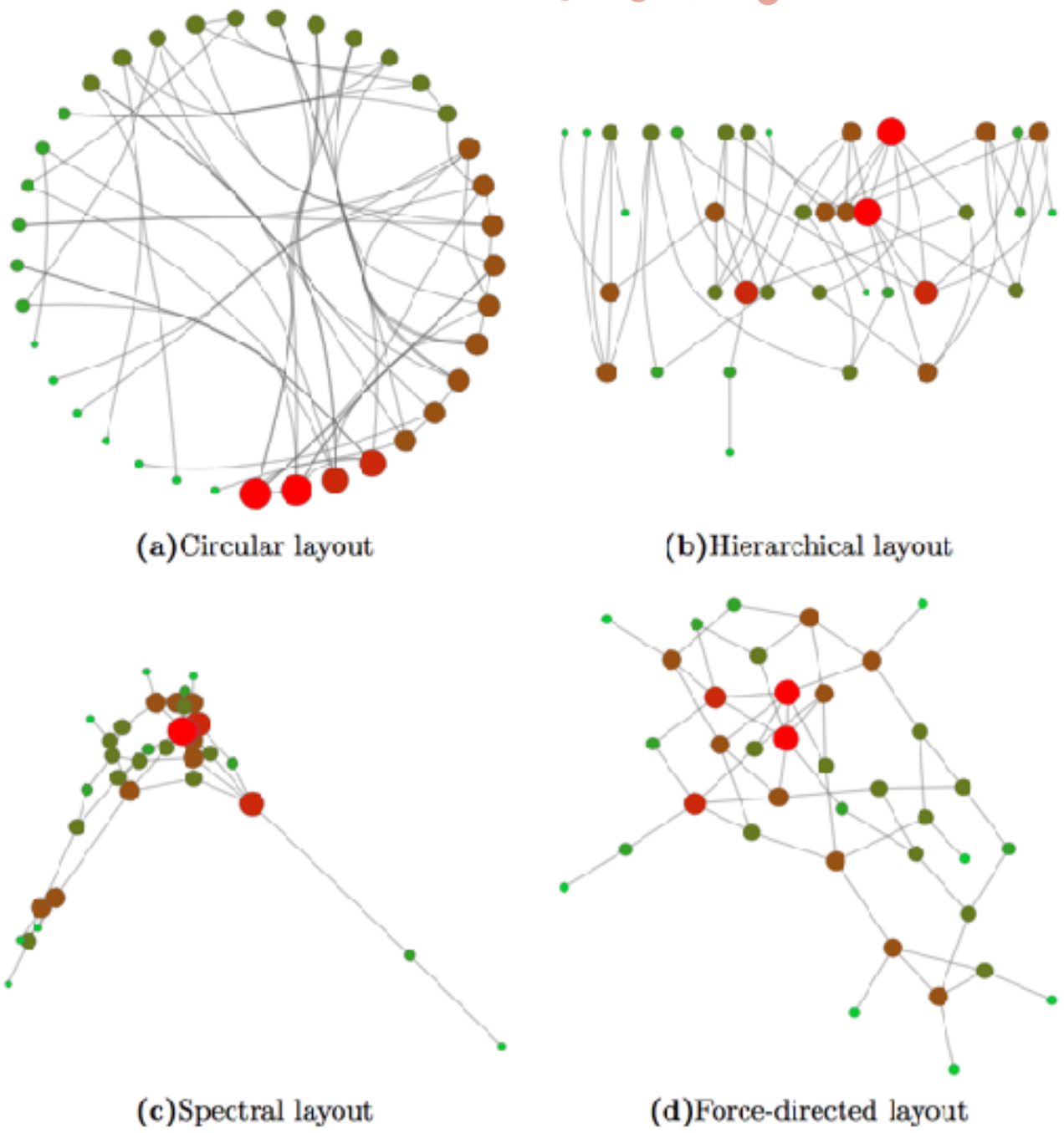








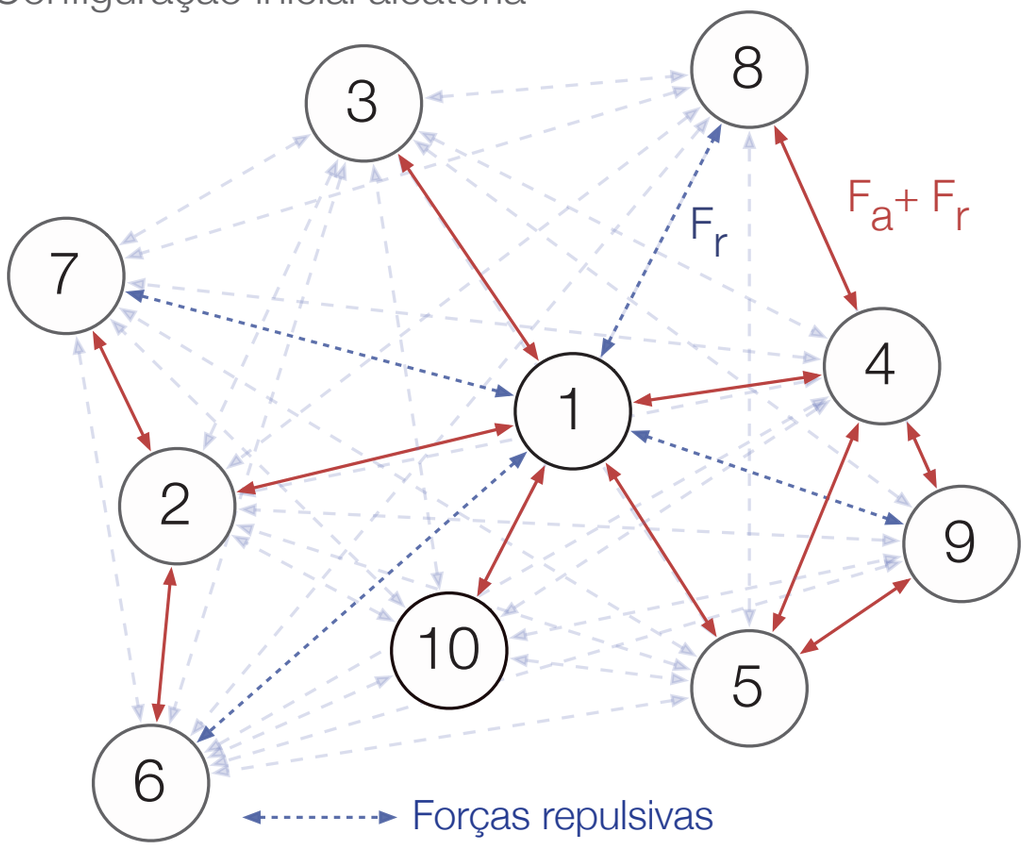
Visualização de redes



Complex systems: features, similarity and connectivity
C. H. Comin, T. K. DM. Peron, F. N. Silva, D. R. Amancio, F. A. Rodrigues, L. da F. Costa
https://arxiv.org/abs/1606.05400

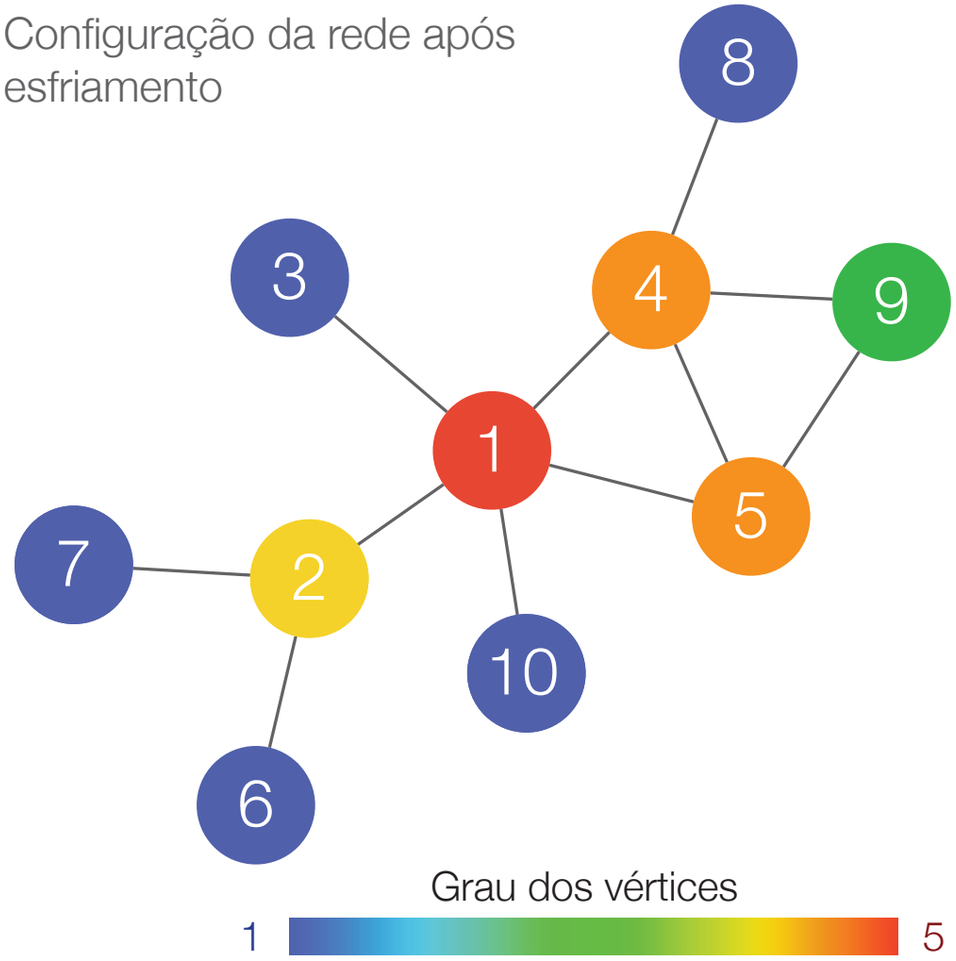
Visualização de redes

Configuração inicial aleatória



Simulação de dinâmica molecular

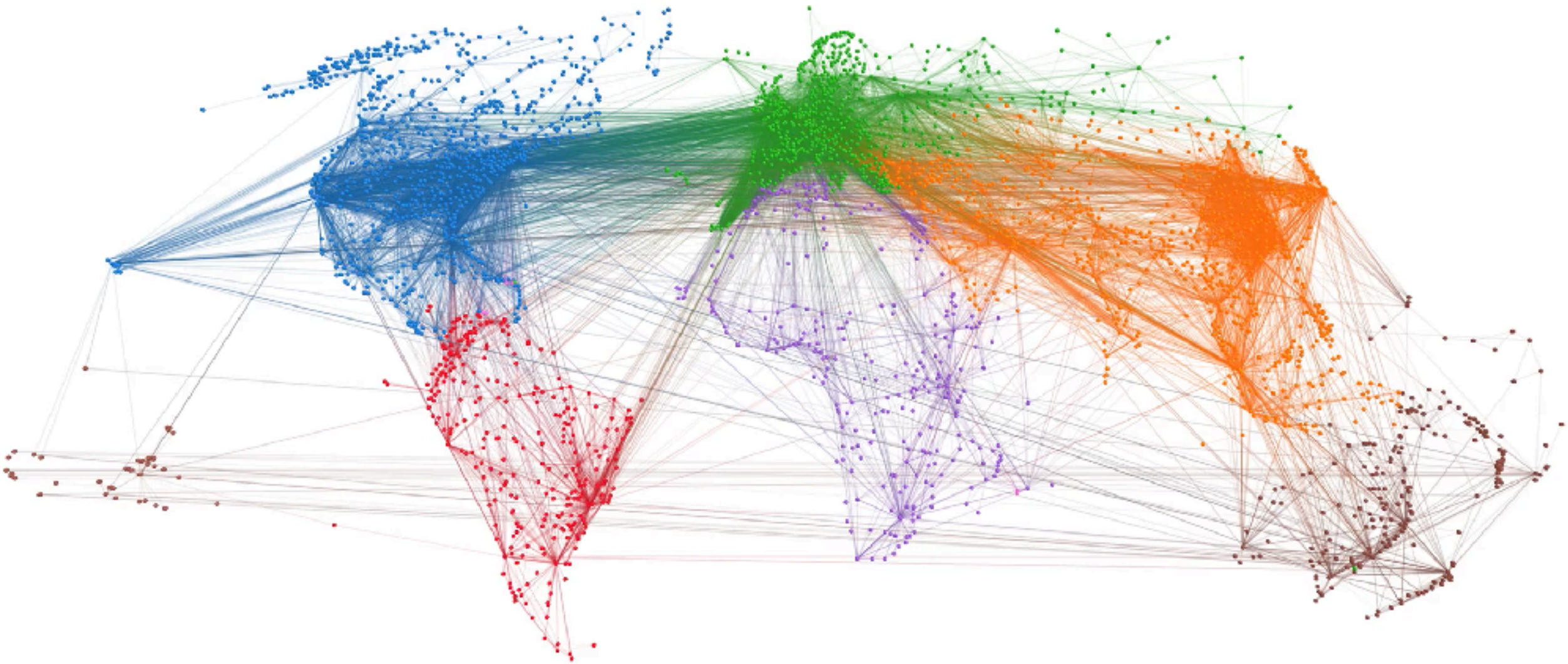
Configuração da rede após esfriamento



Visualizing Complex Networks (CDT-5)
Silva, F. N. and Costa, L. da F.
http://dx.doi.org/10.13140/RG.2.2.21310.74567/1

Exemplos de redes complexas

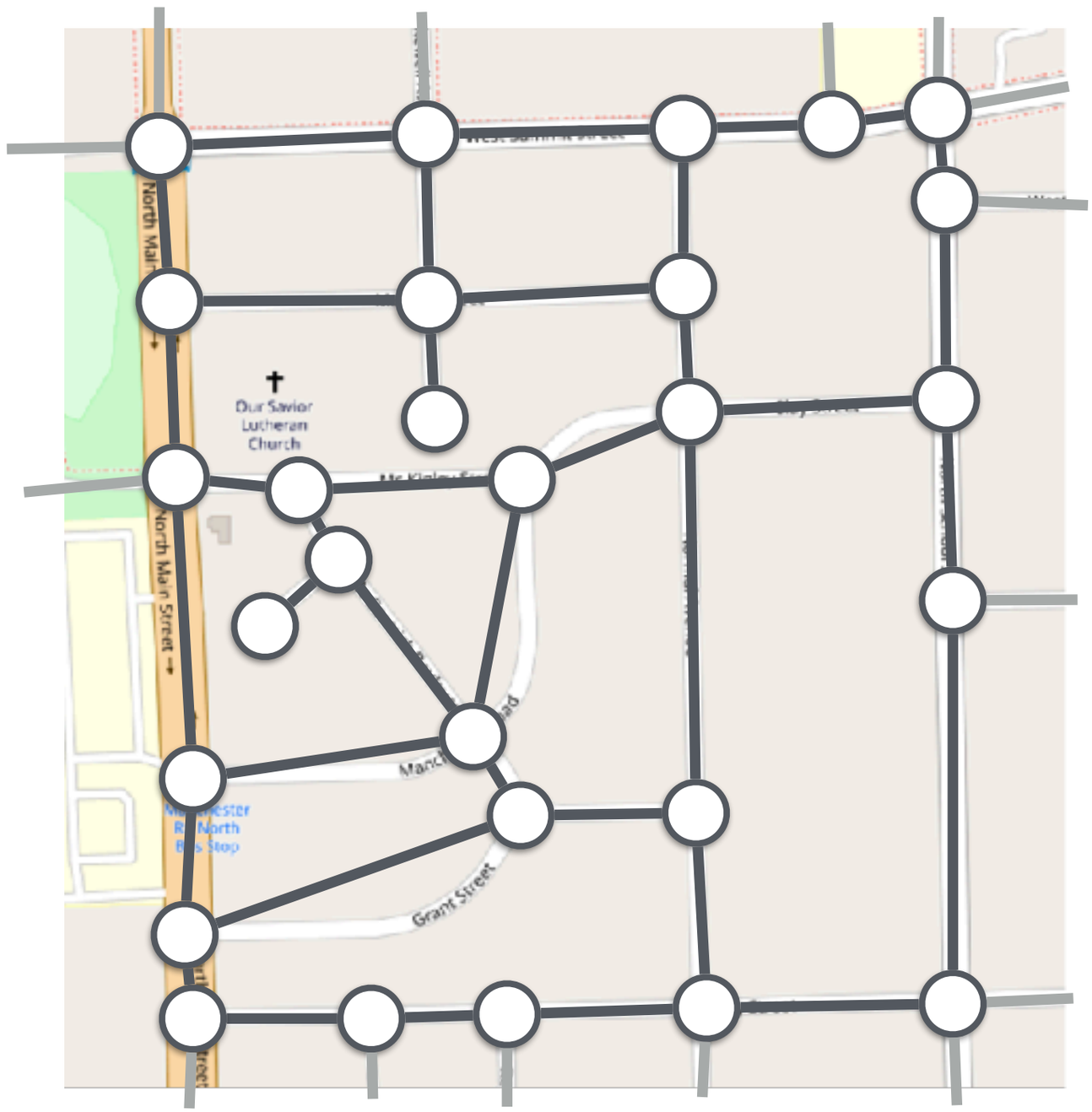
Rede de aeroportos



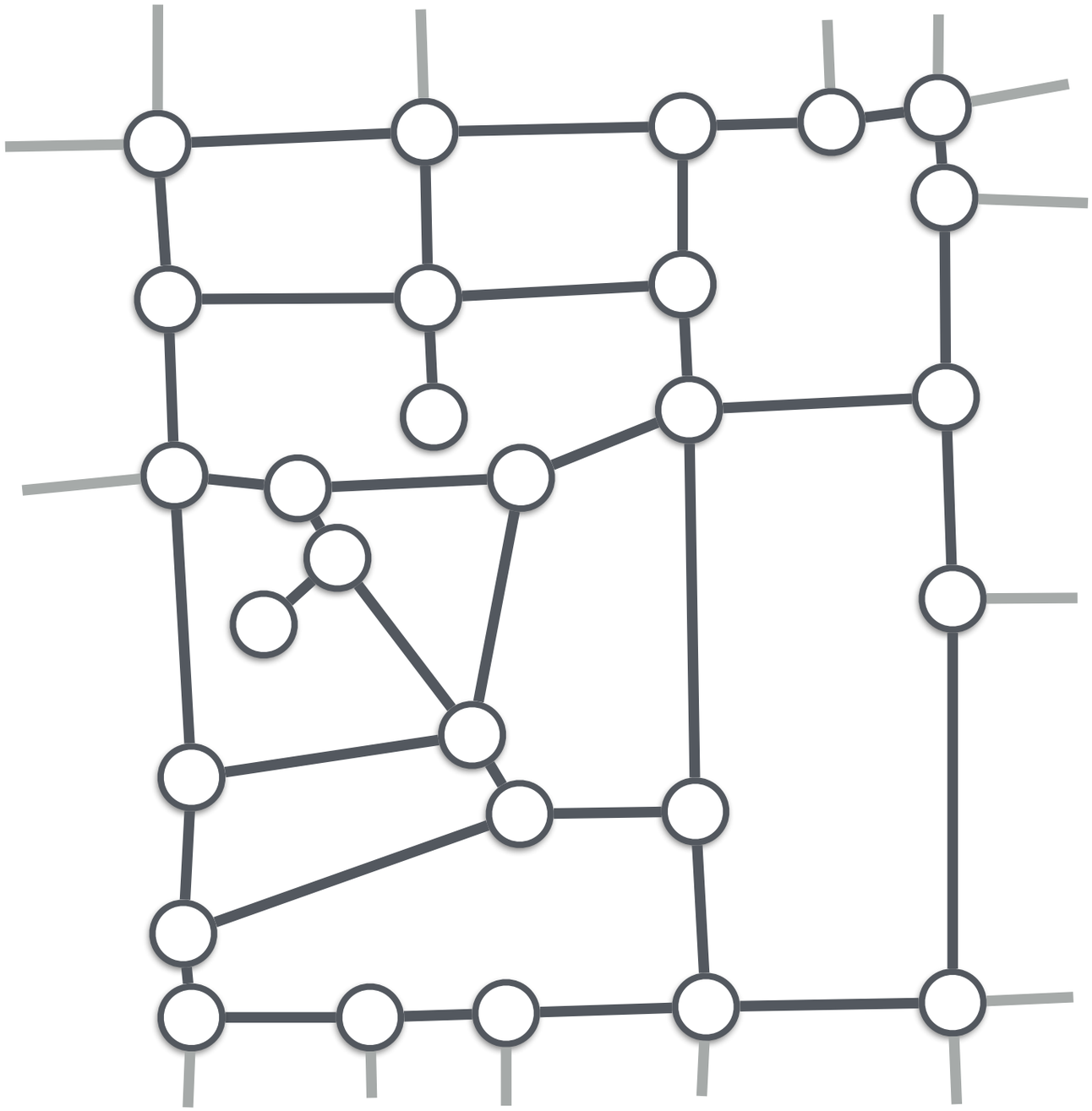
Visualizing Complex Networks (CDT-5)
Silva, F. N. and Costa, L. da F.
http://dx.doi.org/10.13140/RG.2.2.21310.74567/1

Redes urbanas

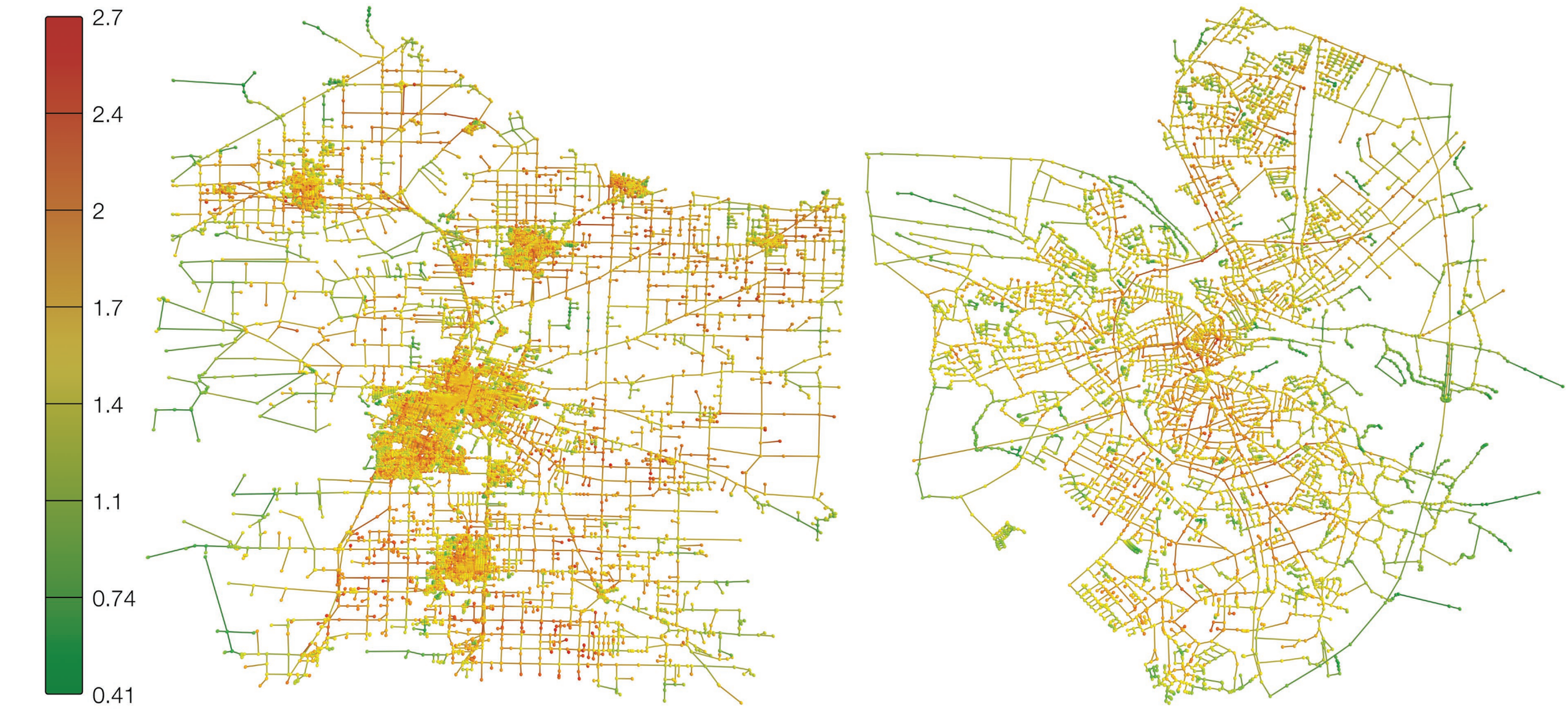
Redes urbanas



Redes urbanas



Redes urbanas



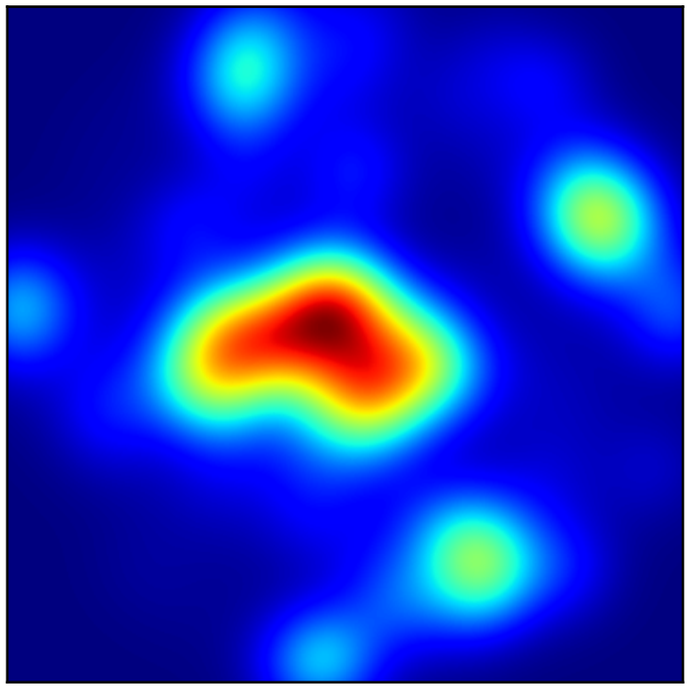
(a) San Joaquin

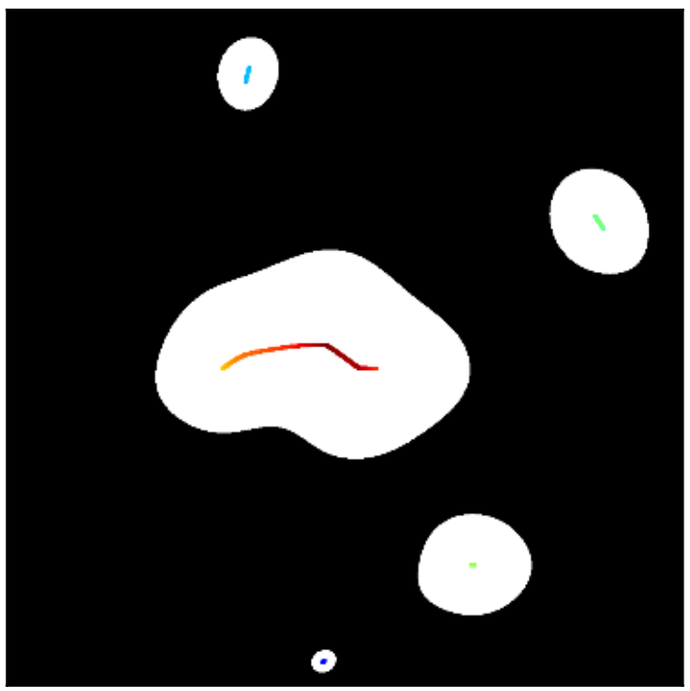
(b) Oldenburg

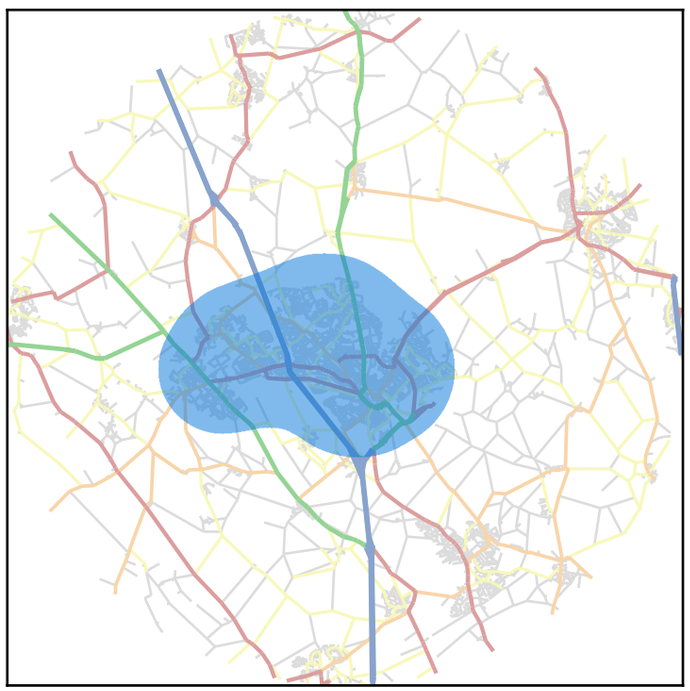
Detecção de bordas em cidades

Área administrativa de São Carlos

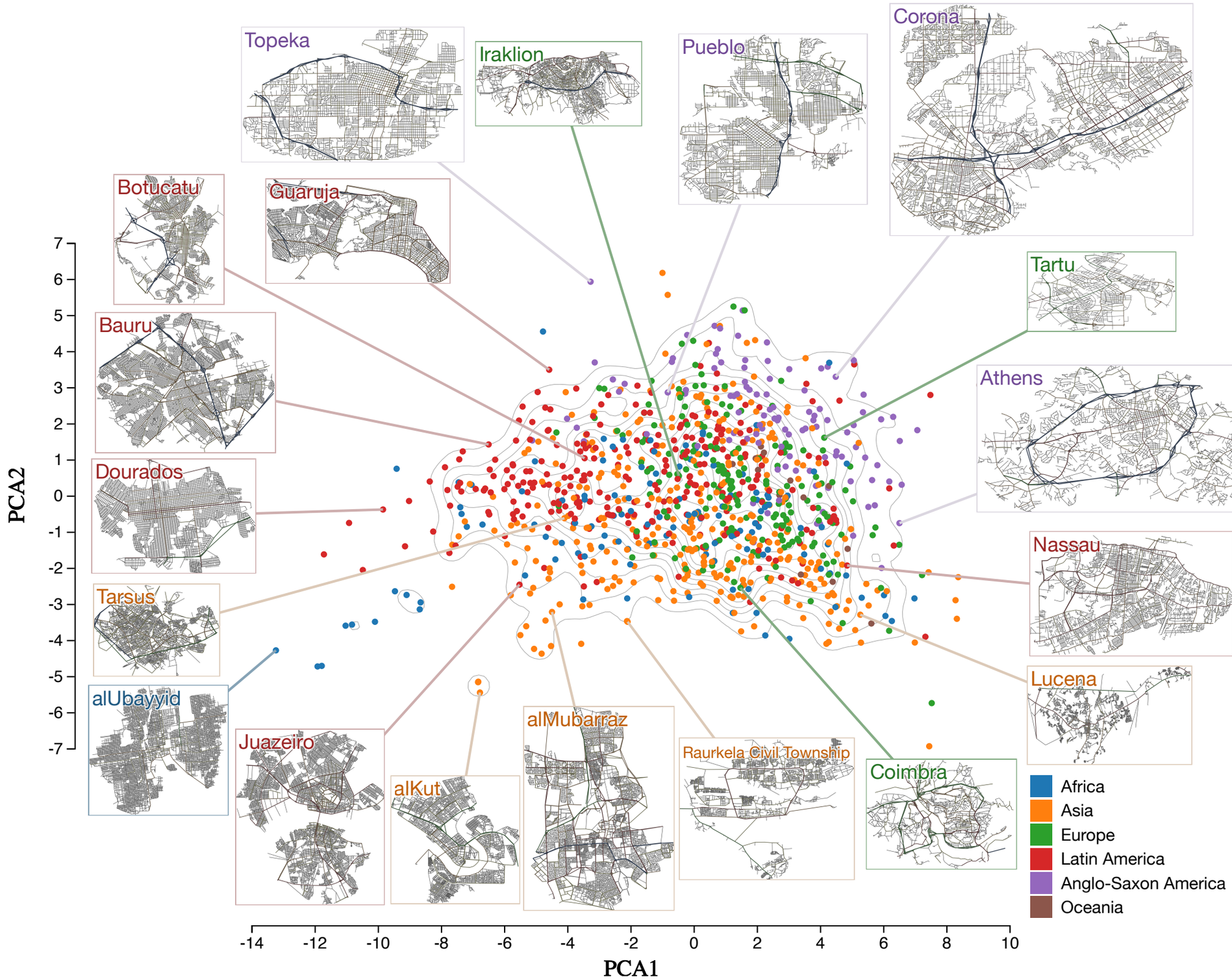
Detecção de bordas em cidades



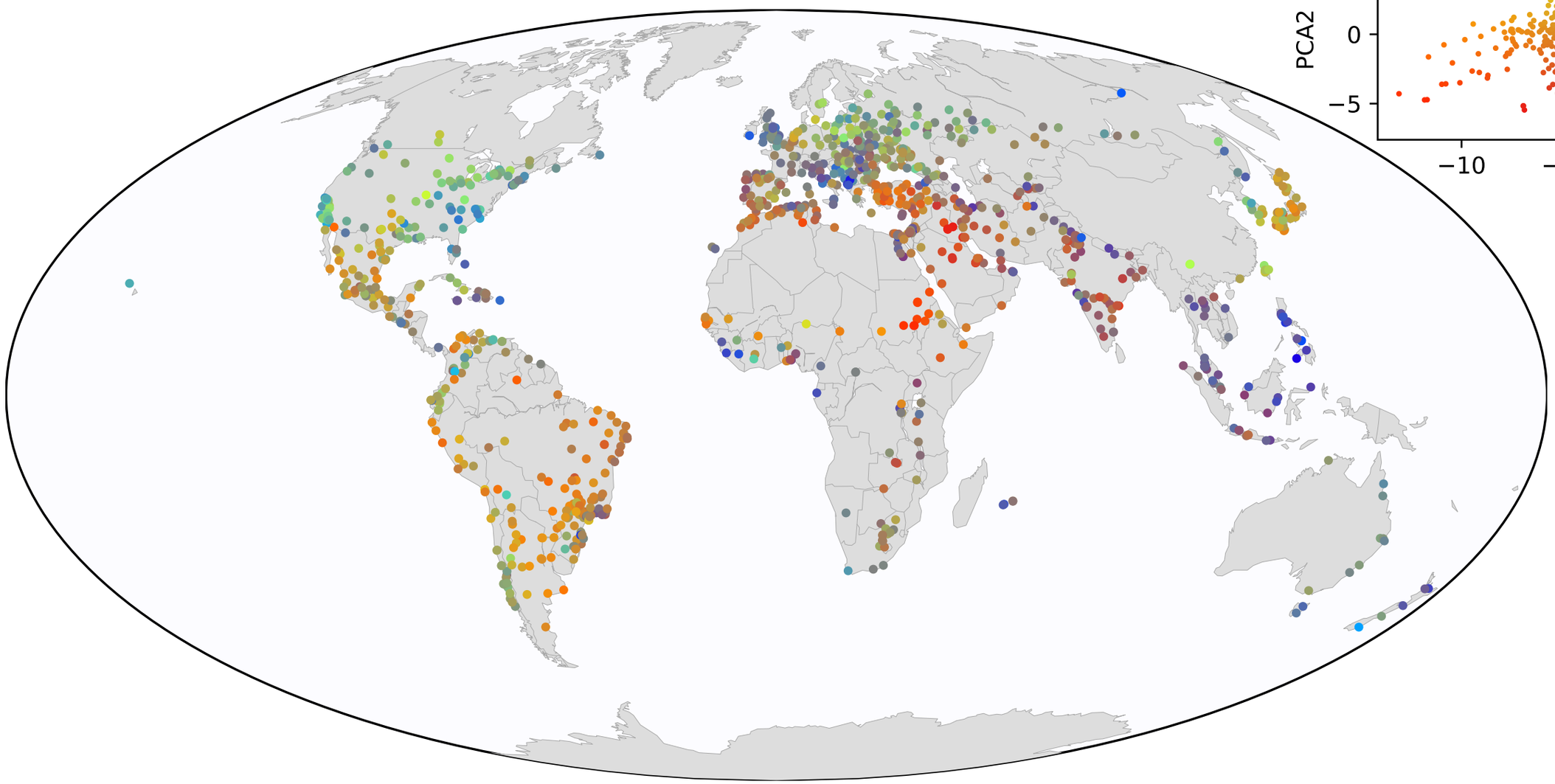




Caracterização de cidades



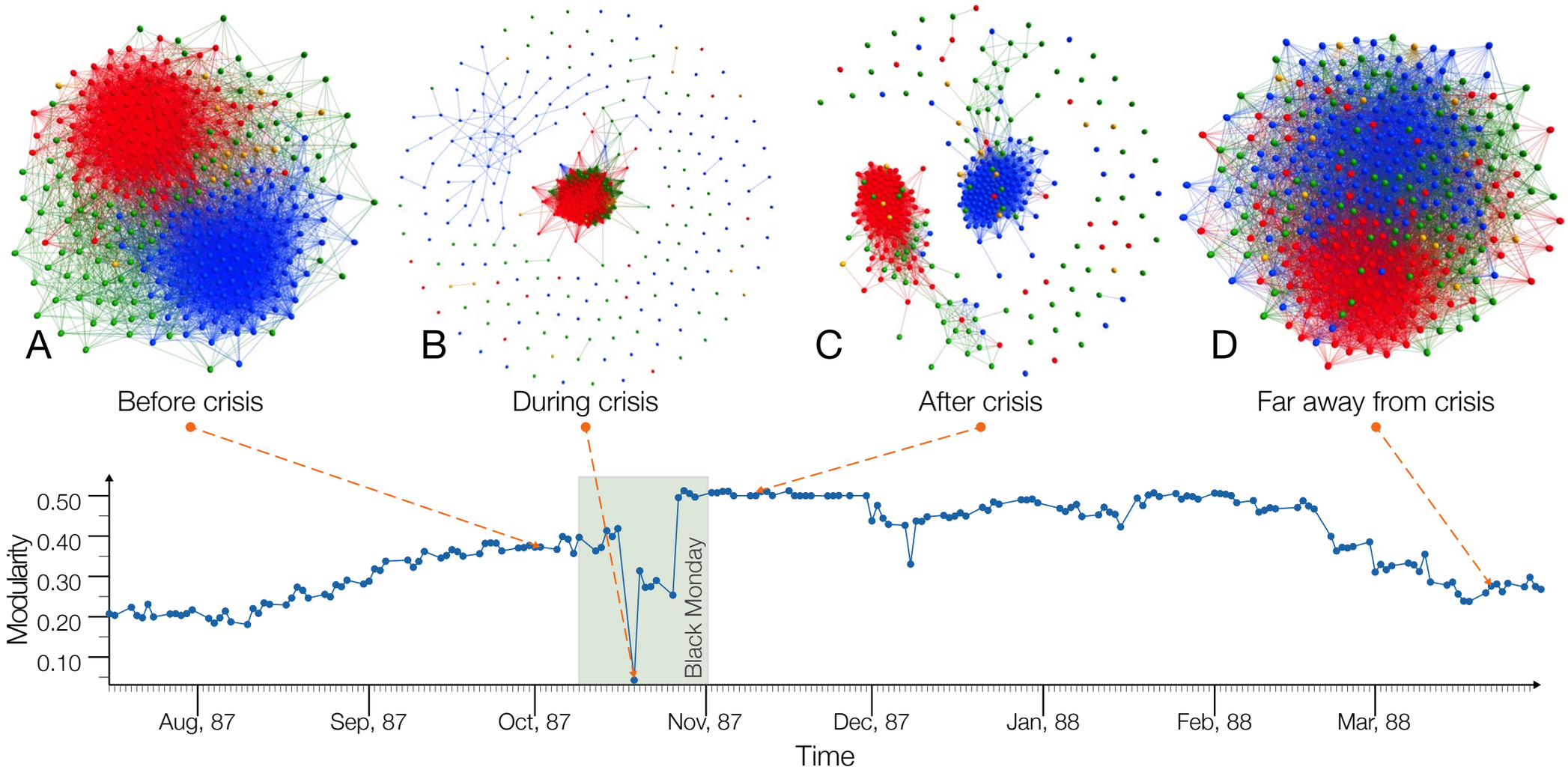
Caracterização de cidades



Topological characterization of world cities
G. S. Domingues, F. N. Silva, C. H. Comin, L. da F. Costa
Journal of Statistical Mechanics: Theory and Experiment, v. 2018, n. 8, p. 083212, 2018
https://arxiv.org/abs/1709.08244

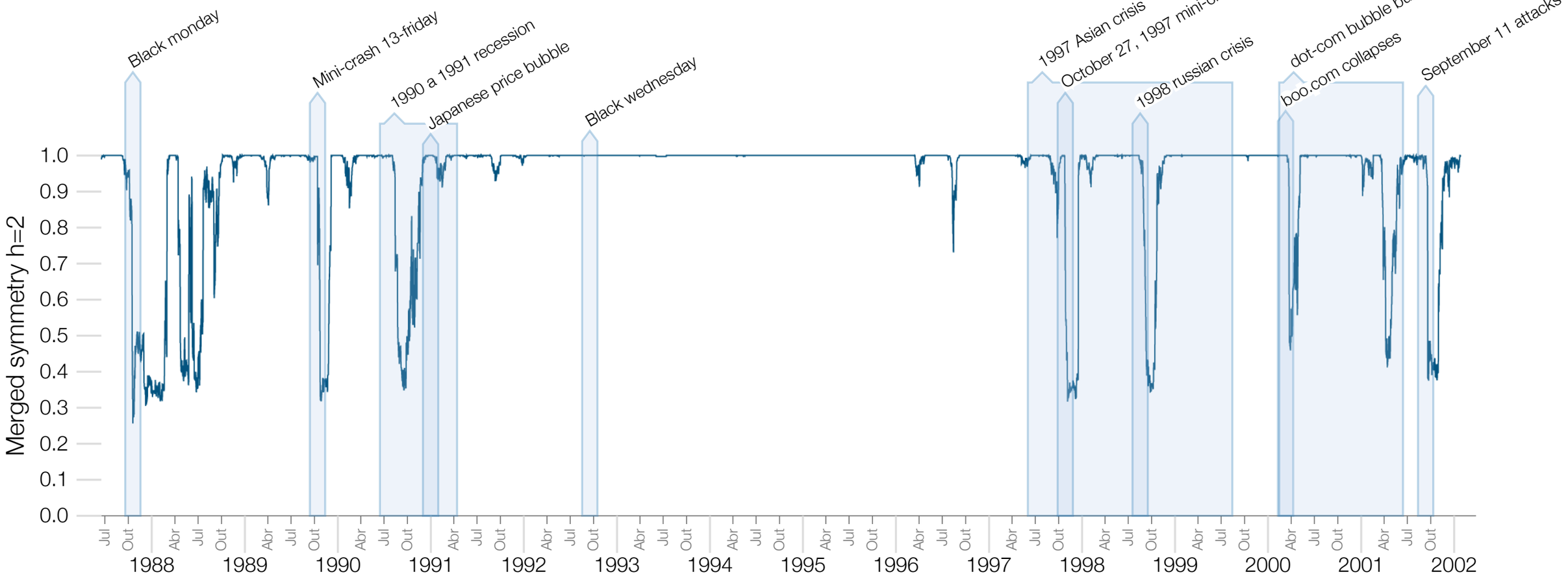
Examples

Financial market networks

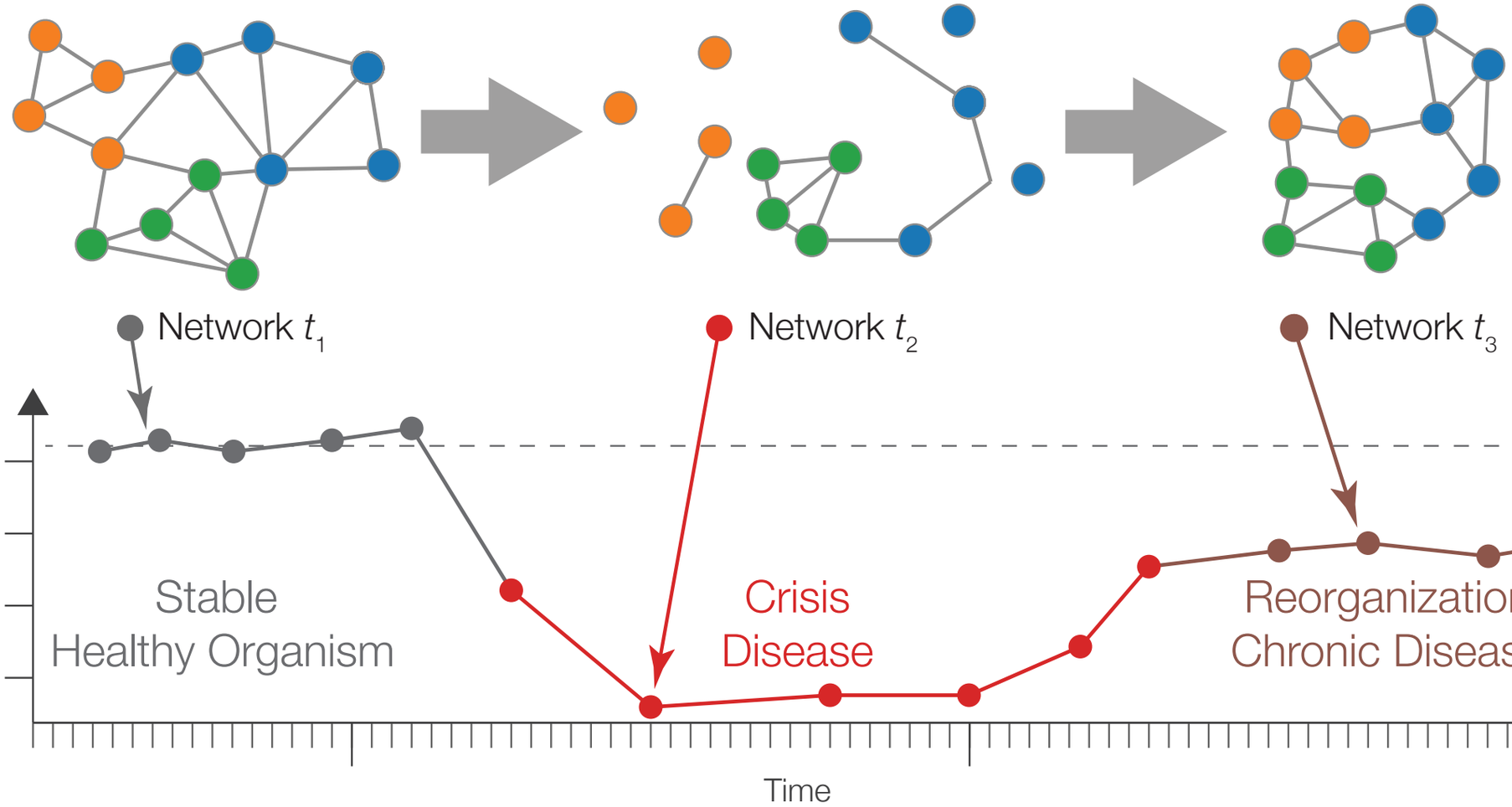


SILVA, F. N.; COMIN, C. H.; PERON, T. K. D.; RODRIGUES, F. A.; YE, C.; WILSON, R. C.; HANCOCK, E.; COSTA, L. da F. On the modular dynamics of financial market networks. 2015 <http://arxiv.org/abs/1501.05040>

Symmetry applied to the financial market network

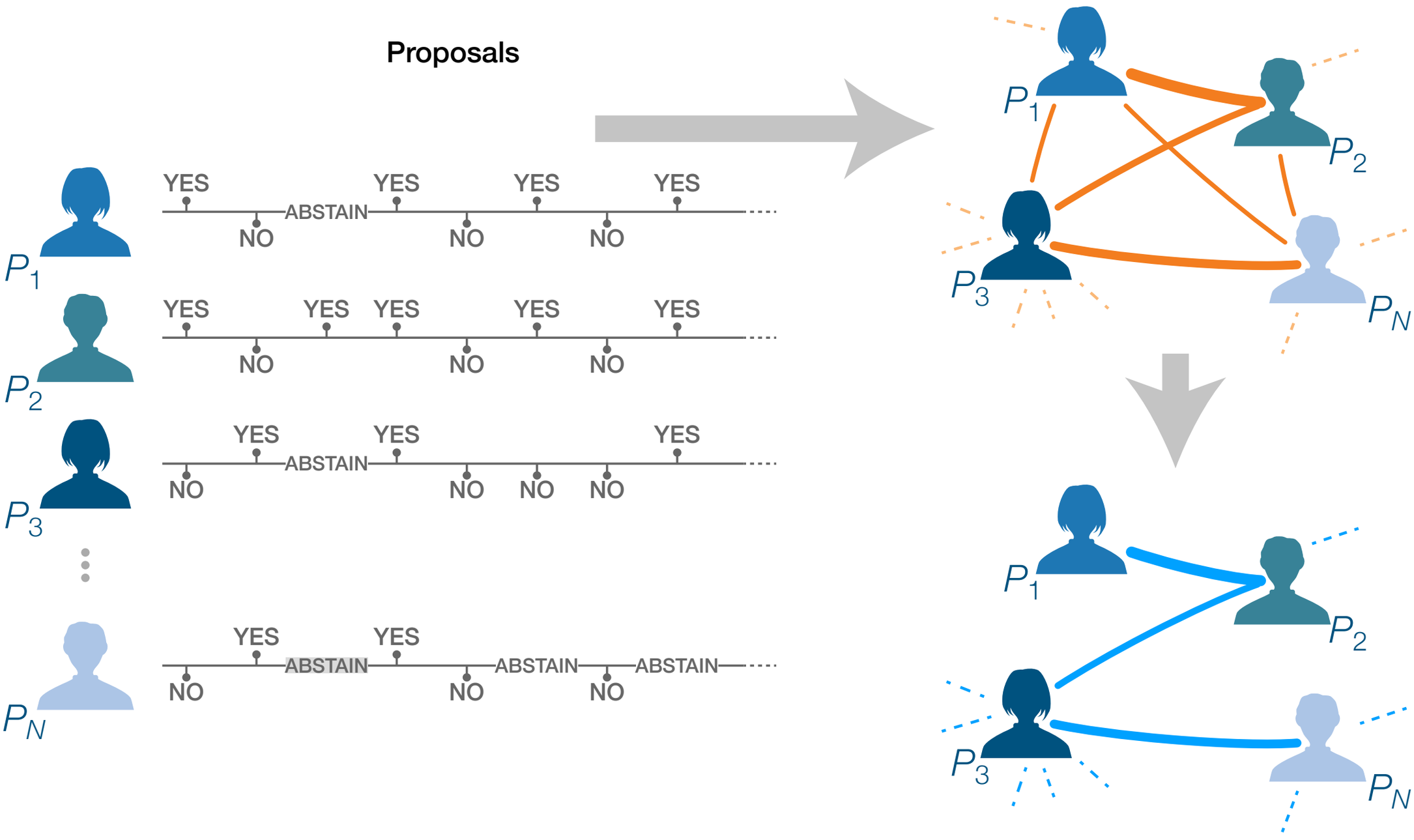


Time evolving network during crisis

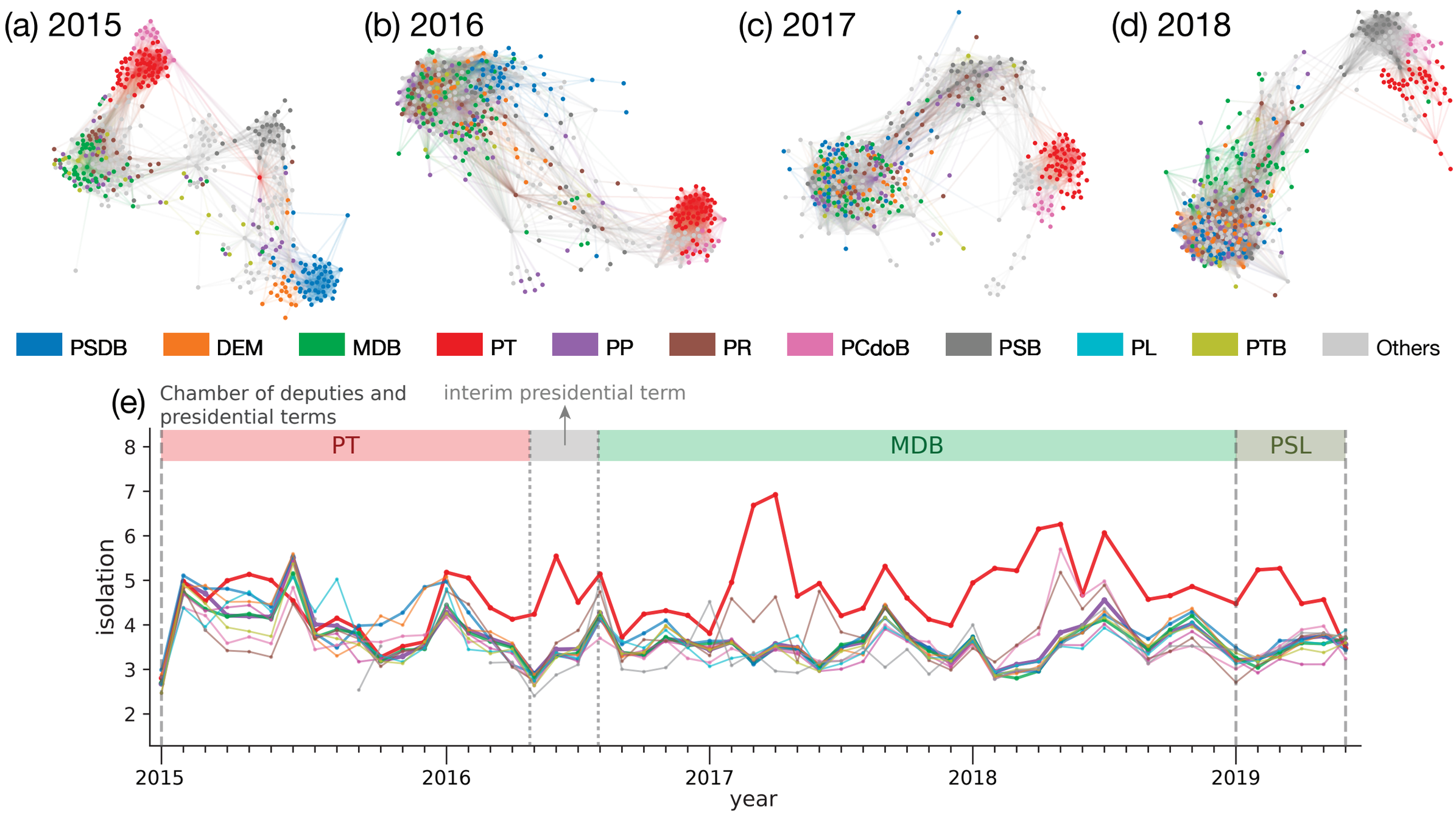


SILVA, F. N.; COMIN, C. H.; PERON, T. K. D.; RODRIGUES, F. A.; YE, C.; WILSON, R. C.; HANCOCK, E.; COSTA, L. da F. On the modular dynamics of financial market networks. 2015 <http://arxiv.org/abs/1501.05040>

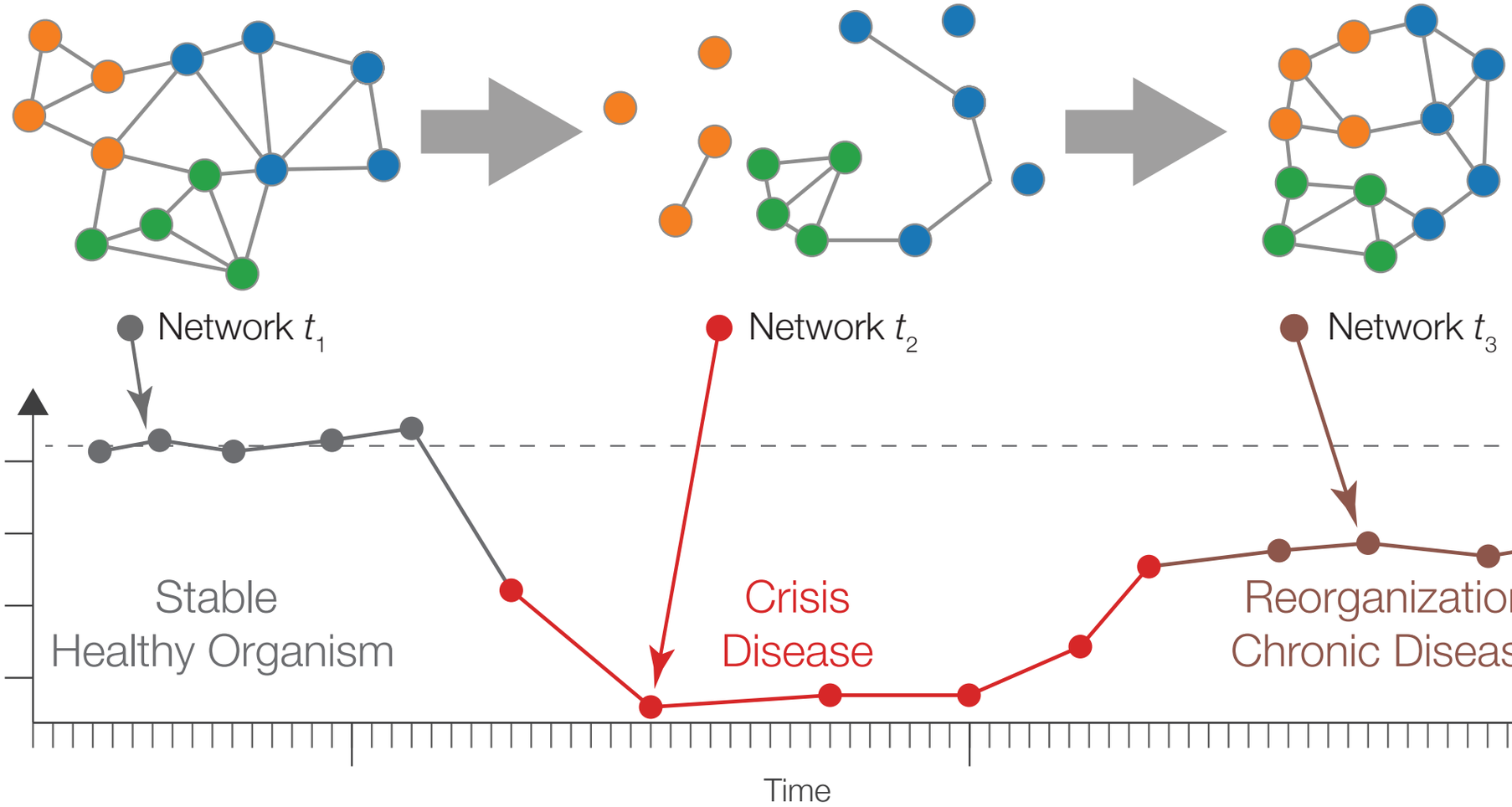
Political networks



Political networks

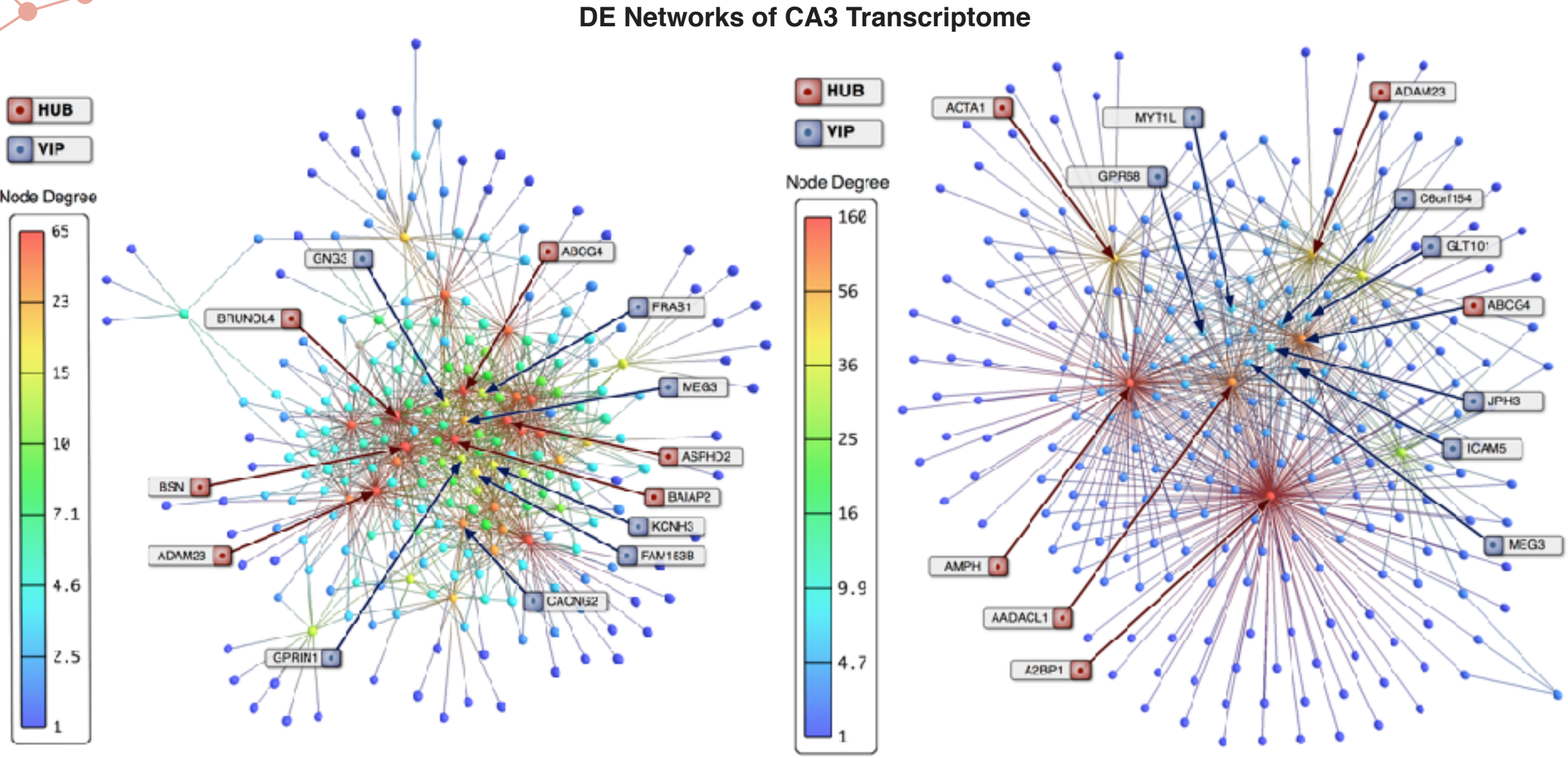


Time evolving network during crisis



SILVA, F. N.; COMIN, C. H.; PERON, T. K. D.; RODRIGUES, F. A.; YE, C.; WILSON, R. C.; HANCOCK, E.; COSTA, L. da F. On the modular dynamics of financial market networks. 2015 <http://arxiv.org/abs/1501.05040>

Gene co-expression networks



“... wondering in his darker moments what Sally would say about that project when she heard of it, and he had hoped that she would not hear of it until all the preparations were so complete that interference would be impossible. He was extremely fond of Sally, but there was, he knew, a lamentable ...”

P. G. Wodehouse
– The Adventures of Sally

Removing functional words

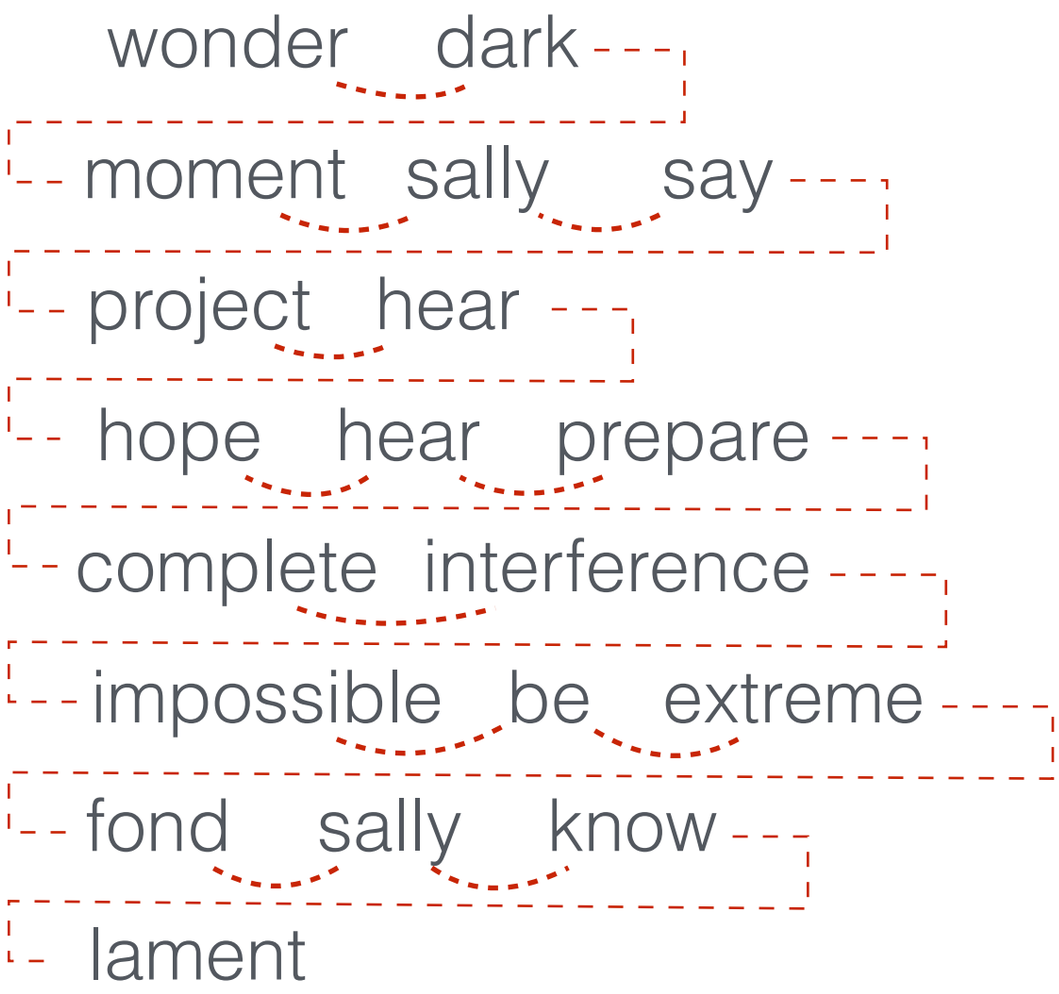
"... wondering in his darker moments what Sally would say about that project when she heard of it, and he had hoped that she would not hear of it until all the preparations were so complete that interference would be impossible. He was extremely fond of Sally, but there was, he knew, a lamentable ..."

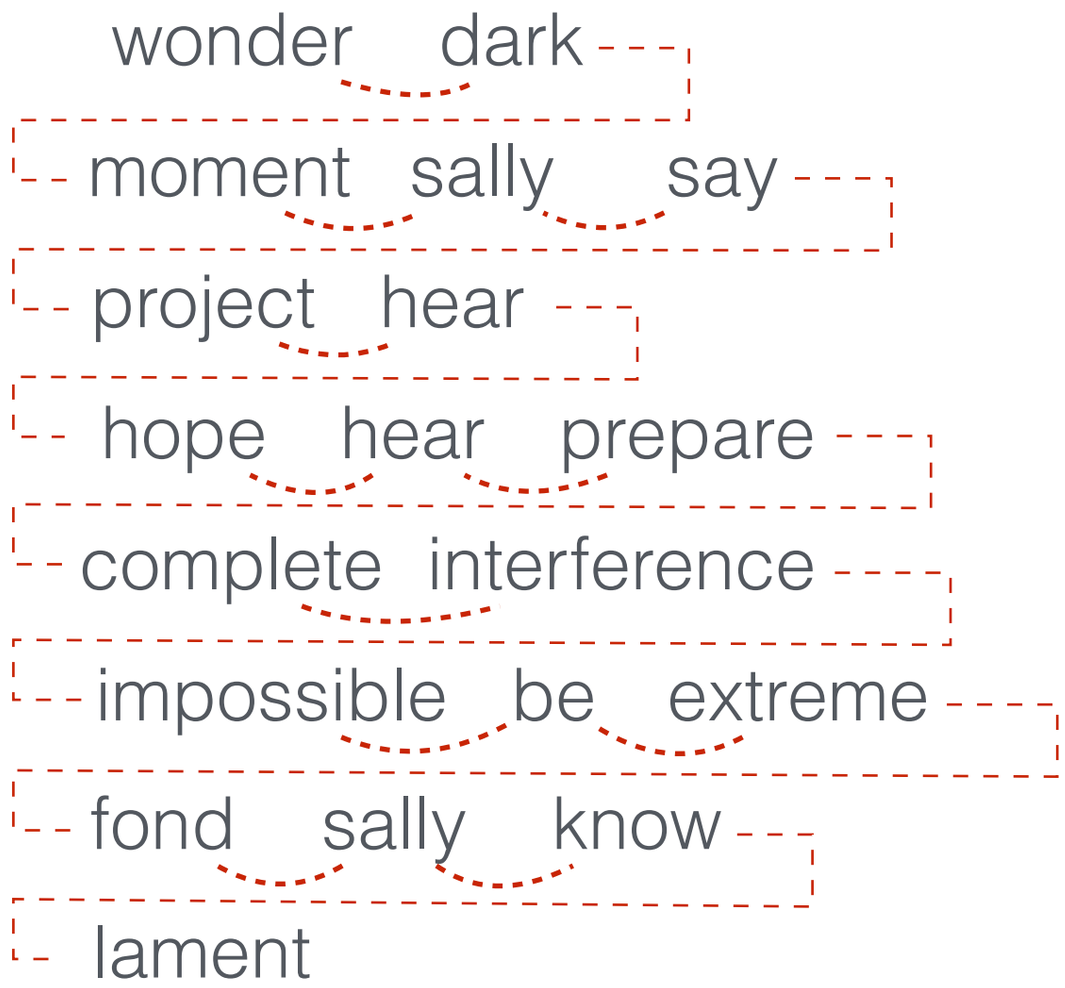
P. G. Wodehouse
– The Adventures of Sally

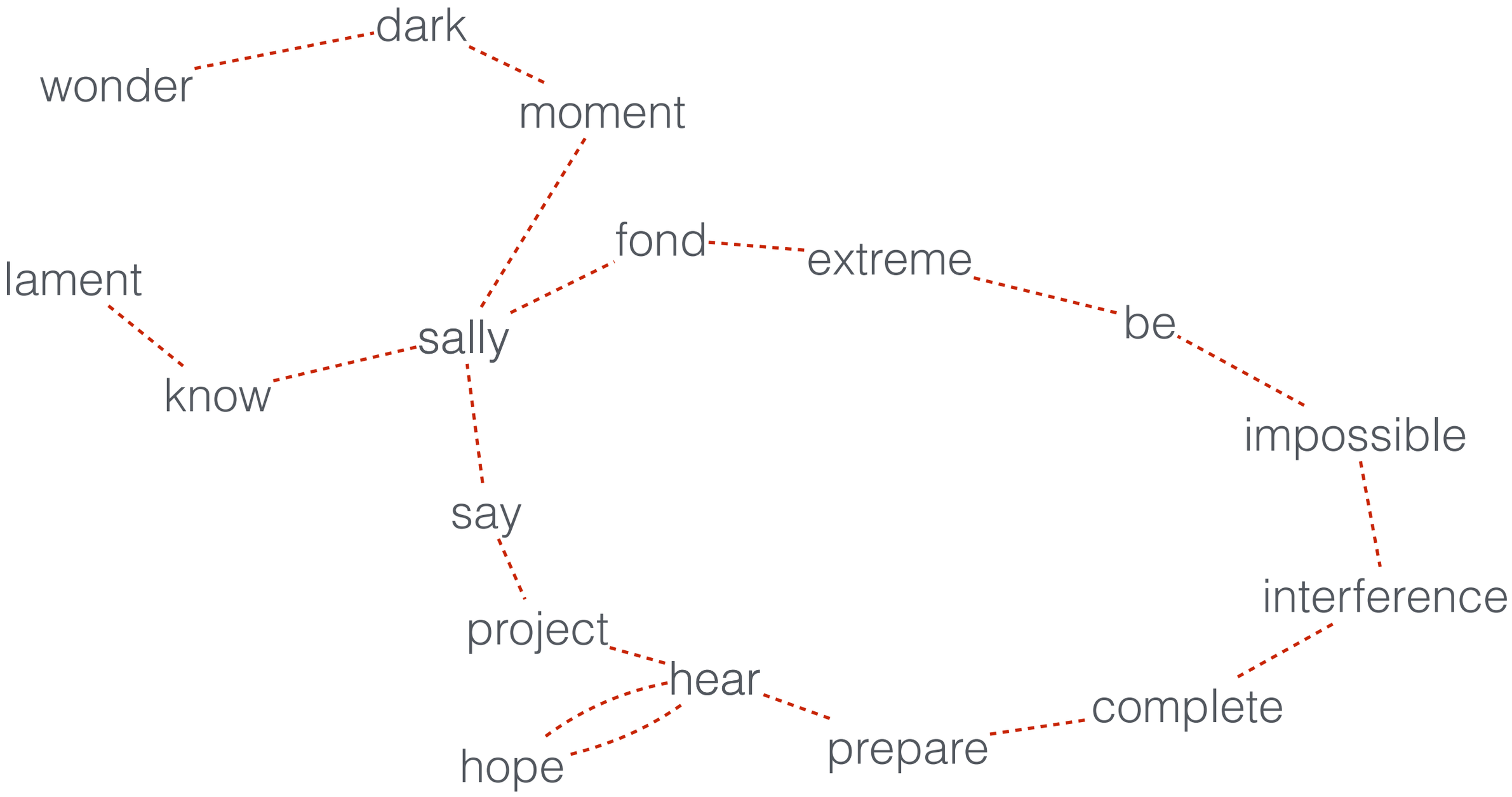
Lemmatization

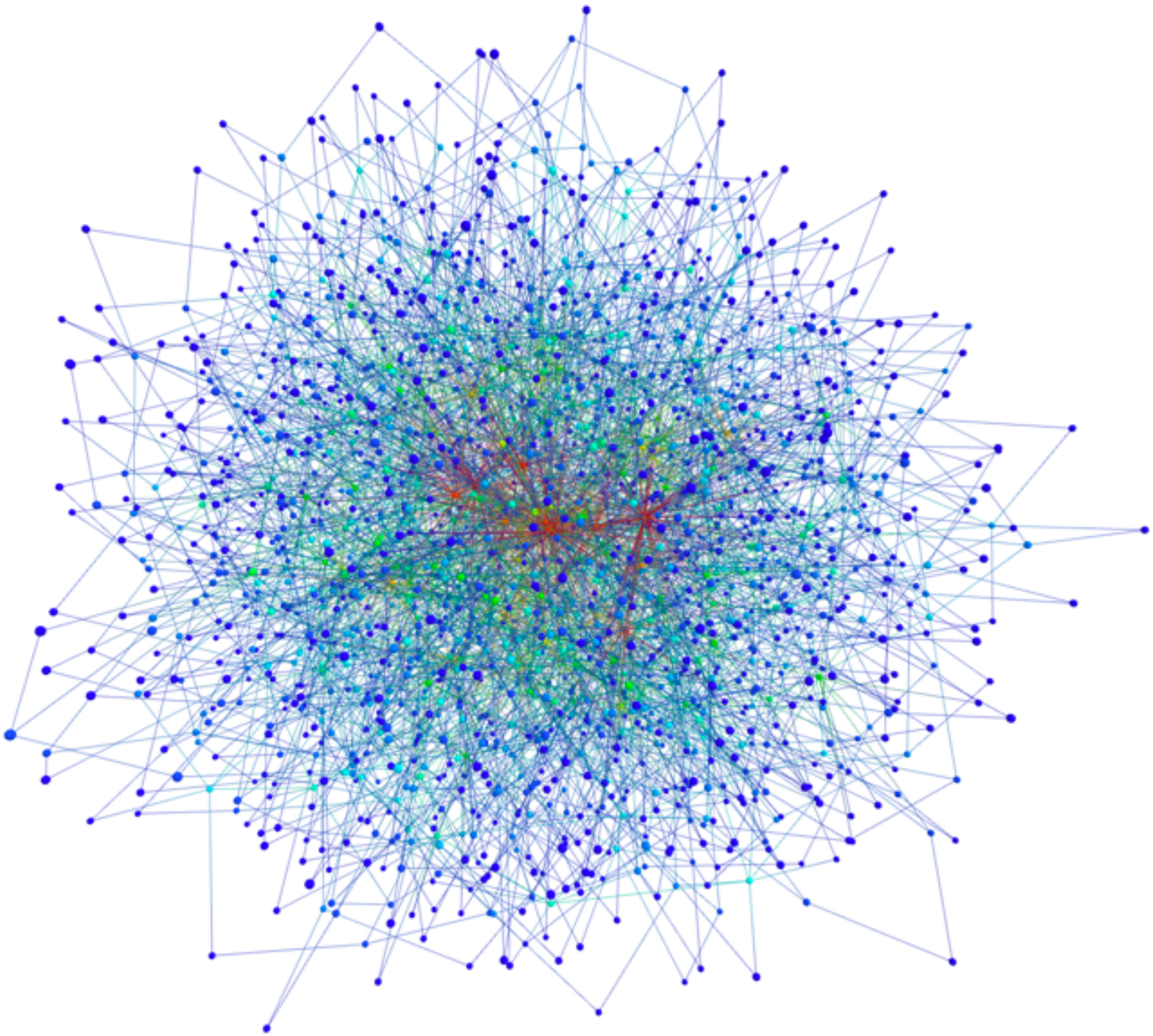
"... wondering in his darker moments what Sally would say about that project when she heard of it, and he had hoped that she would not hear of it until all the preparations were so complete that interference would be impossible. He was extremely fond of Sally, but there was, he knew, a lamentable ..."

P. G. Wodehouse
– The Adventures of Sally



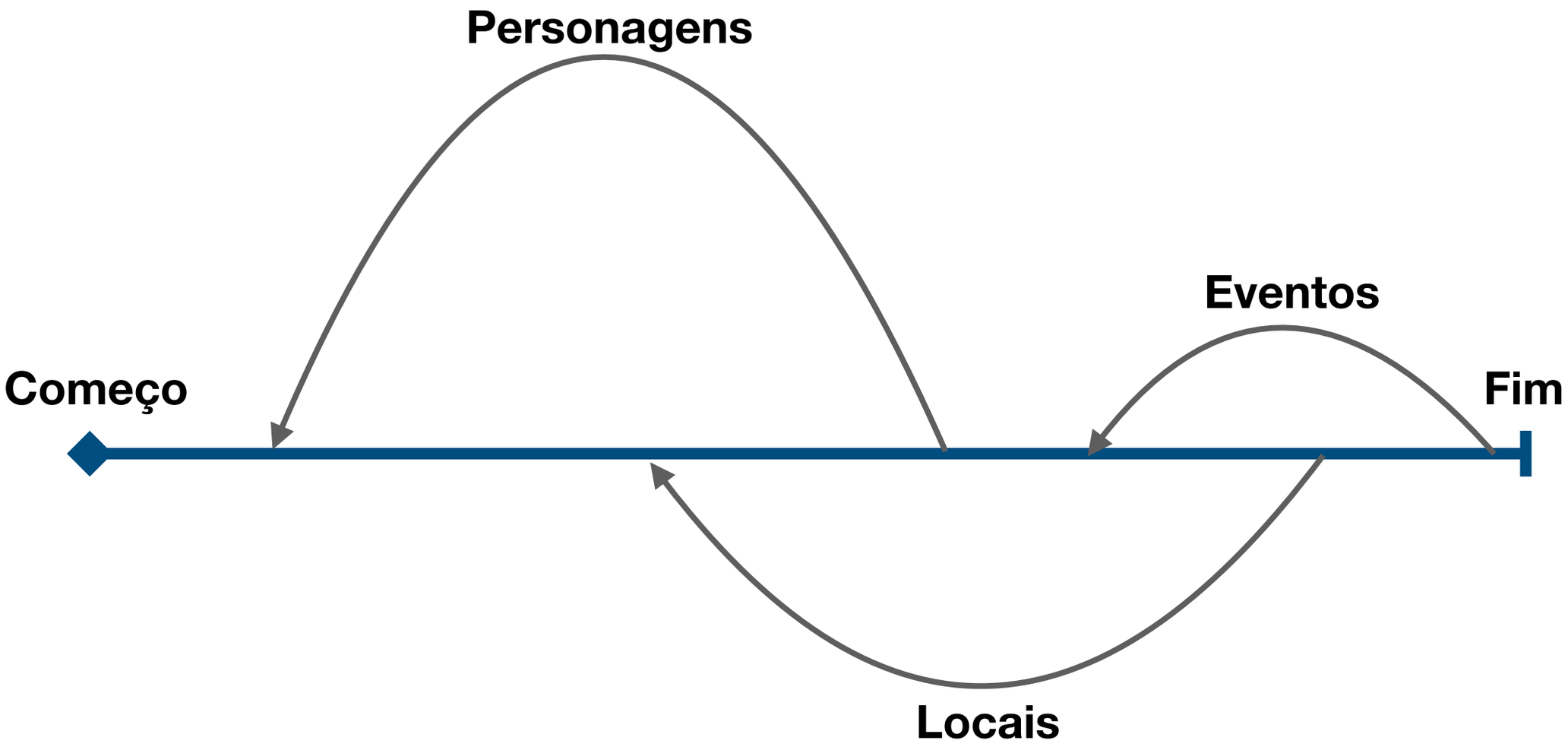

wonder dark
moment sally say
project hear
hope hear prepare
complete interference
impossible be extreme
fond sally know
lament


dark
wonder
moment
fond
extreme
lament
be
sally
know
impossible
say
interference
project
hear
complete
hope
prepare

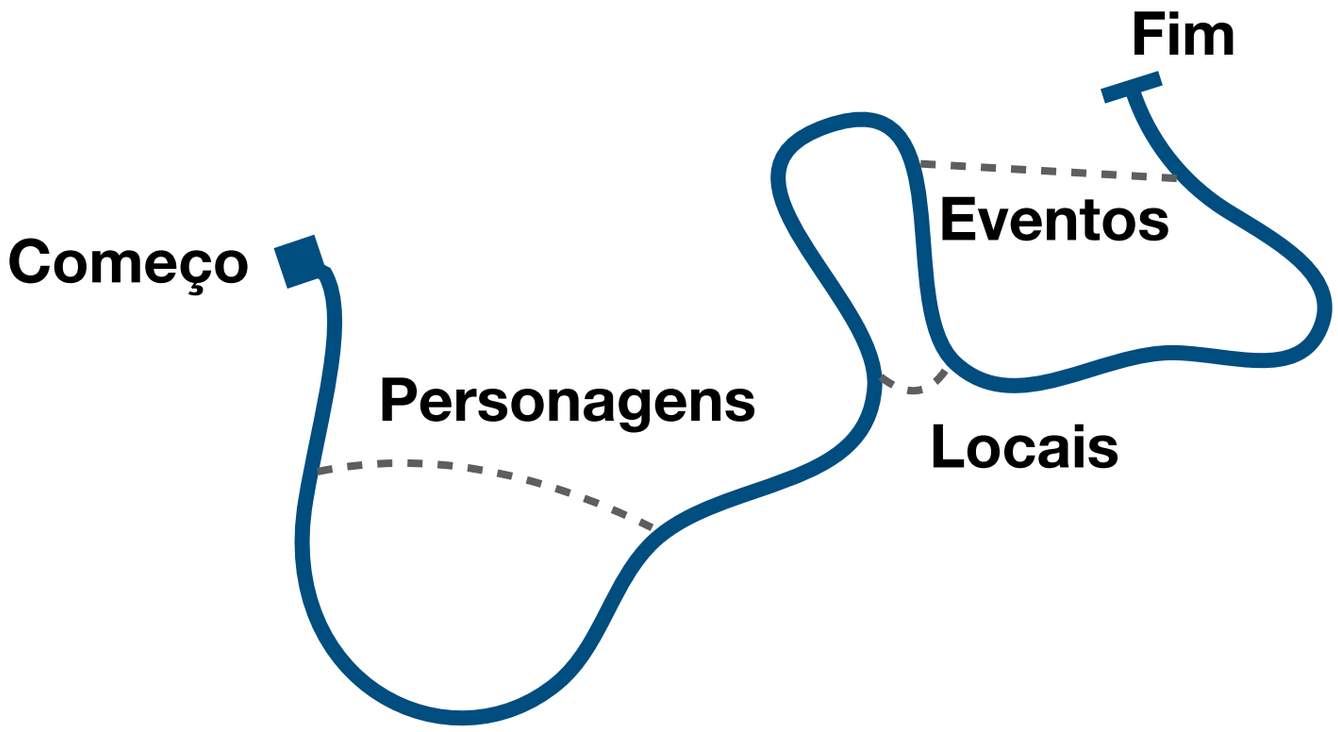


Narrativa

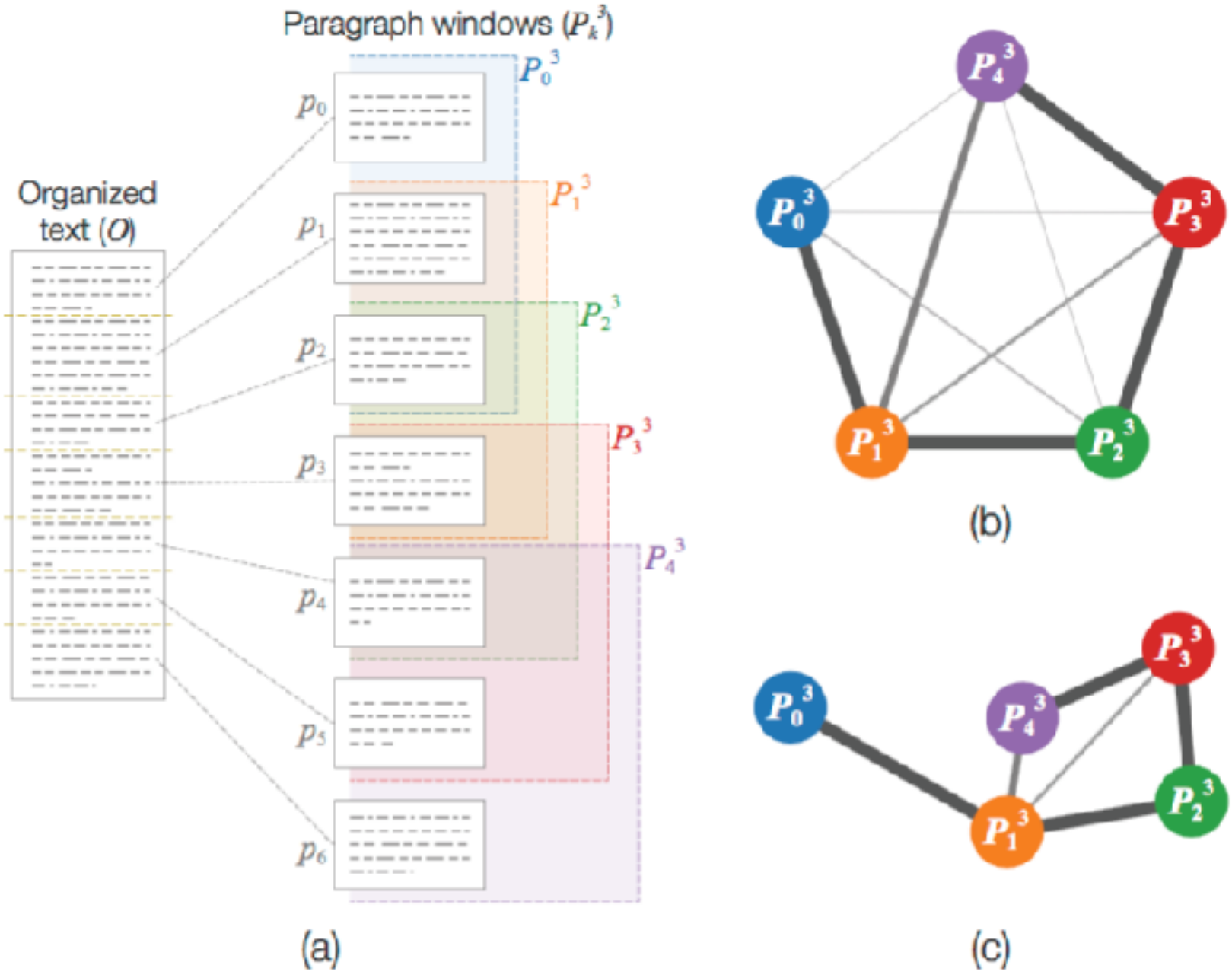
Narrative



Narrative

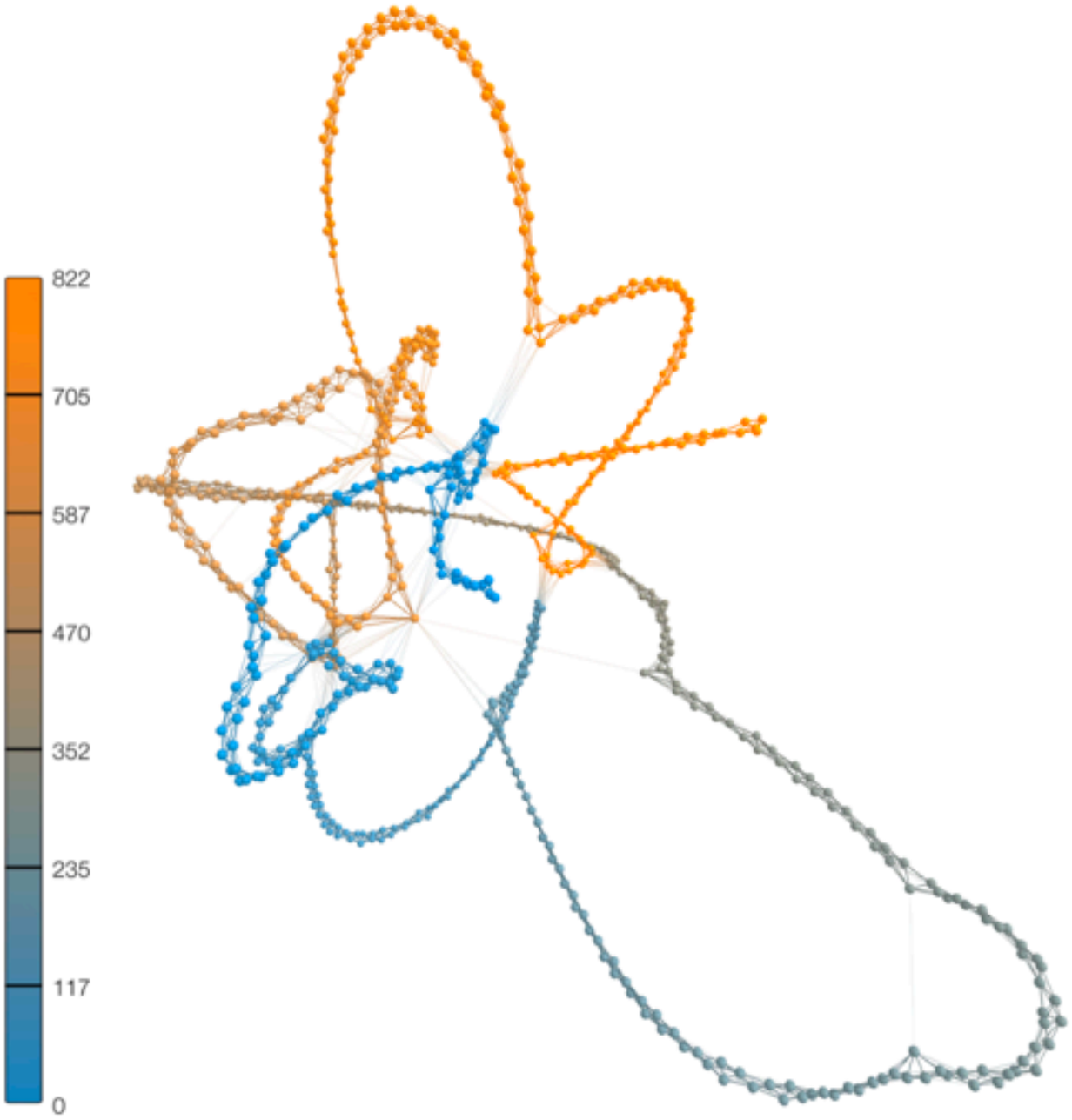


Análise de textos



Representation of texts as complex networks: a mesoscopic approach
H. F. de Arruda, F. N. Silva, V. Q. Marinho, D. R. Amancio, L. da F. Costa
Journal of Complex Networks, p. cnx023, 2017
https://arxiv.org/abs/1606.09636

Odyssey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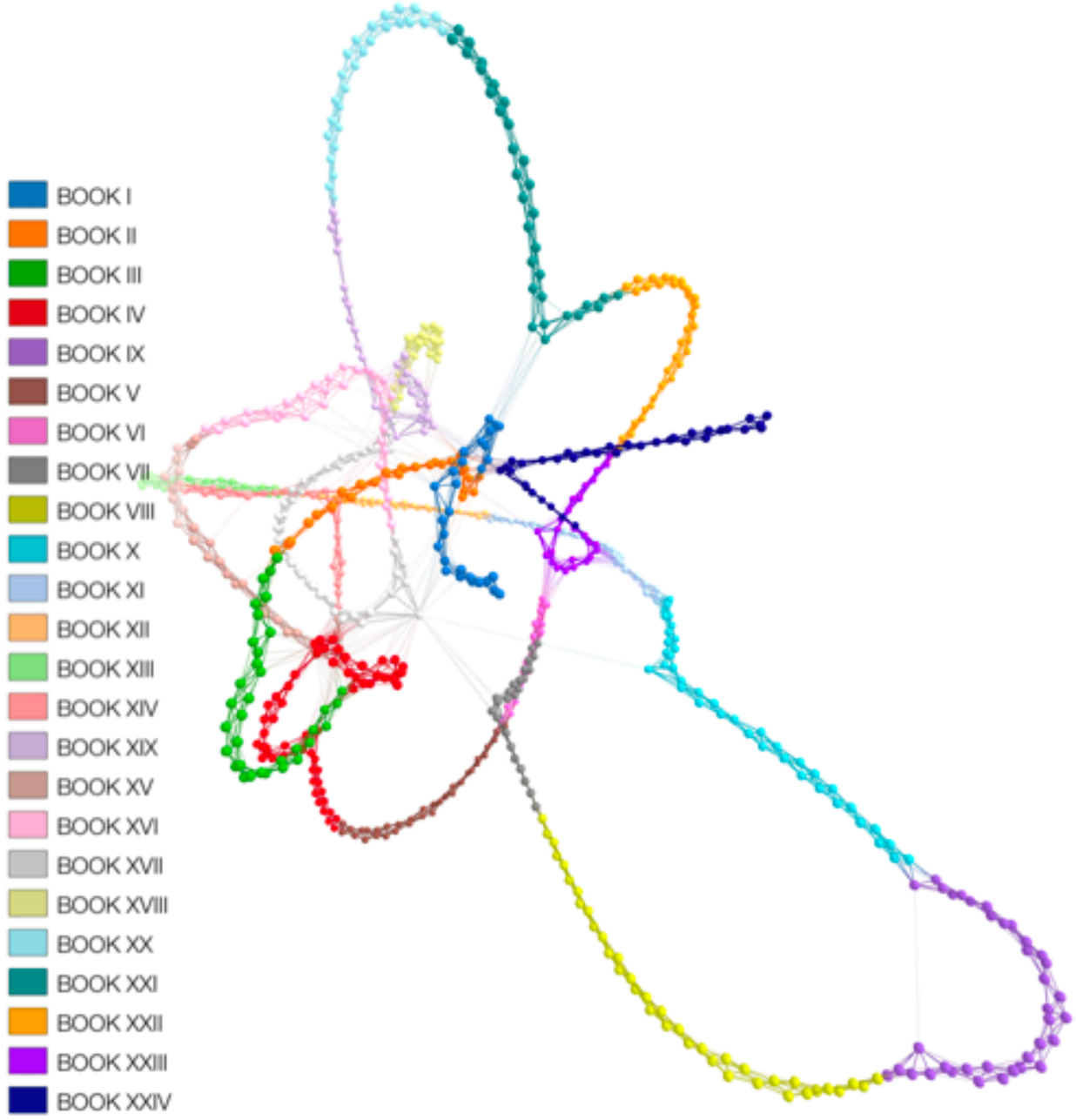
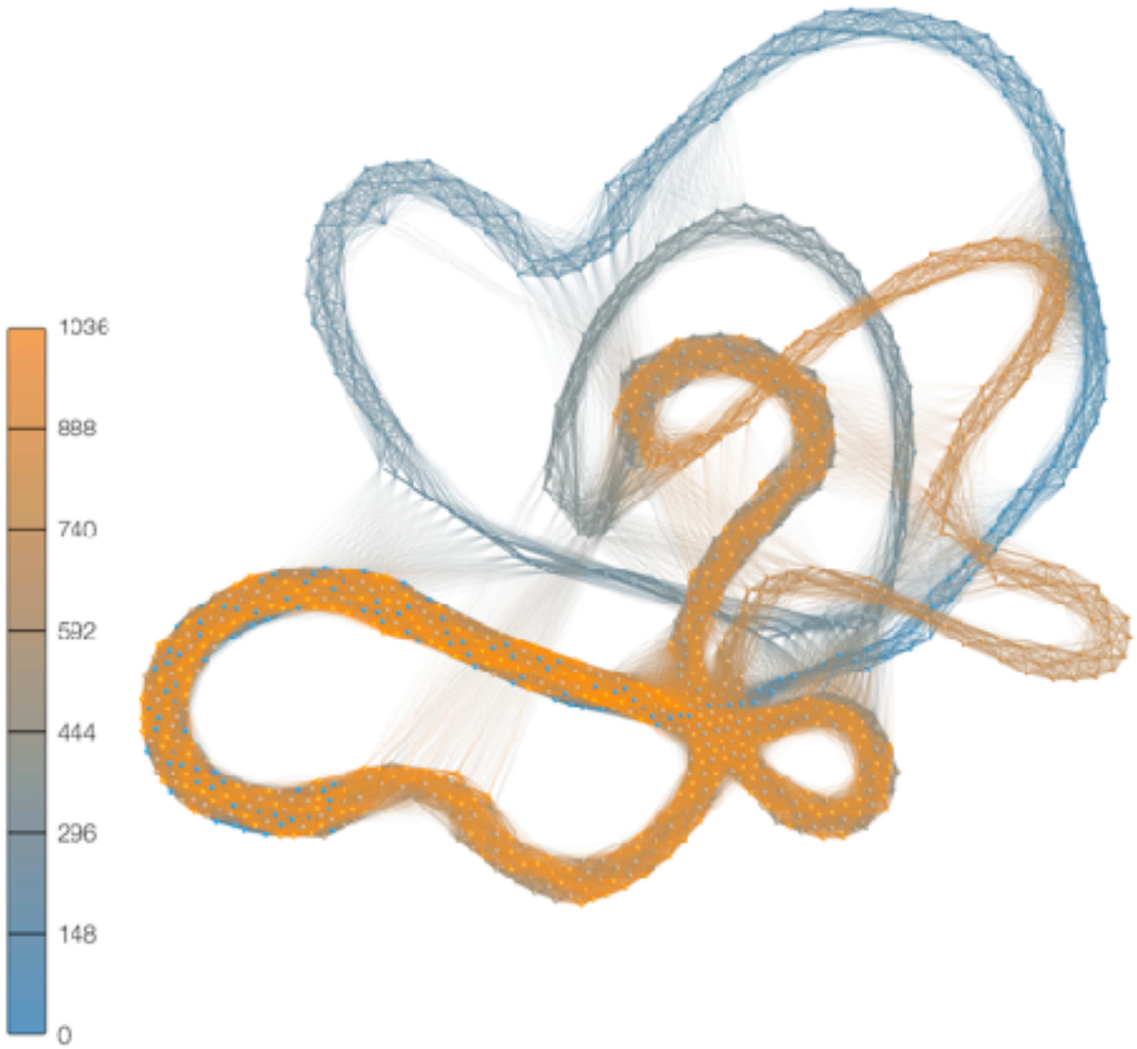
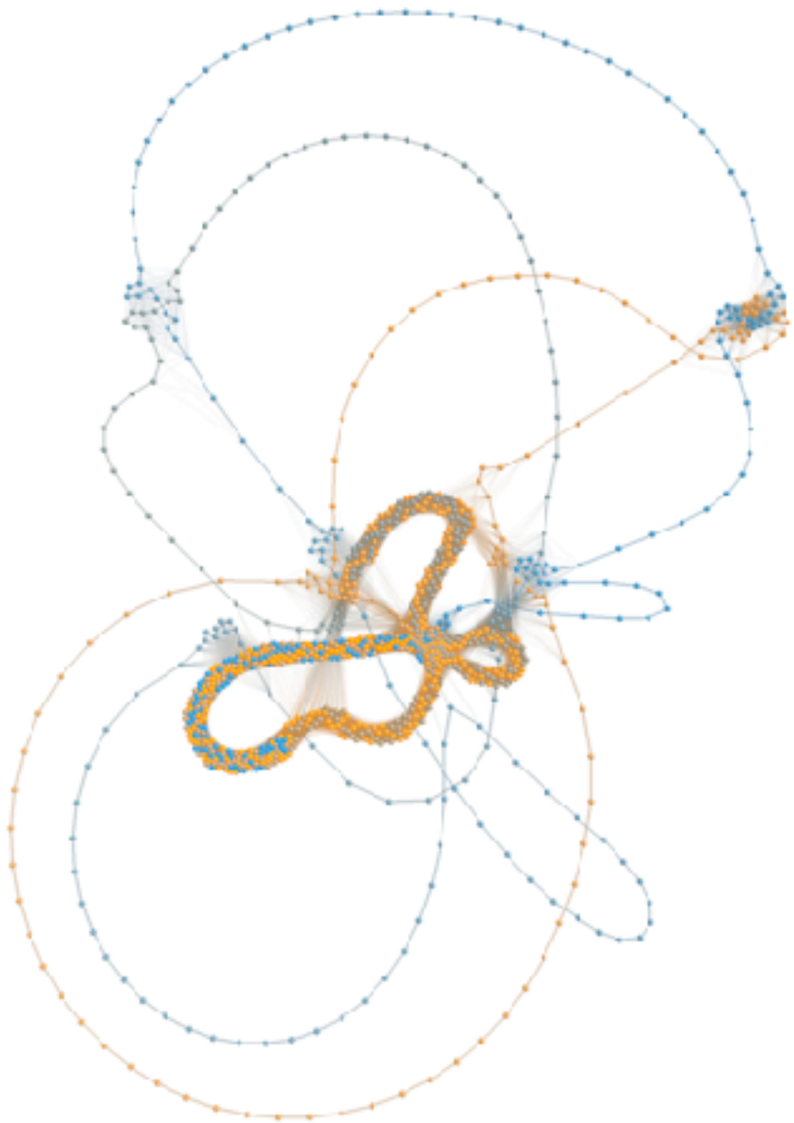

BOOK I
BOOK II
BOOK III
BOOK IV
BOOK IX
BOOK V
BOOK VI
BOOK VII
BOOK VIII
BOOK X
BOOK XI
BOOK XII
BOOK XIII
BOOK XIV
BOOK XIX
BOOK XV
BOOK XVI
BOOK XVII
BOOK XVIII
BOOK XX
BOOK XXI
BOOK XXII
BOOK XXIII
BOOK XXIV

Lyrics



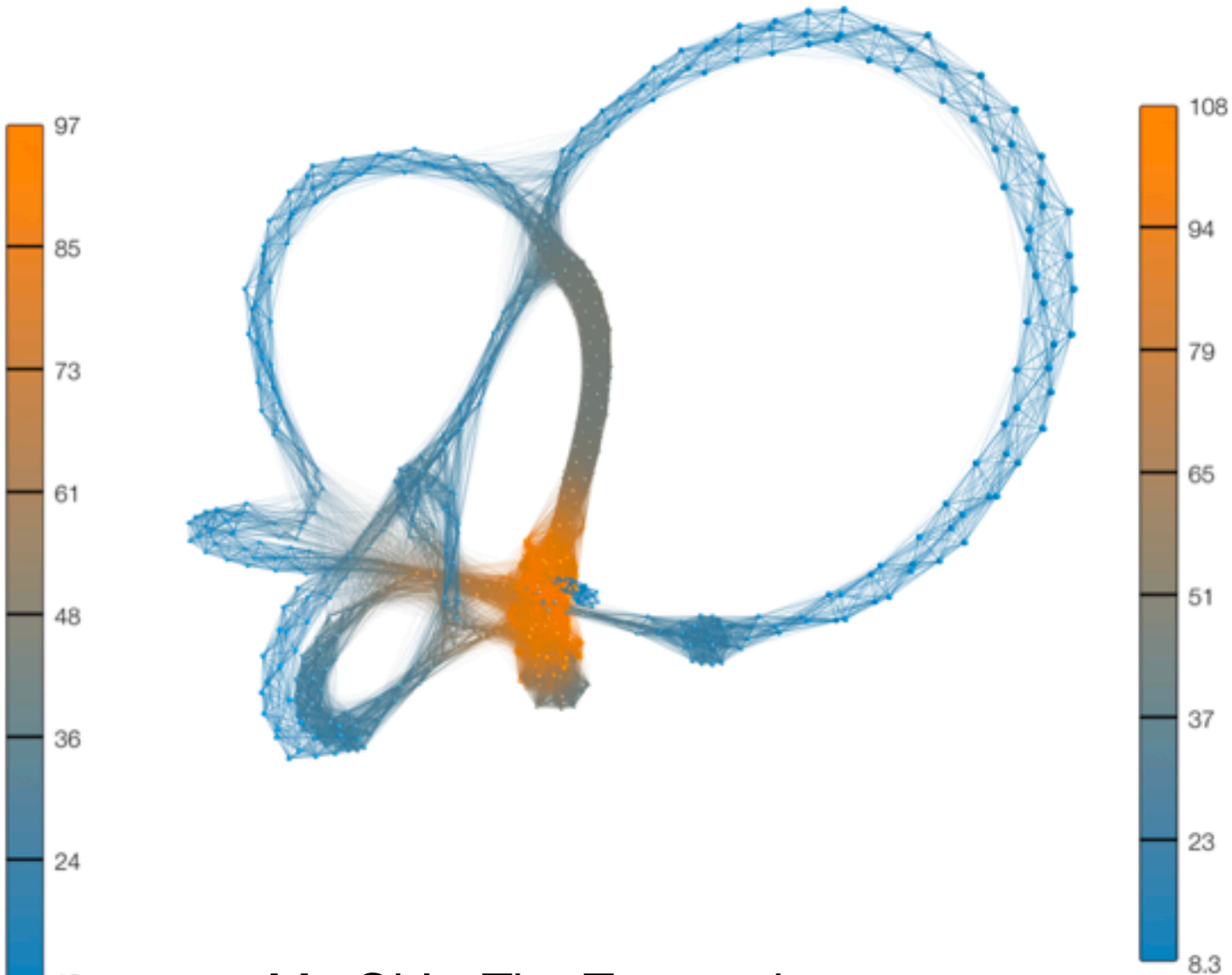
Dancing Queen - ABBA



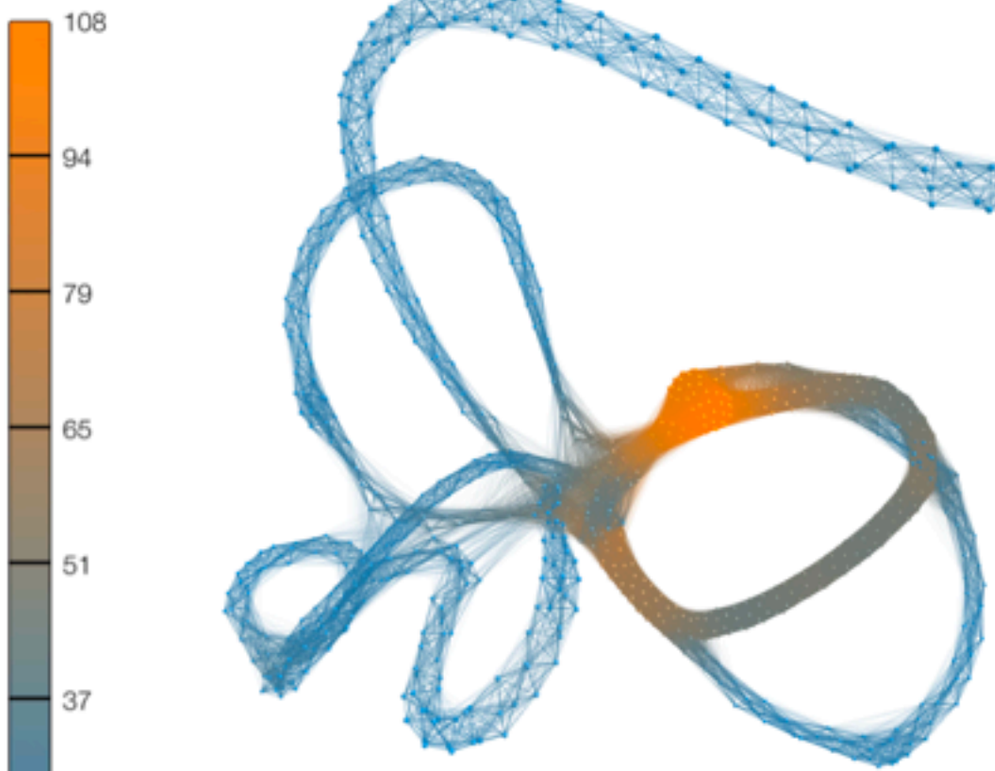
Pruned version

Mesoscopic Network Analyses of Song Lyrics
H. F. de Arruda, F. N. Silva, A. de A. Costa, S. M. Reia, D. R. Amancio, L. da F. Costa
(In preparation)

Lyrics



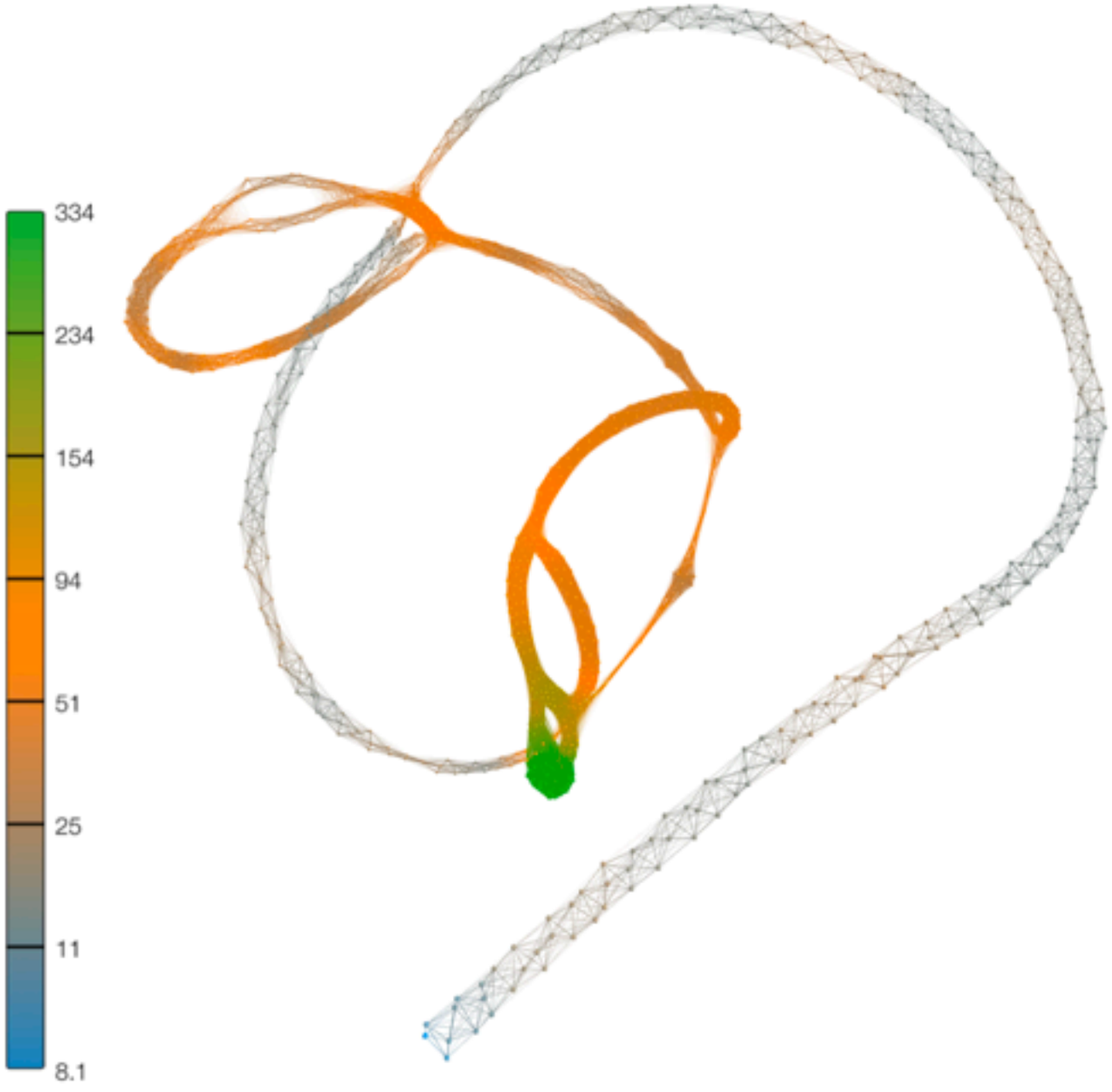
My Girl - The Temptations



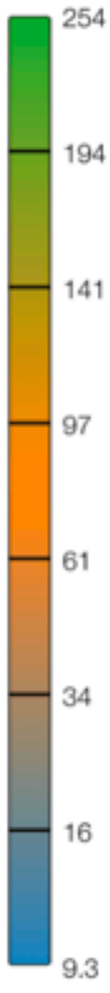
Footloose - Kenny Loggins

Mesoscopic Network Analyses of Song Lyrics
H. F. de Arruda, F. N. Silva, A. de A. Costa, S. M. Reia, D. R. Amancio, L. da F. Costa
(In preparation)

Lyrics



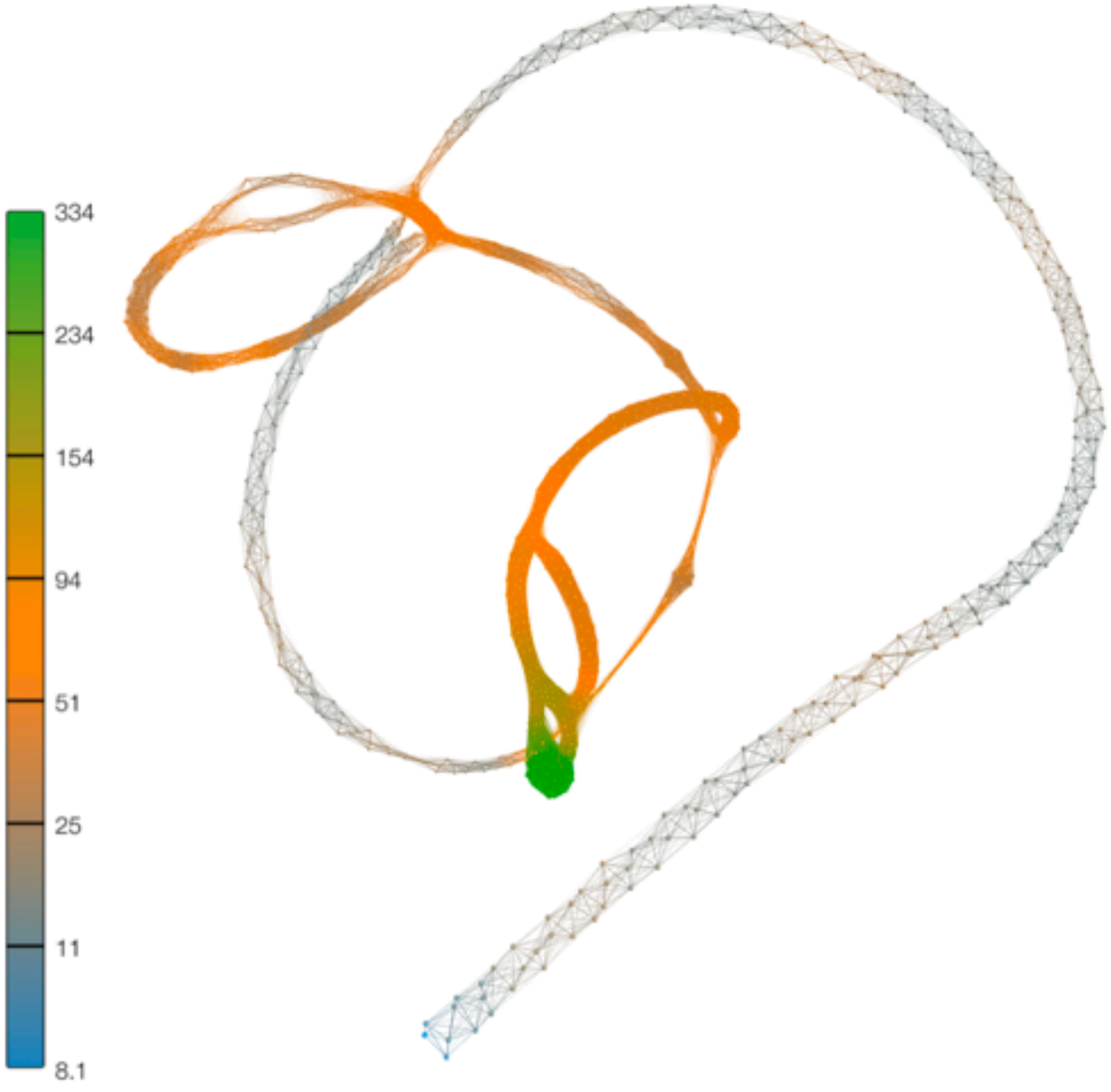
Roar - Kate Perry



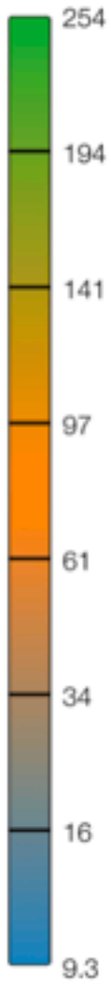
Baby - Justin Bieber

Mesoscopic Network Analyses of Song Lyrics
H. F. de Arruda, F. N. Silva, A. de A. Costa, S. M. Reia, D. R. Amancio, L. da F. Costa
(In preparation)

Lyrics



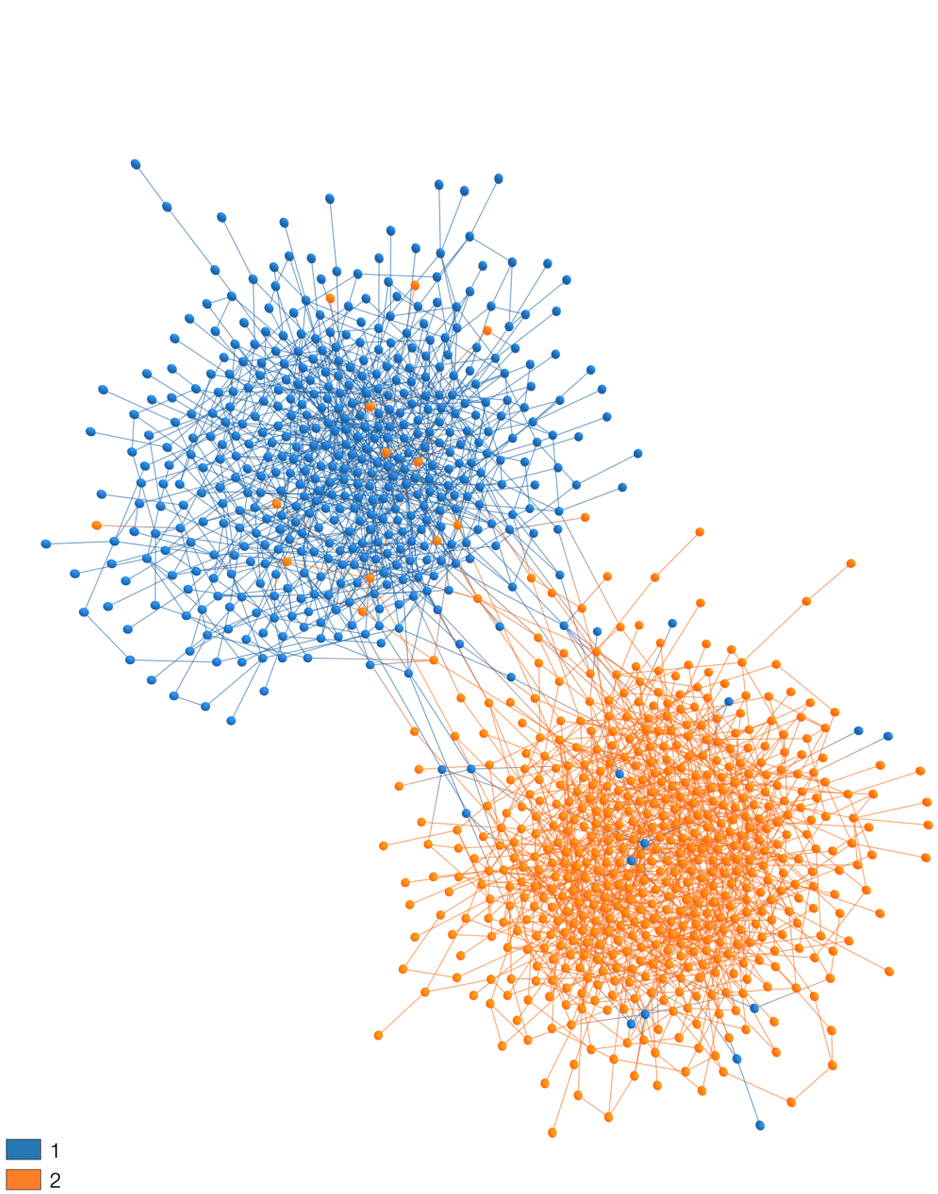
Roar - Kate Perry

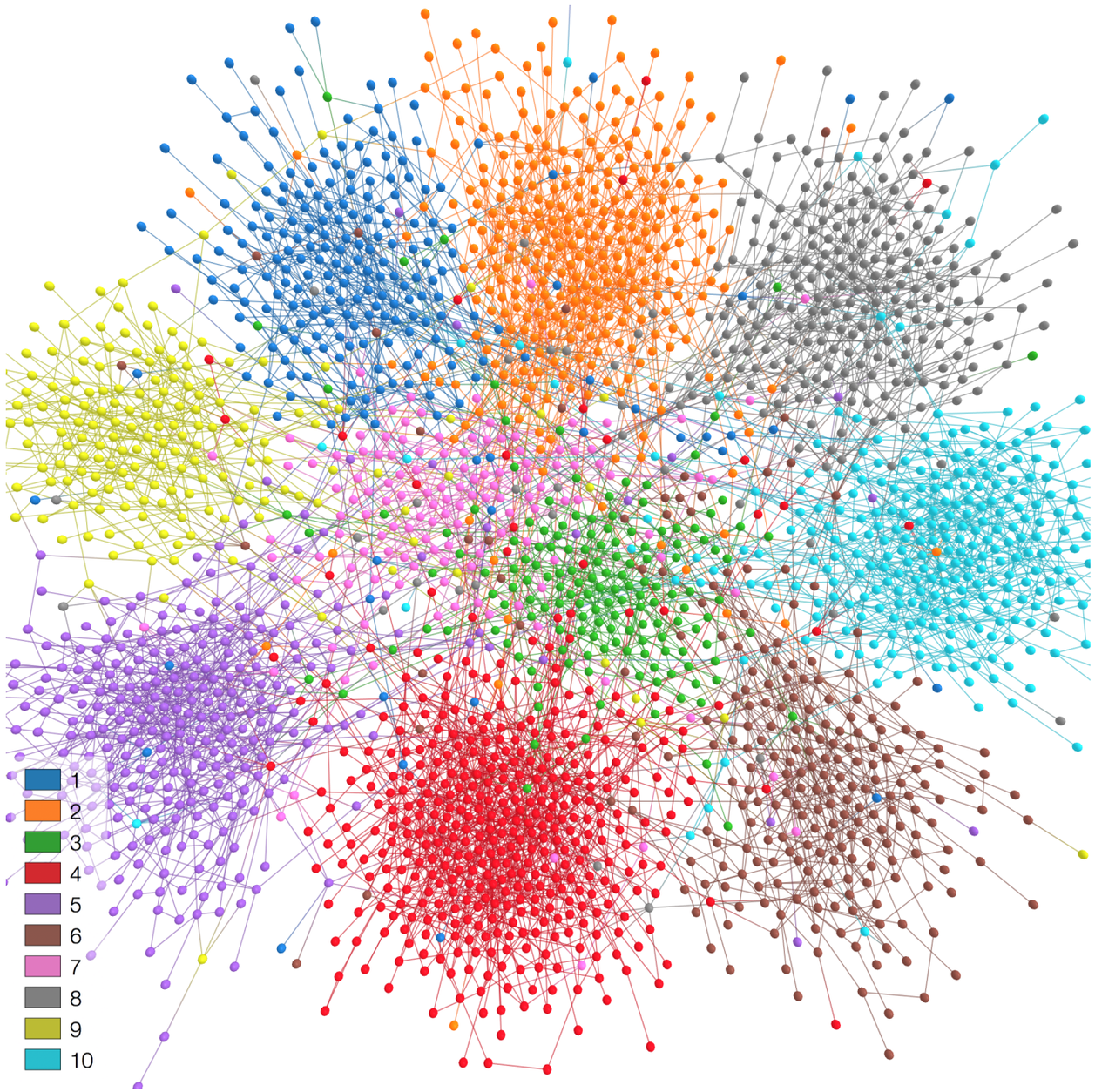


Baby - Justin Bieber

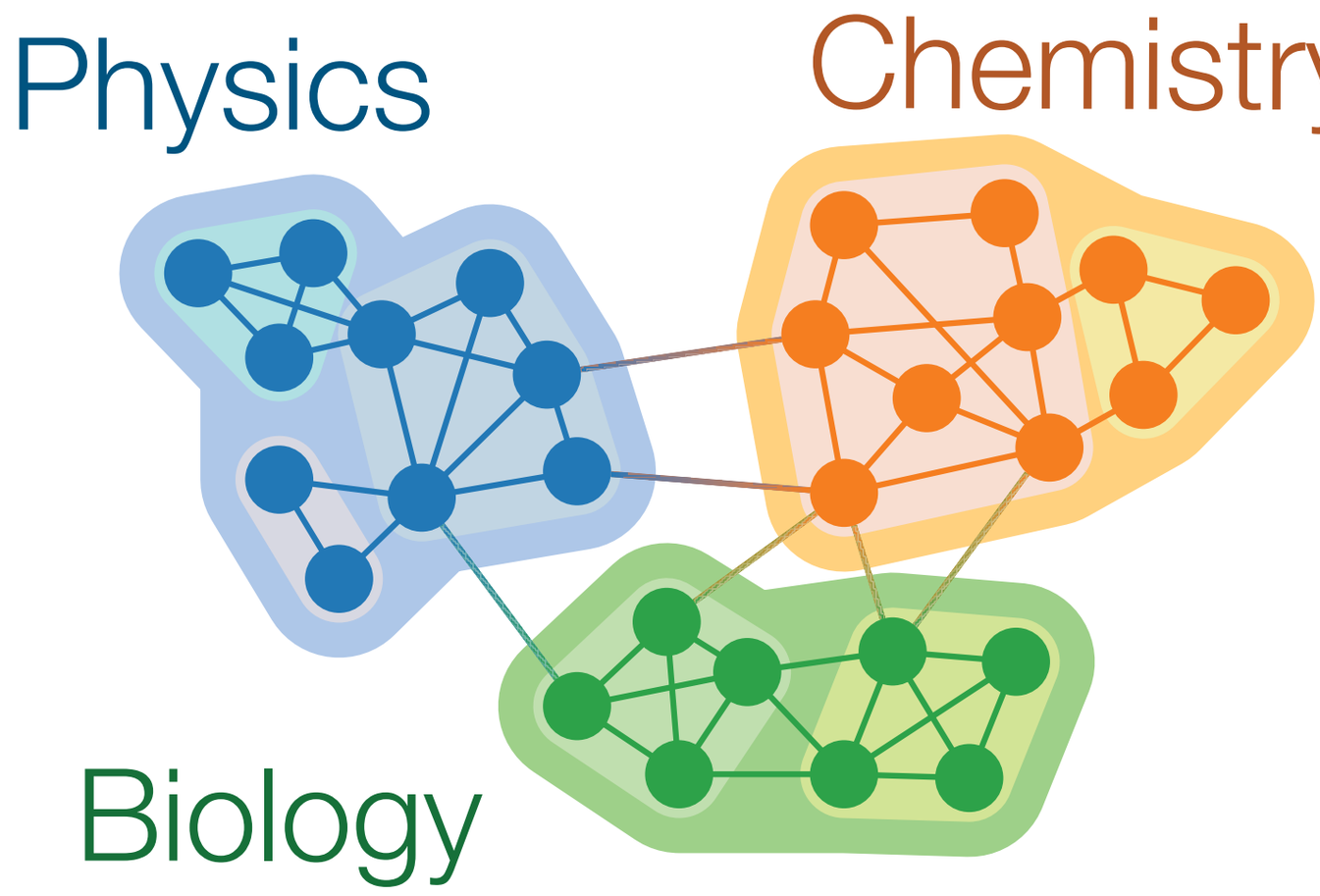
Mesoscopic Network Analyses of Song Lyrics
H. F. de Arruda, F. N. Silva, A. de A. Costa, S. M. Reia, D. R. Amancio, L. da F. Costa
(In preparation)

Social Bubbles dynamics using Sznajd Model

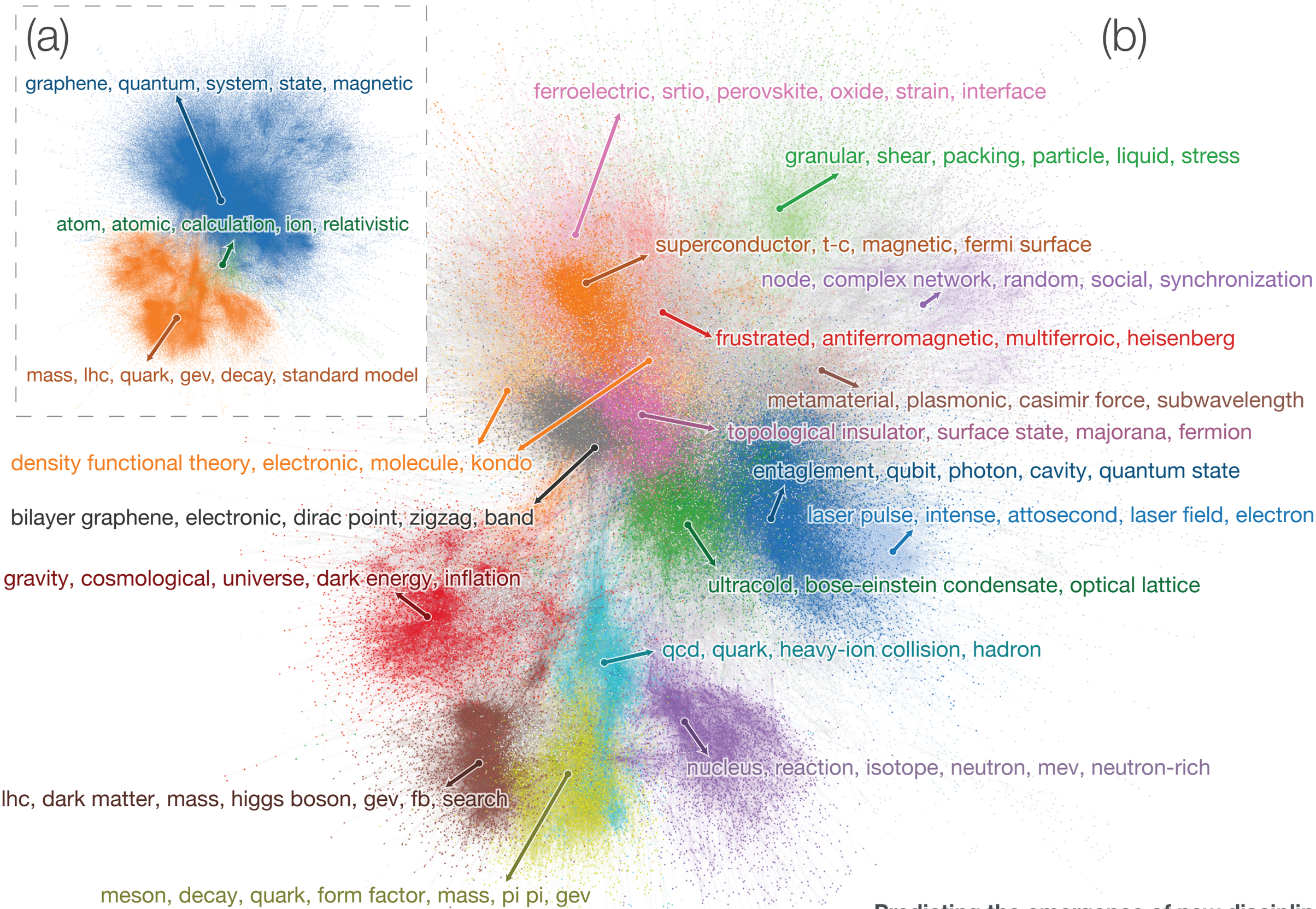




Opinion Diversity and Social Bubbles in Adaptive Sznajd Networks
A Benatti, HF de Arruda, FN Silva, CH Comin, LF Costa
arXiv preprint arXiv:1905.00867

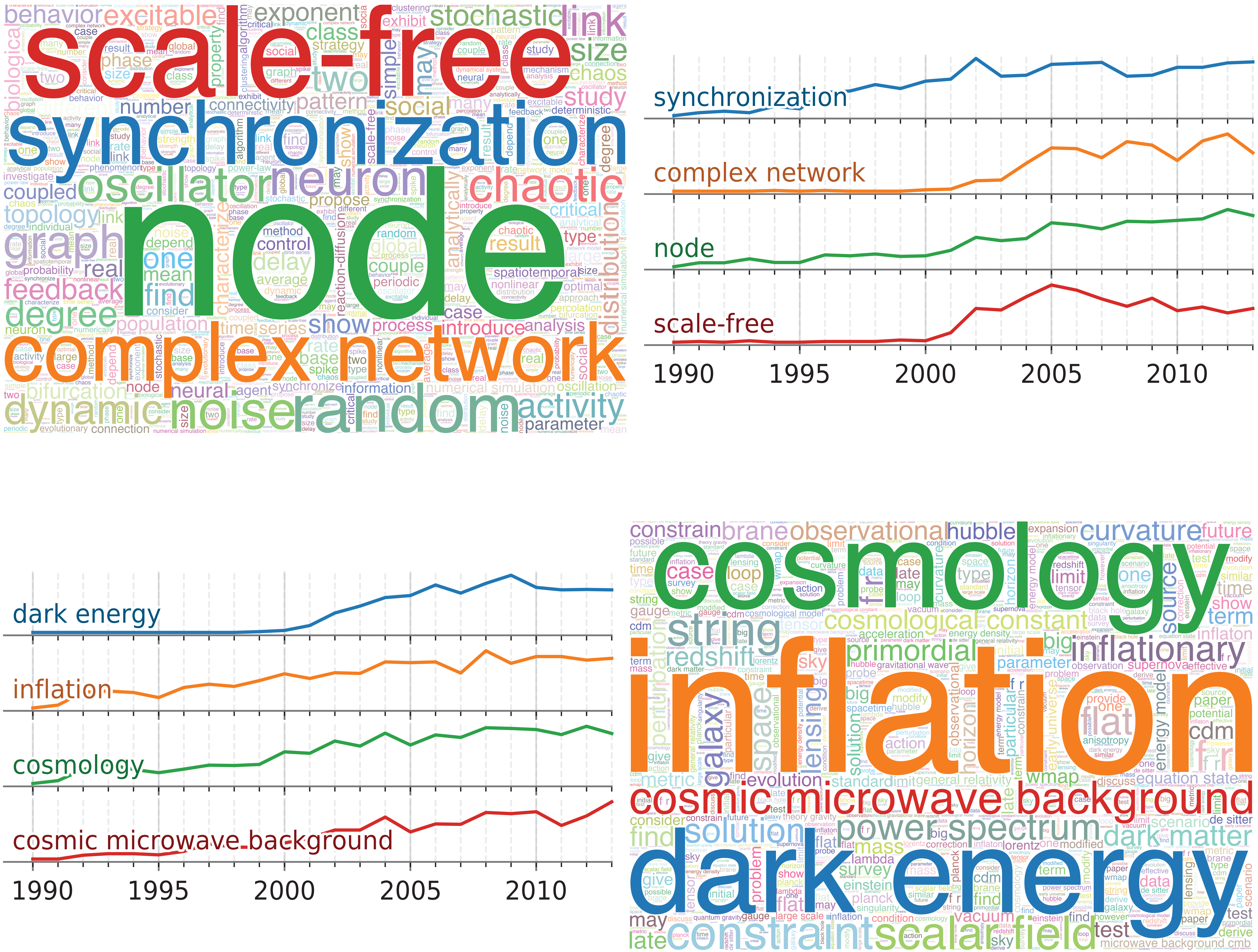

Physics
Chemistry
Biology

Dynamics of scientific disciplines



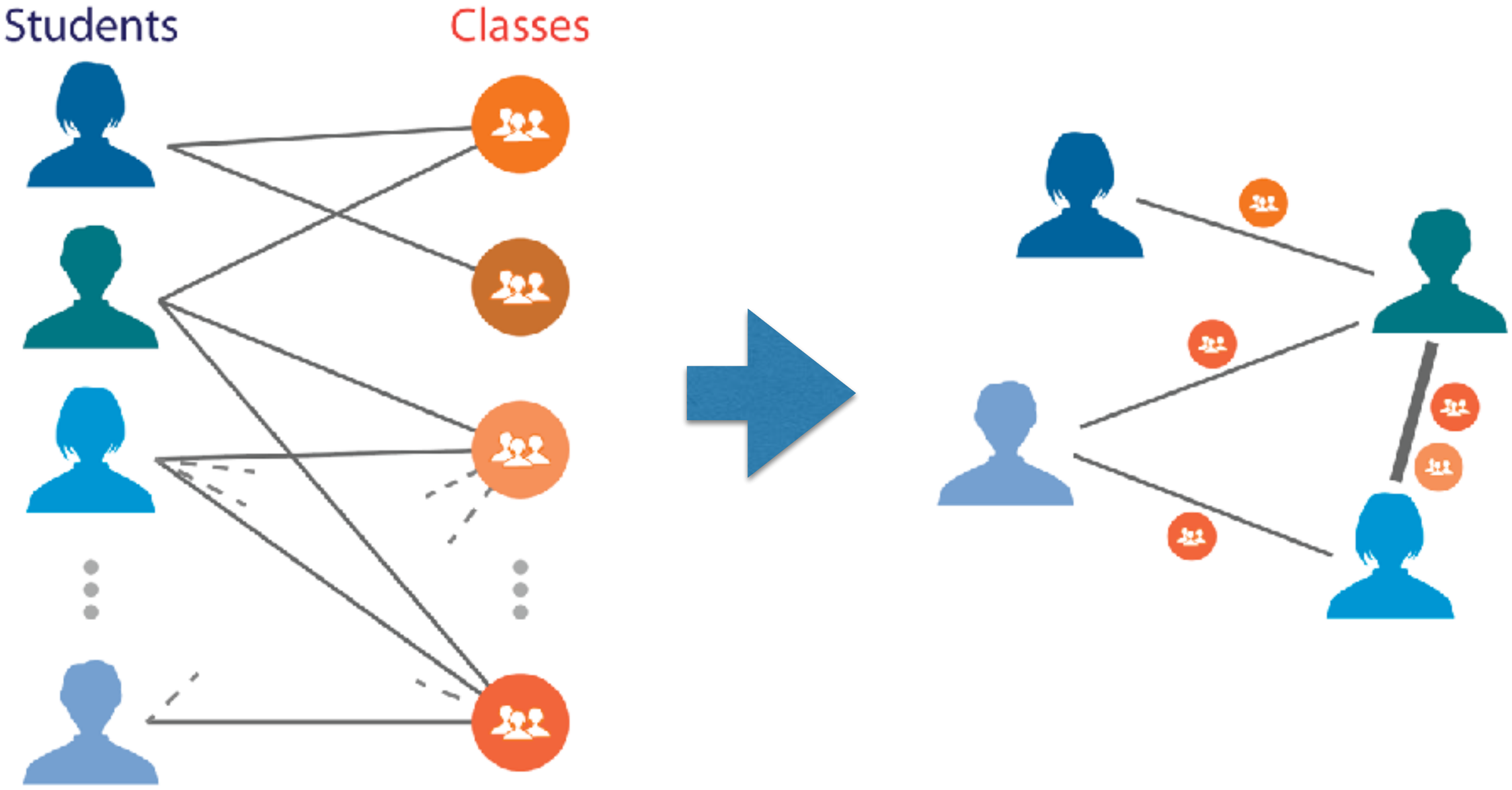
Predicting the emergence of new disciplines

F. N. Silva, A. Tandon, D. R. Amancio, A. Flammini, F. Menczer, S. Milosevic, Fortunato, S. (In preparation)



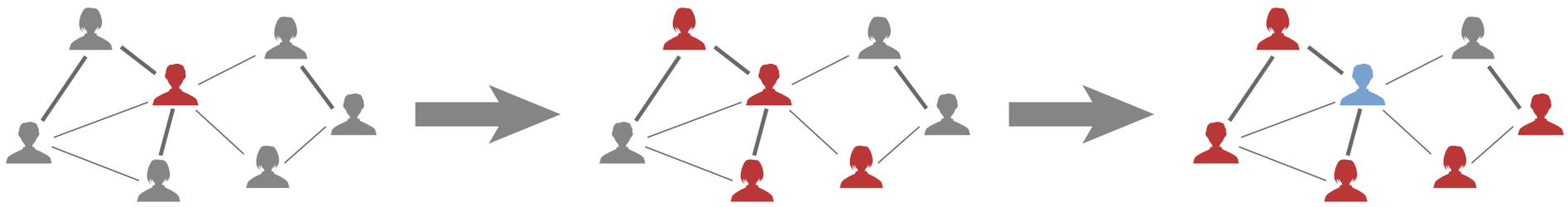
scale-free
synchronization
node
complex network
oscillator
neuron
chaotic
graph
degree
random
noise
dynamic
activity
feedback
topology
coupled
stochastic
exponent
excitable
behavior
link
size
chaos
study
synchronization
complex network
node
scale-free
1990
1995
2000
2005
2010
dark energy
inflation
cosmology
cosmic microwave background
1990
1995
2000
2005
2010
cosmology
inflation
cosmic microwave background
dark energy
power spectrum
cosmological constant
inflationary
string
redshift
primordial
curvature
hubble
observational
brane
constrain
dark matter
solution
scalar field
constraint

Epidemias, modelo SIR



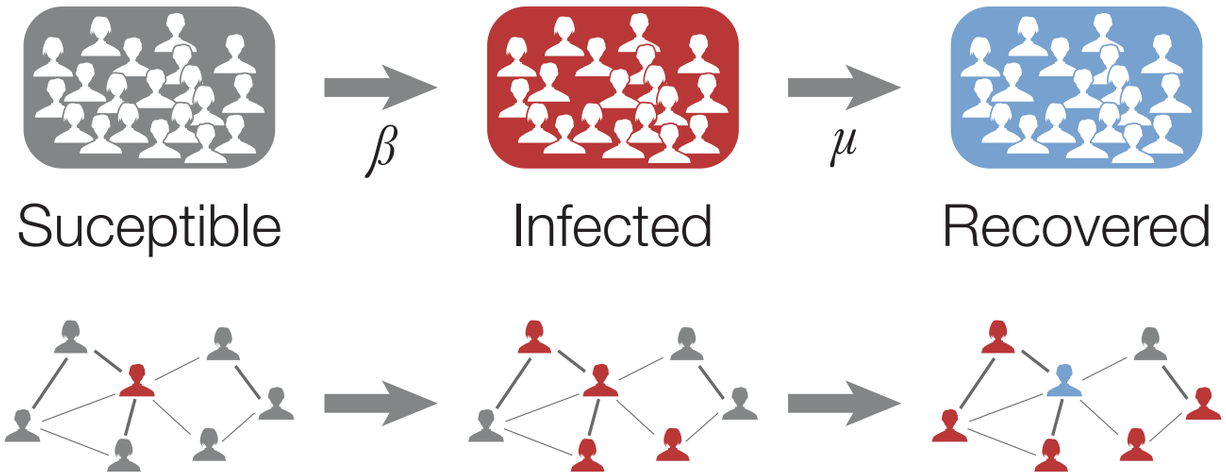
Epidemias, modelo SIR

Suceptible Infected Recovered

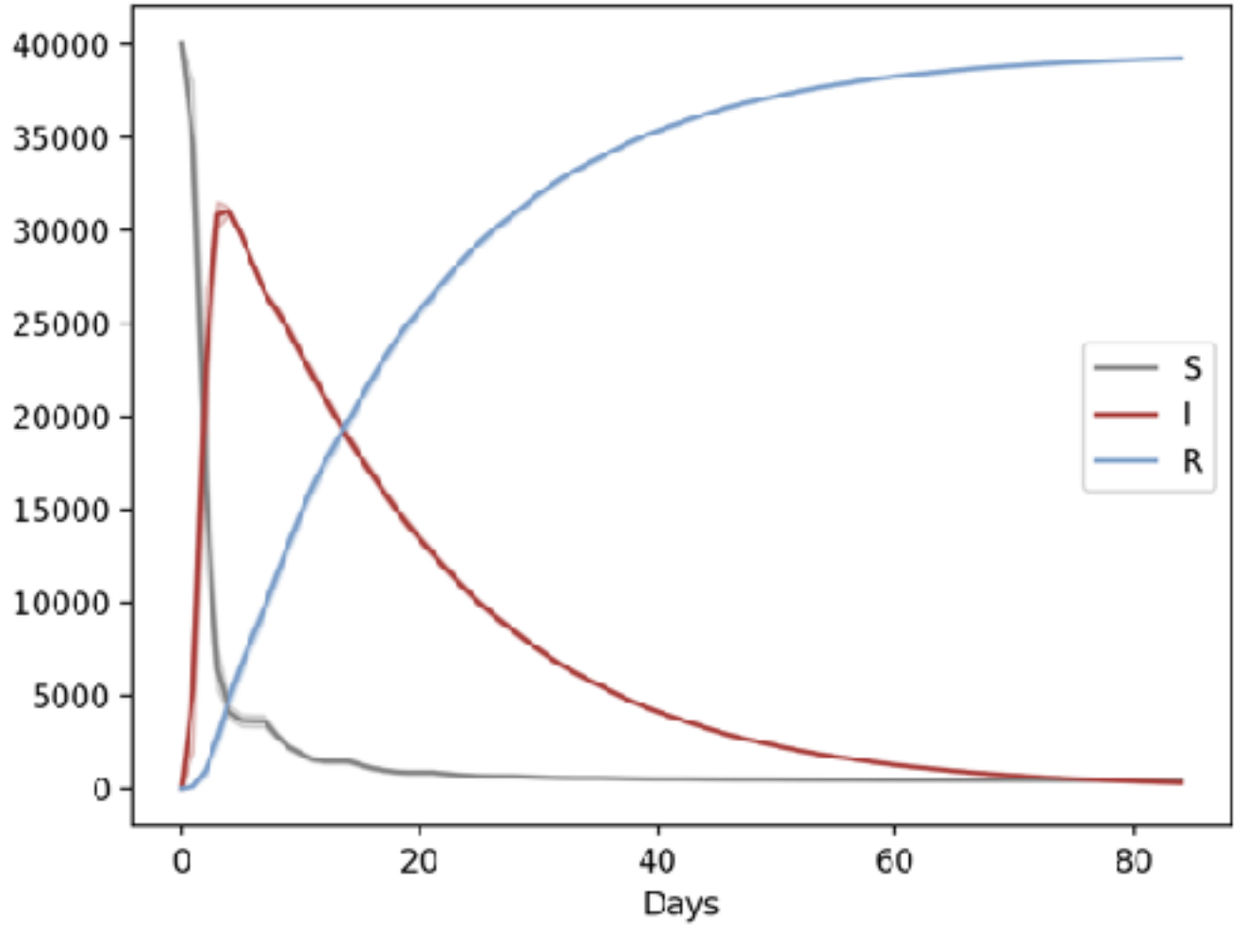


http://bl.ocks.org/ccattuto/raw/5892995/

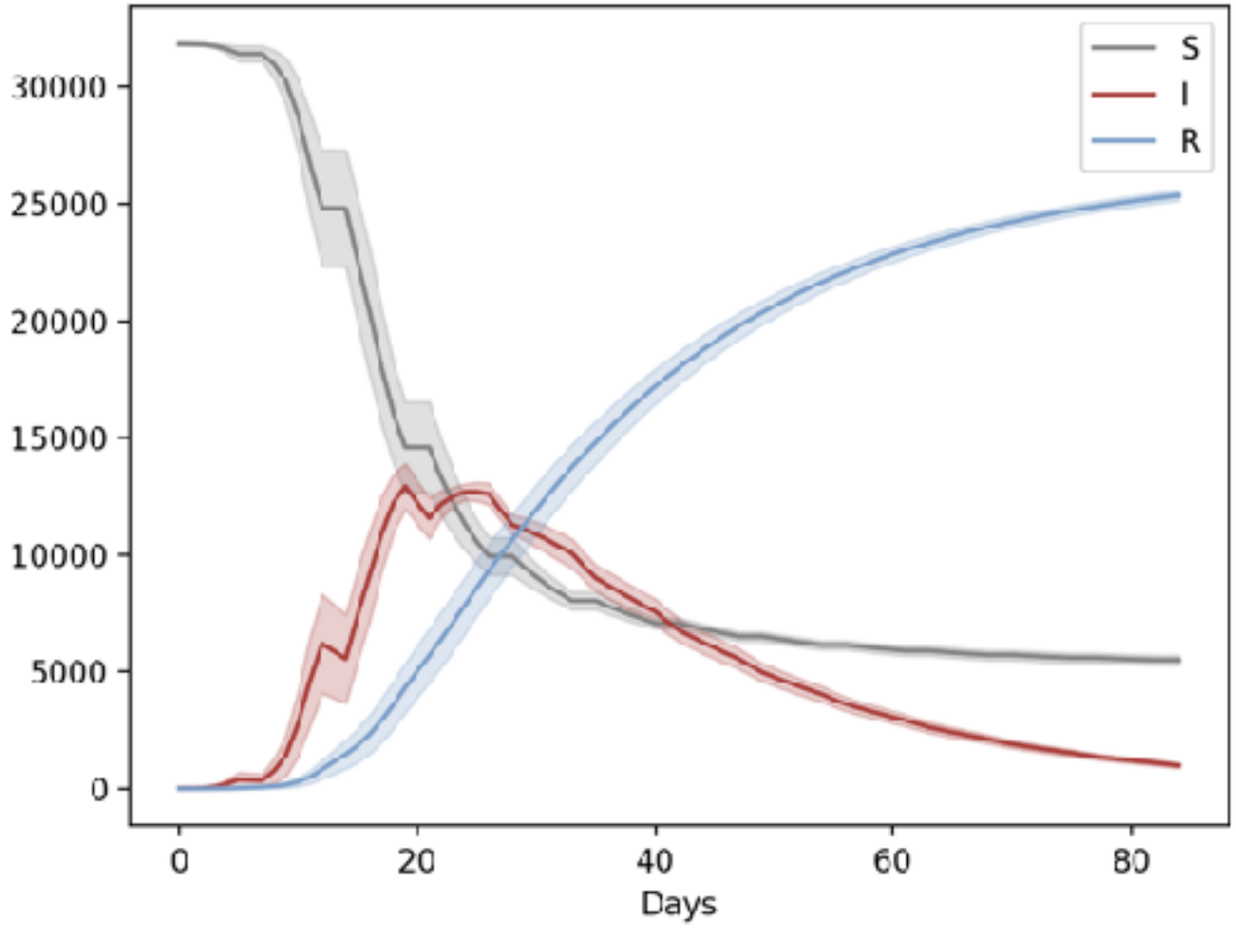
Epidemias, modelo SIR



Todas as classes



50% das classes online



Sociology

History

Philosophy

Biology

Medicine

Mathematics

Engineering

Physics

Chemistry

Links

Crie seu grafo
https://bl.ocks.org/mbostock/929623

Crie seu grafo dirigido
http://bl.ocks.org/rkirsling/5001347

Jogo vacinação baseado em redes
vax.herokuapp.com

Modelo SIR
http://bl.ocks.org/ccattuto/raw/5892995/

Modelo Erdos-Renyi
http://bl.ocks.org/christophermanning/4187201

Modelo Barabasi-Albert
https://bl.ocks.org/filipinascimento/raw/20357a893d16df569e8925d14d9533f5/

Visualizações
http://cyvision.ifsc.usp.br/networkstools/

Links vídeos de visualização de redes
https://youtu.be/jy5Dx_W9knc

Estados brasileiros ilustrando metodo direcionado por forças
https://bl.ocks.org/filipinascimento/raw/e656330ffd3ffcfaa59216d869fcdc06
Textos didáticos sobre redes complexas
(CDT, em inglês)
https://www.researchgate.net/project/Costas-Didactic-Texts-CDTs

Documentário: Seis graus de separação.
www.youtube.com/watch?v=BQ7UDWn_uws

Nerdologia: Seis graus de separação
www.youtube.com/watch?v=YMI3CrChwSk

Site do livro sobre o assunto
barabasi.com/networksciencebook/

Análise das redes dos filmes de Star Wars
http://evelinag.com/blog/2015/12-15-star-wars-social-network/index.html

A first Course in network science (Livro)
https://cambridgeuniversitypress.github.io/FirstCourseNetworkScience/