



Complex networks



Interactive visualization



Data analysis

Filipi Nascimento Silva  
Research Scientist at IUNI



# Research Interests

# Science of science

# Urban network analysis

# Network visualization

# Text analysis

# Gene co-expression

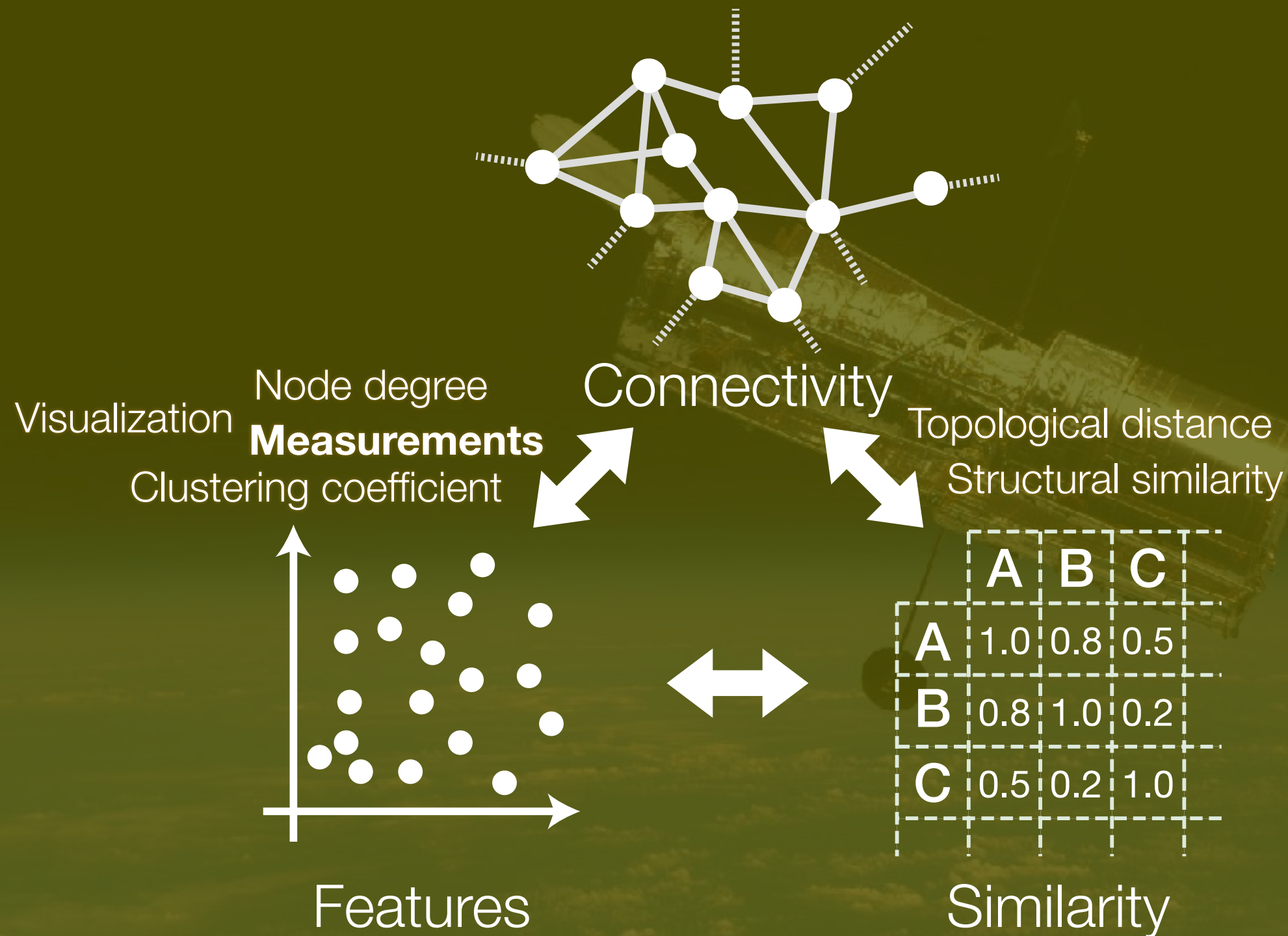
# Networks

# Social





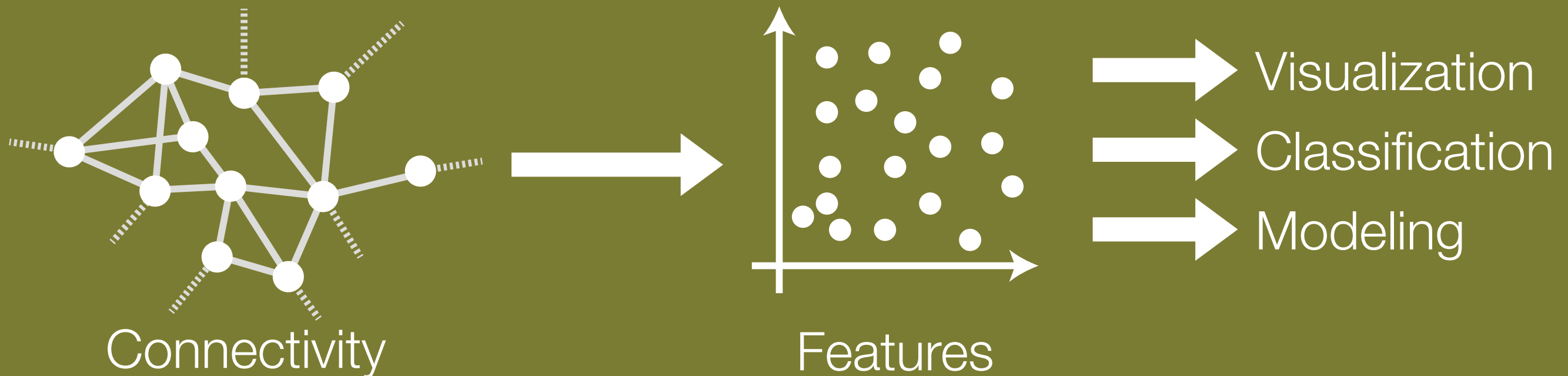
# Representing and modeling complex systems





# Representing and modeling complex systems

Informative features for nodes?



Global vs local measurements

Dependence with the size of networks is not desirable



internet

arts

geology

WWW

health

scientific  
collaboration

urban  
network

molecular  
biology

images

sociology

airports

ecology

disease  
dissemination

cellphone  
network

financial  
market

music

neuroscience

linguistics

etc, etc,  
etc

genetics

proteins



# Quantifying the interdisciplinarity of scientific journals and fields

Journal of Informetrics 7 (2013) 469–477



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Journal of Informetrics

journal homepage: [www.elsevier.com/locate/joi](http://www.elsevier.com/locate/joi)



## Quantifying the interdisciplinarity of scientific journals and fields



F.N. Silva<sup>a,\*</sup>, F.A. Rodrigues<sup>b</sup>, O.N. Oliveira Jr<sup>a</sup>, L. da F. Costa<sup>a</sup>

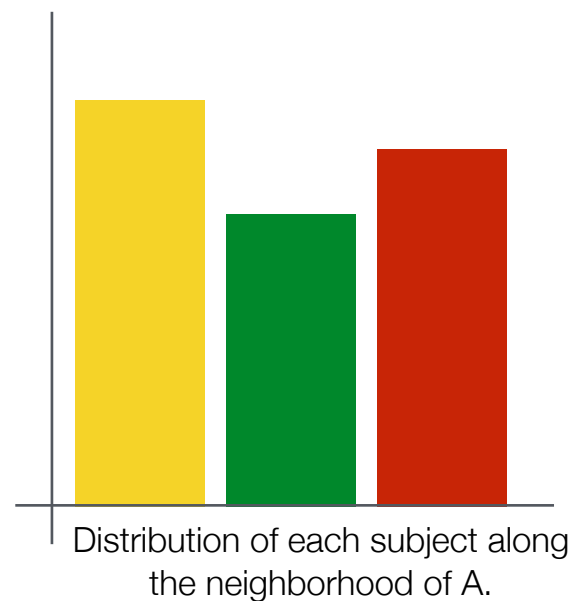
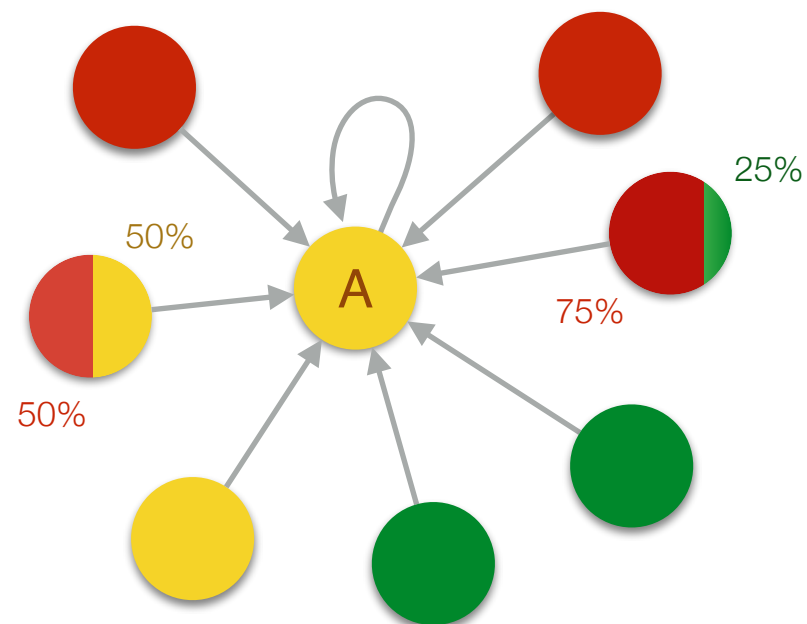
<sup>a</sup> Institute of Physics of São Carlos, University of São Paulo, Brazil

<sup>b</sup> Institute of Mathematics and Computer Sciences, University of São Paulo, National Institute of Science and Technology for Complex Systems, Rio de Janeiro, Brazil

# Quantifying the interdisciplinarity of scientific journals and fields

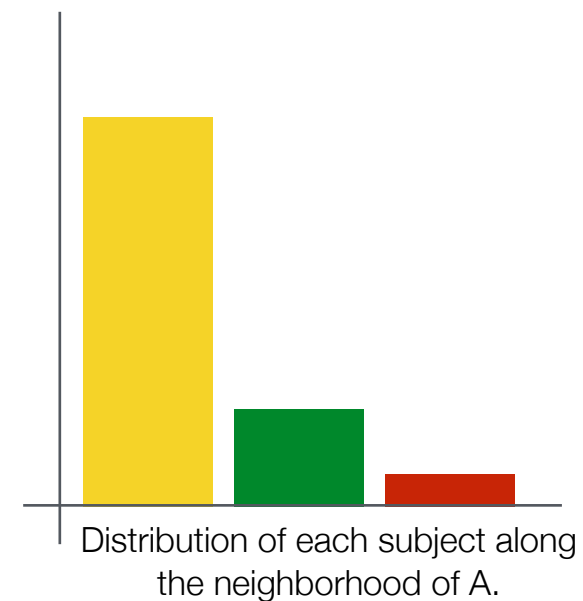
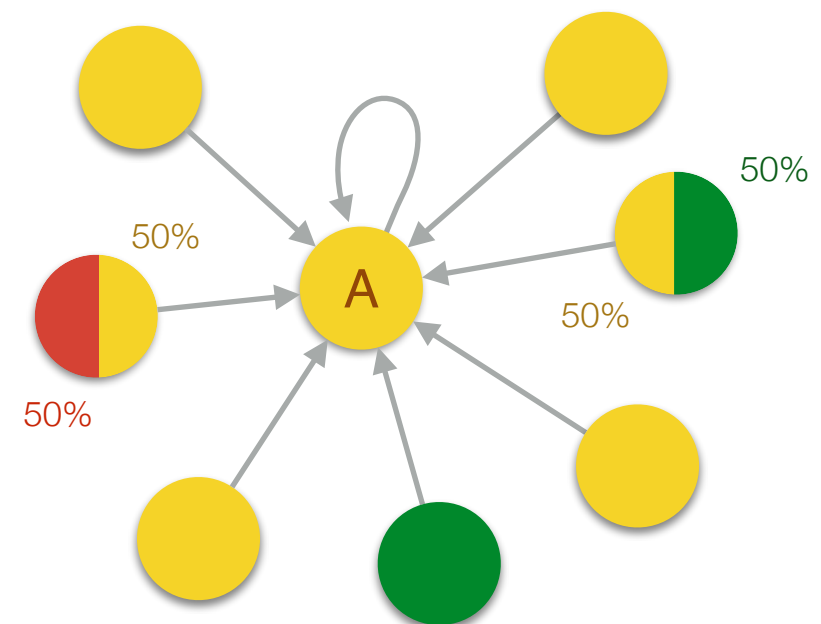
Configuration of **High**  
subject entropy for A.

*High interdisciplinarity*

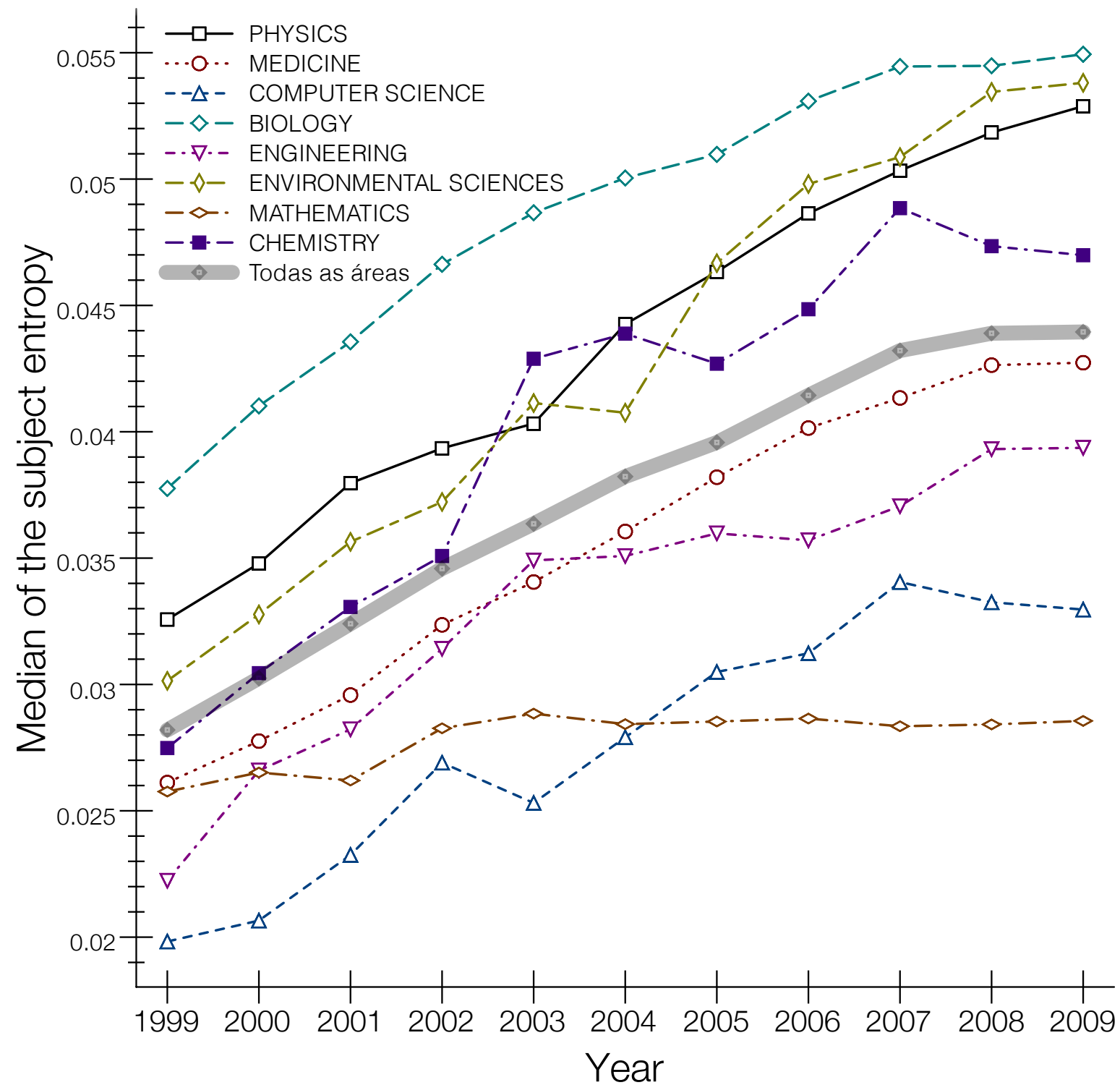


Configuration of **Low**  
subject entropy for A.

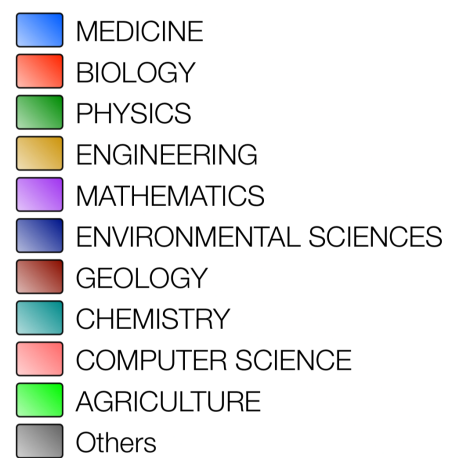
*Low interdisciplinarity*



# Quantifying the interdisciplinarity of scientific journals and fields







#	Journal	Subject Entropy
1	Nature	8.61
2	Science	8.38
3	PNAS	7.22
4	Journal of Biological Chemistry	5.07
5	The New England Journal of Medicine	4.20
6	PRL	4.08
7	Journal of the American Chemical Society	3.52
8	The Lancet	3.43

Quantifying the interdisciplinarity of scientific journals and fields  
 F. N. Silva, F. A. Rodrigues, O.N. Oliveira Jr. and L. da F. Costa  
 Journal of Informetrics. Volume 7, Issue 2, Pages 469-477 (Apr, 2013)

# Bibliographic summarization

Journal of Informetrics 10 (2016) 487–502



Contents lists available at ScienceDirect

Journal of Informetrics

journal homepage: [www.elsevier.com/locate/joi](http://www.elsevier.com/locate/joi)



## Using network science and text analytics to produce surveys in a scientific topic



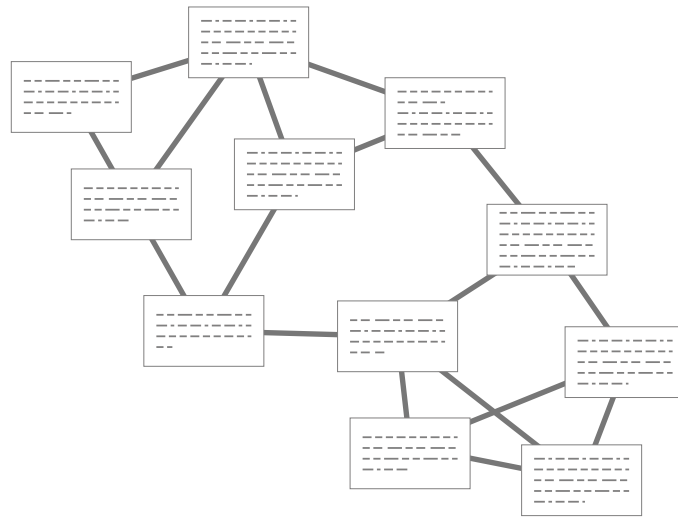
Filipi N. Silva<sup>a</sup>, Diego R. Amancio<sup>b,\*</sup>, Maria Bardosova<sup>c</sup>, Luciano da F. Costa<sup>a</sup>,  
Osvaldo N. Oliveira Jr.<sup>a</sup>

<sup>a</sup> São Carlos Institute of Physics, University of São Paulo, São Carlos, Brazil

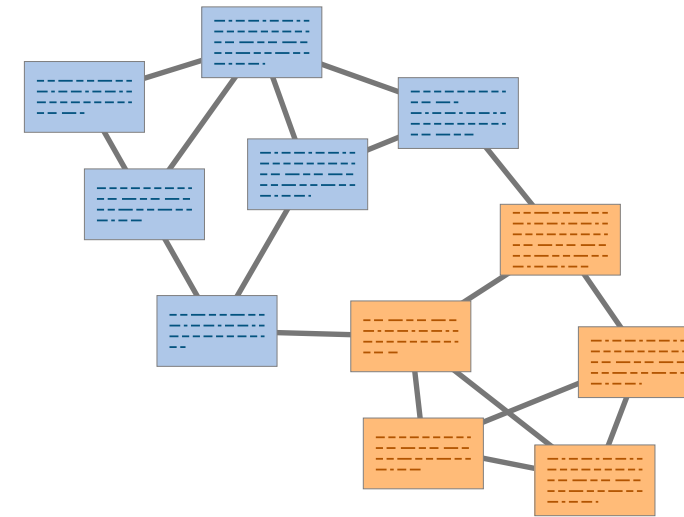
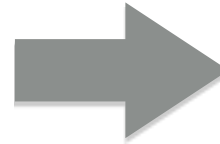
<sup>b</sup> Institute of Mathematics and Computer Science, University of São Paulo, São Carlos, Brazil

<sup>c</sup> Tyndall National Institute, Cork City, Ireland

Using network science and text analytics to produce surveys in a scientific topic  
Filipi N Silva, D.R. Amancio, M Bardosova, L. da F. Costa and Osvaldo N Oliveira Jr.  
Journal of Informetrics. Volume 10, 487-502 (2016)



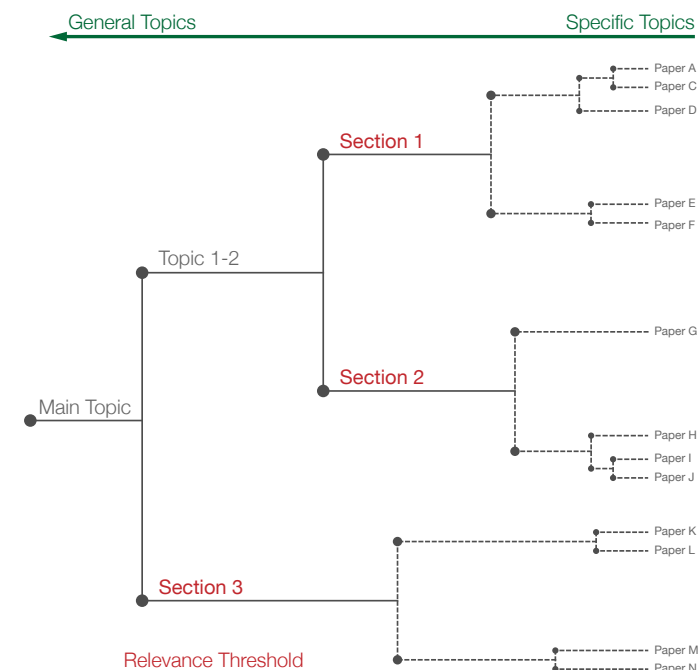
Citation network



Community structure



Paper abstracts

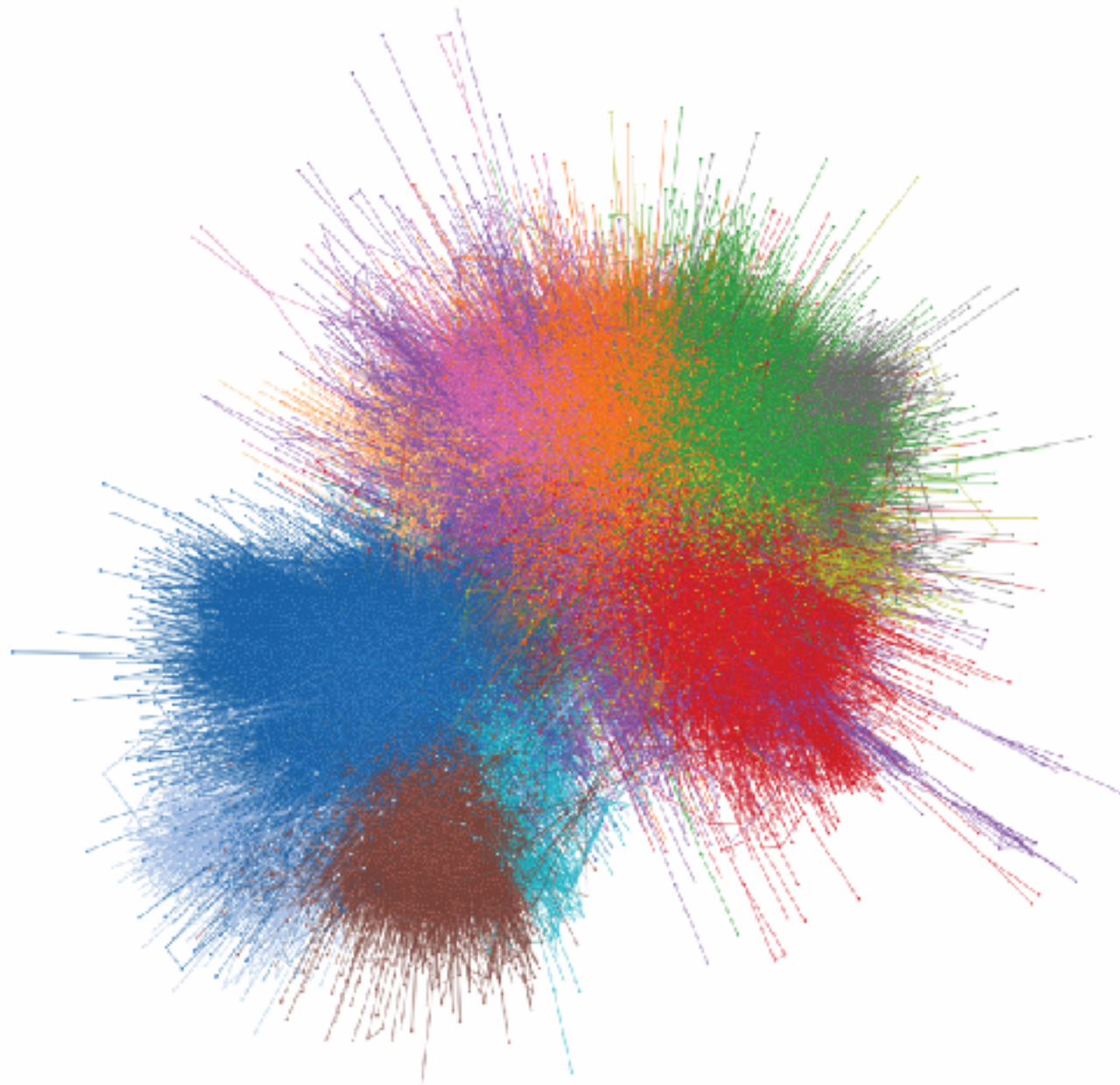
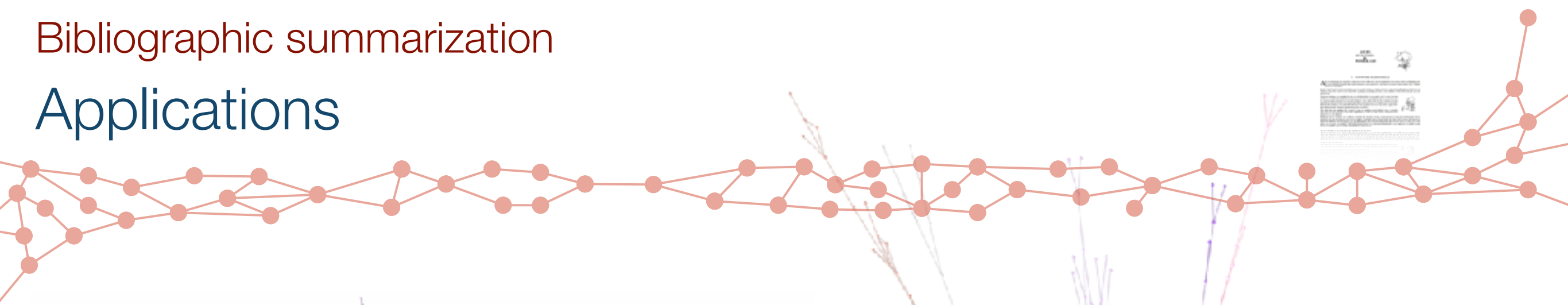


Survey structure





## Applications



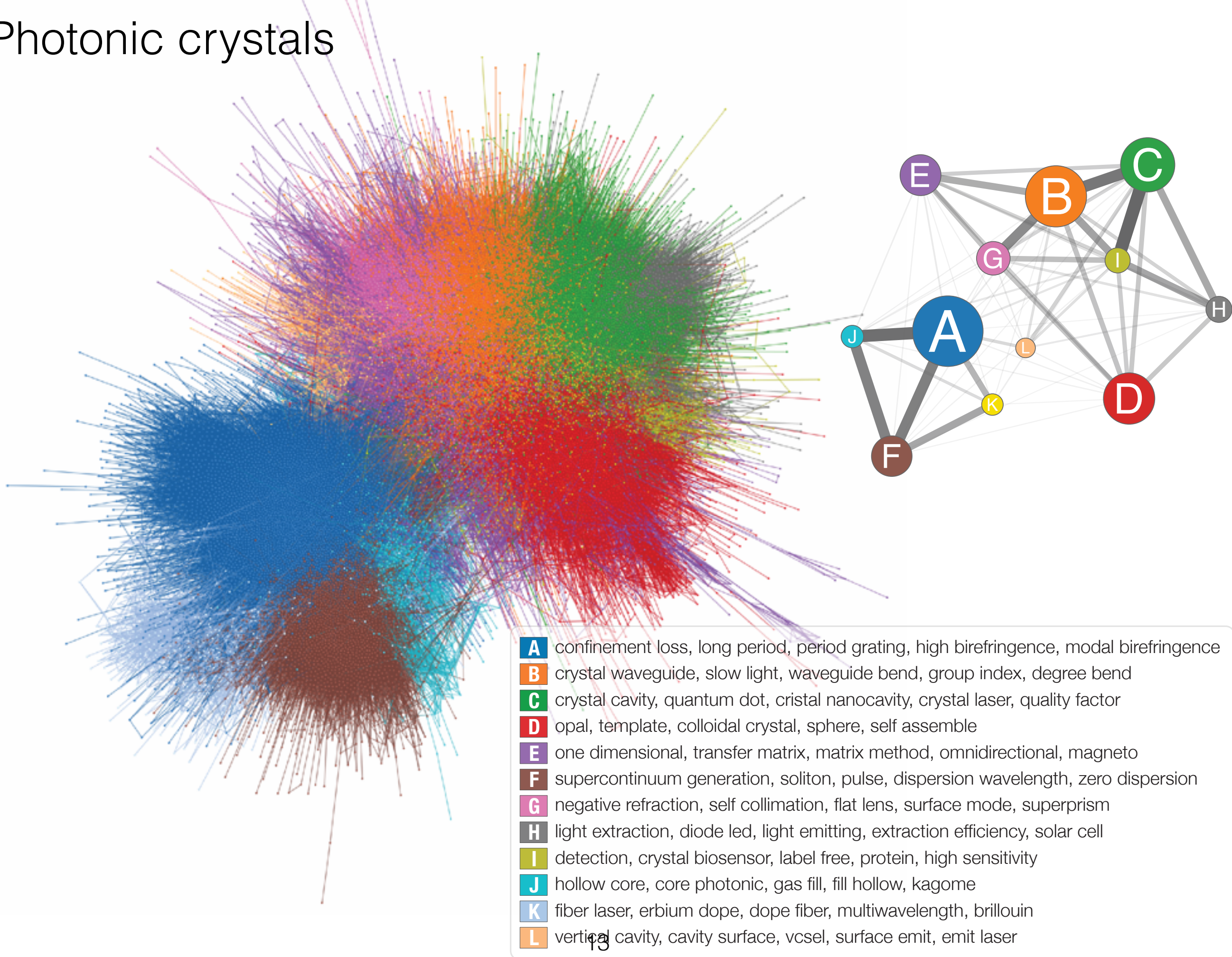
Photonic crystals



Complex networks

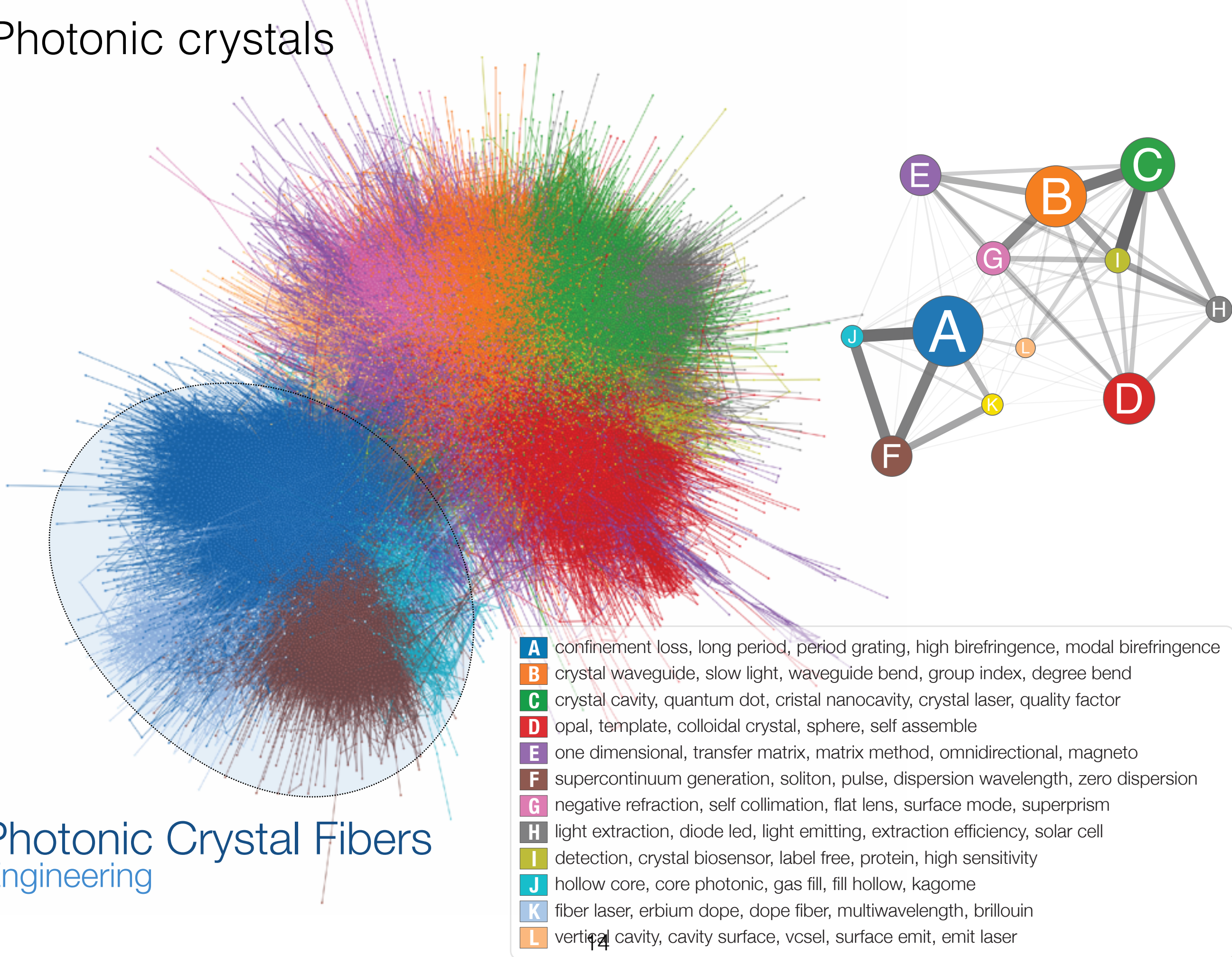


# Photonic crystals





# Photonic crystals





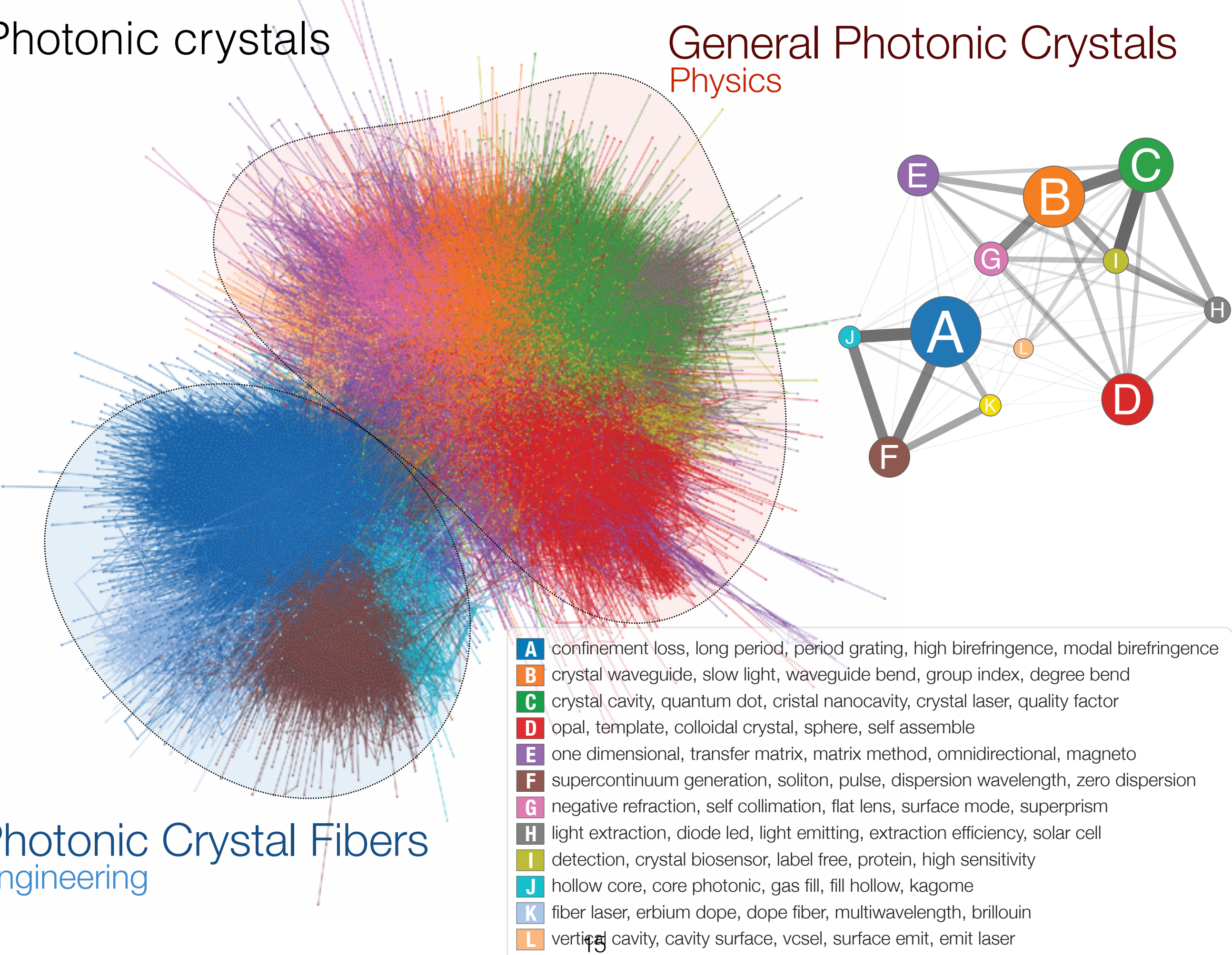
# Photonic crystals

# General Photonic Crystals

Physics

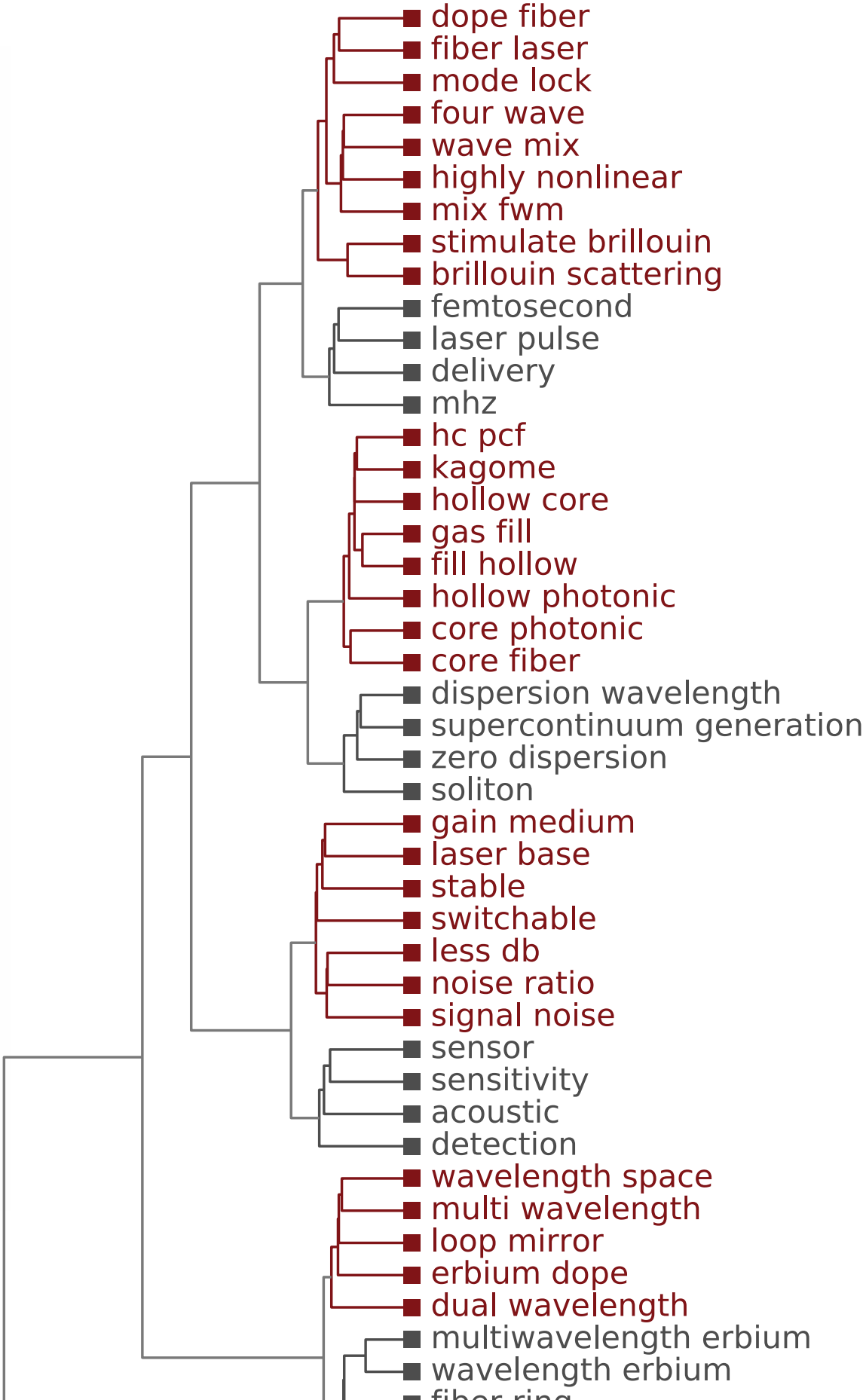
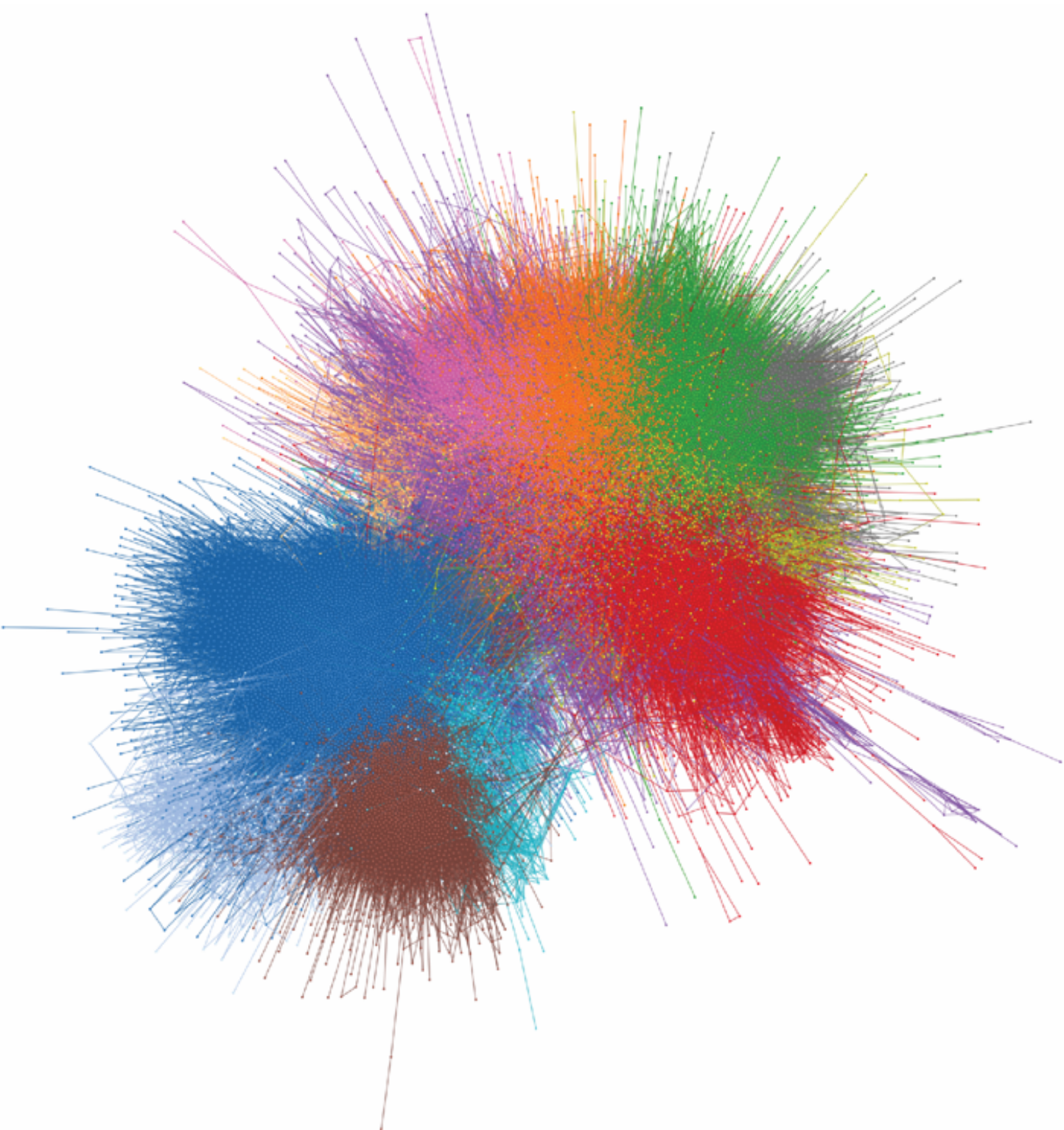
# Photonic Crystal Fibers

Engineering

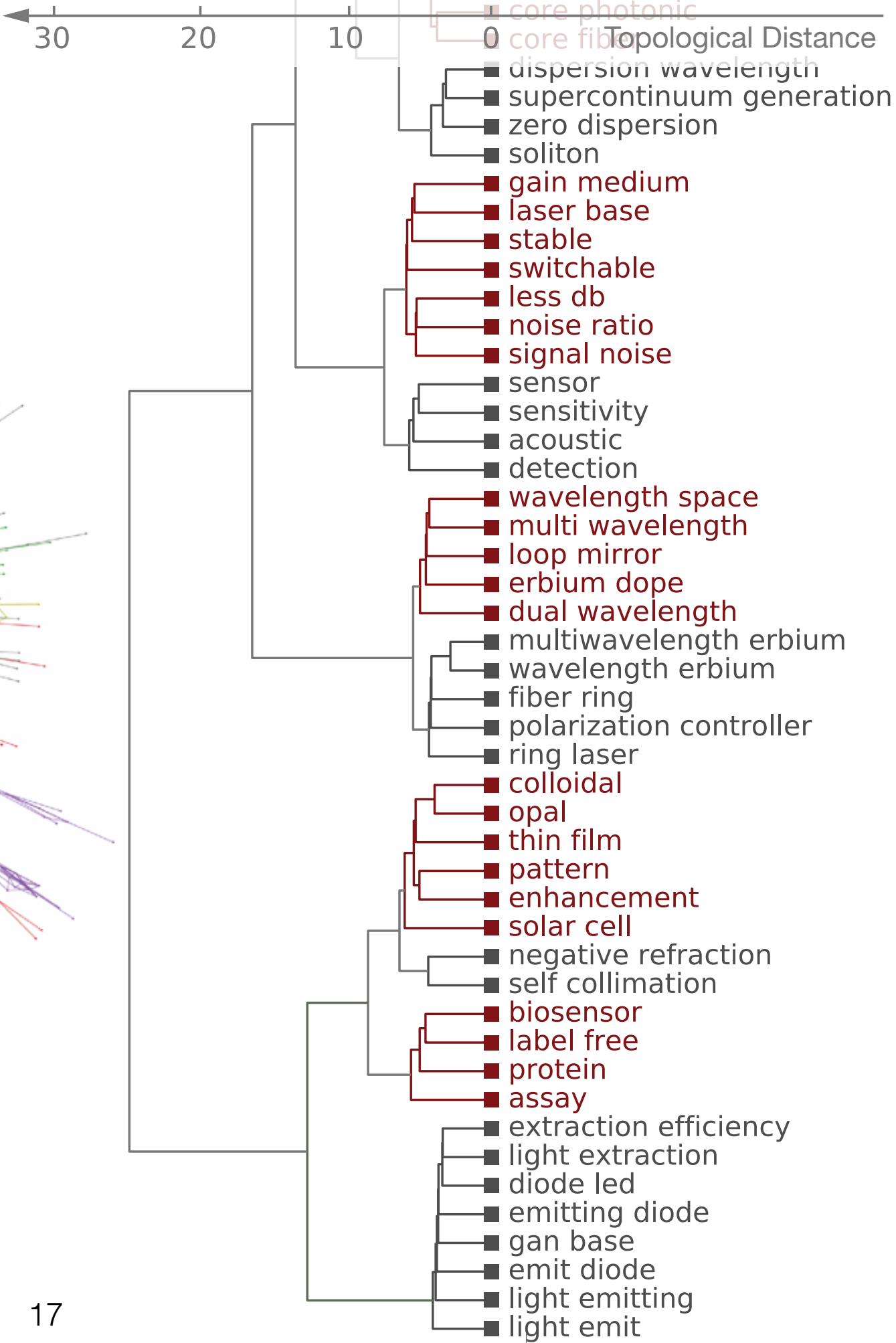
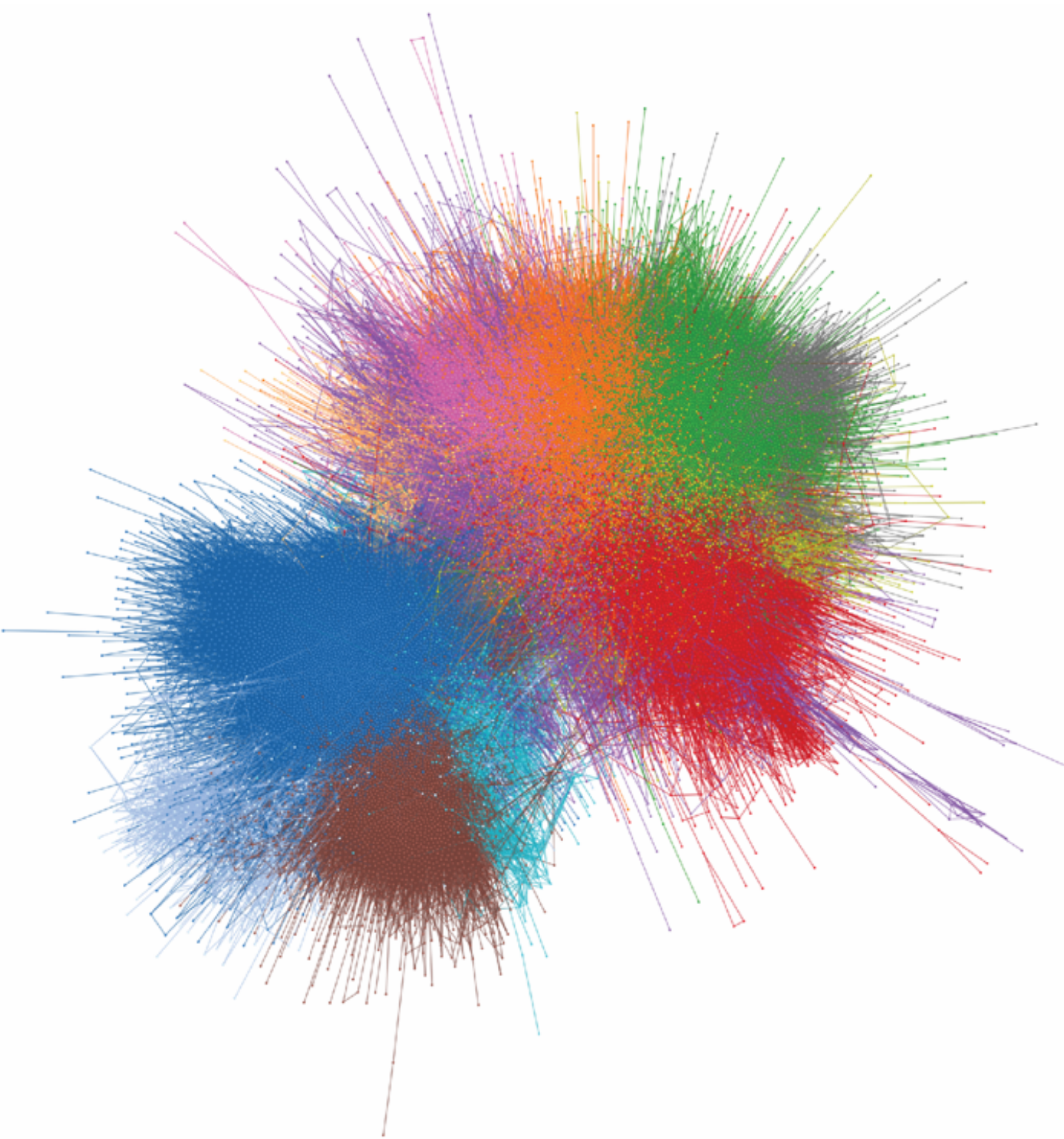




# Photonic crystals

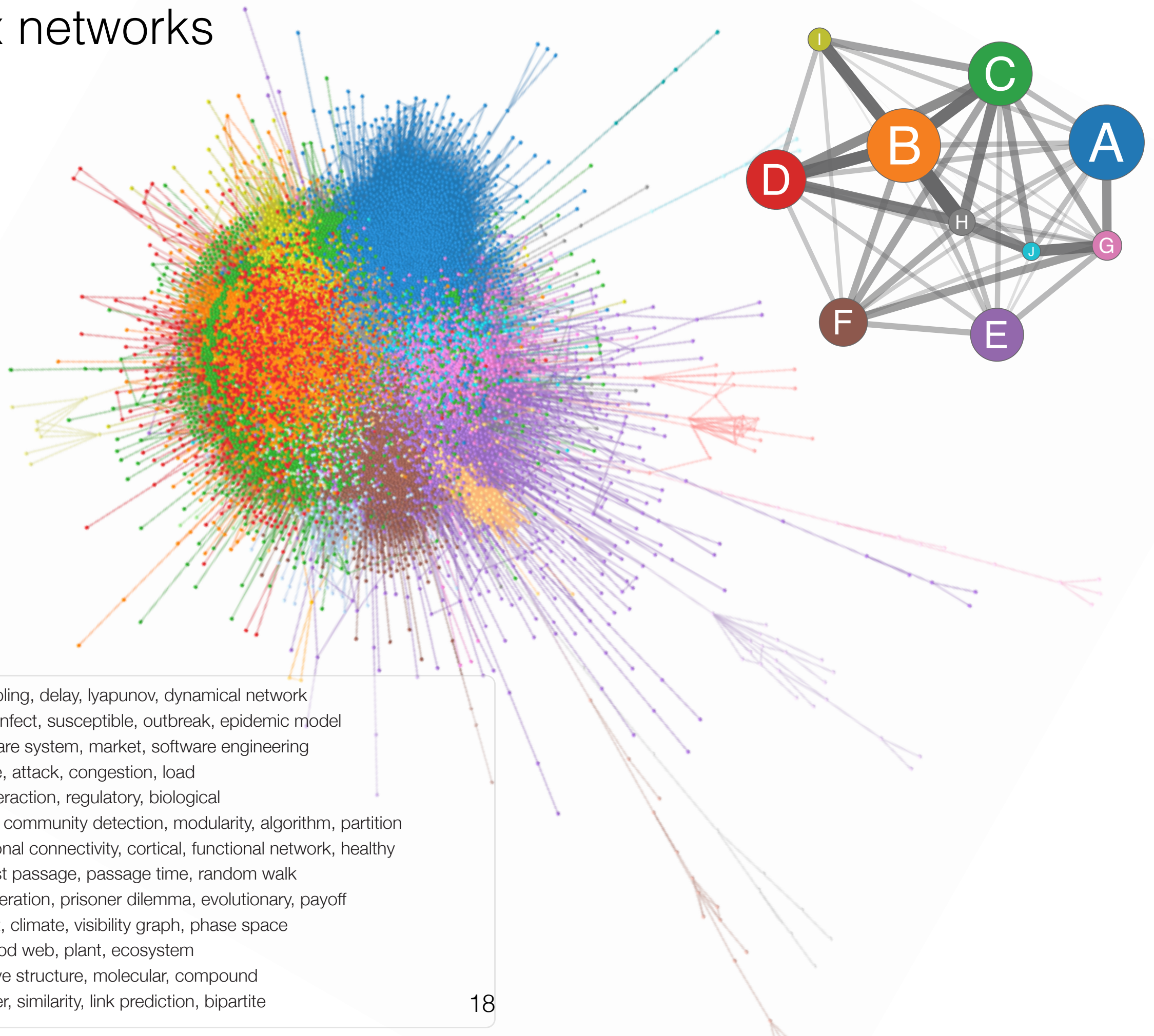


# Photonic crystals

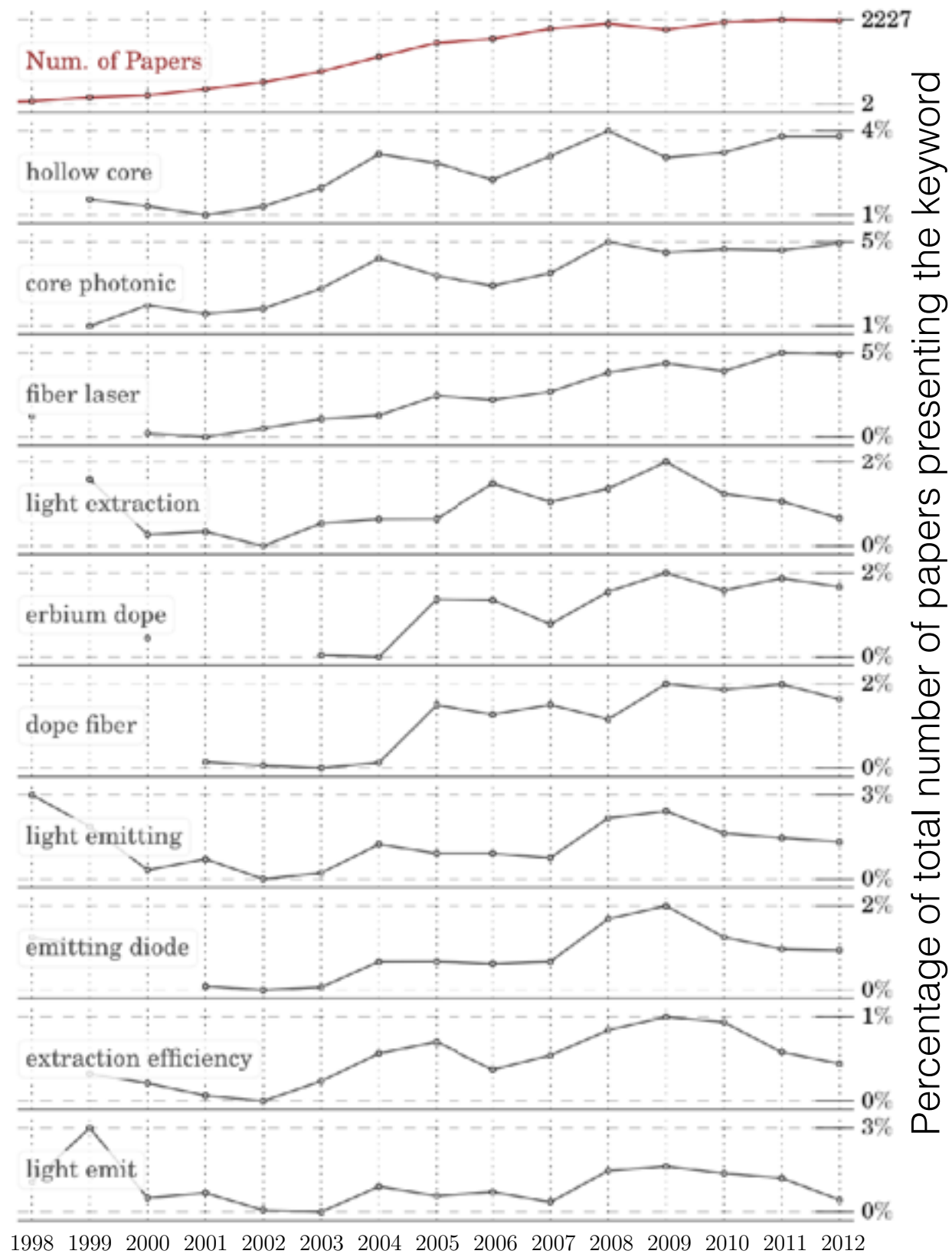




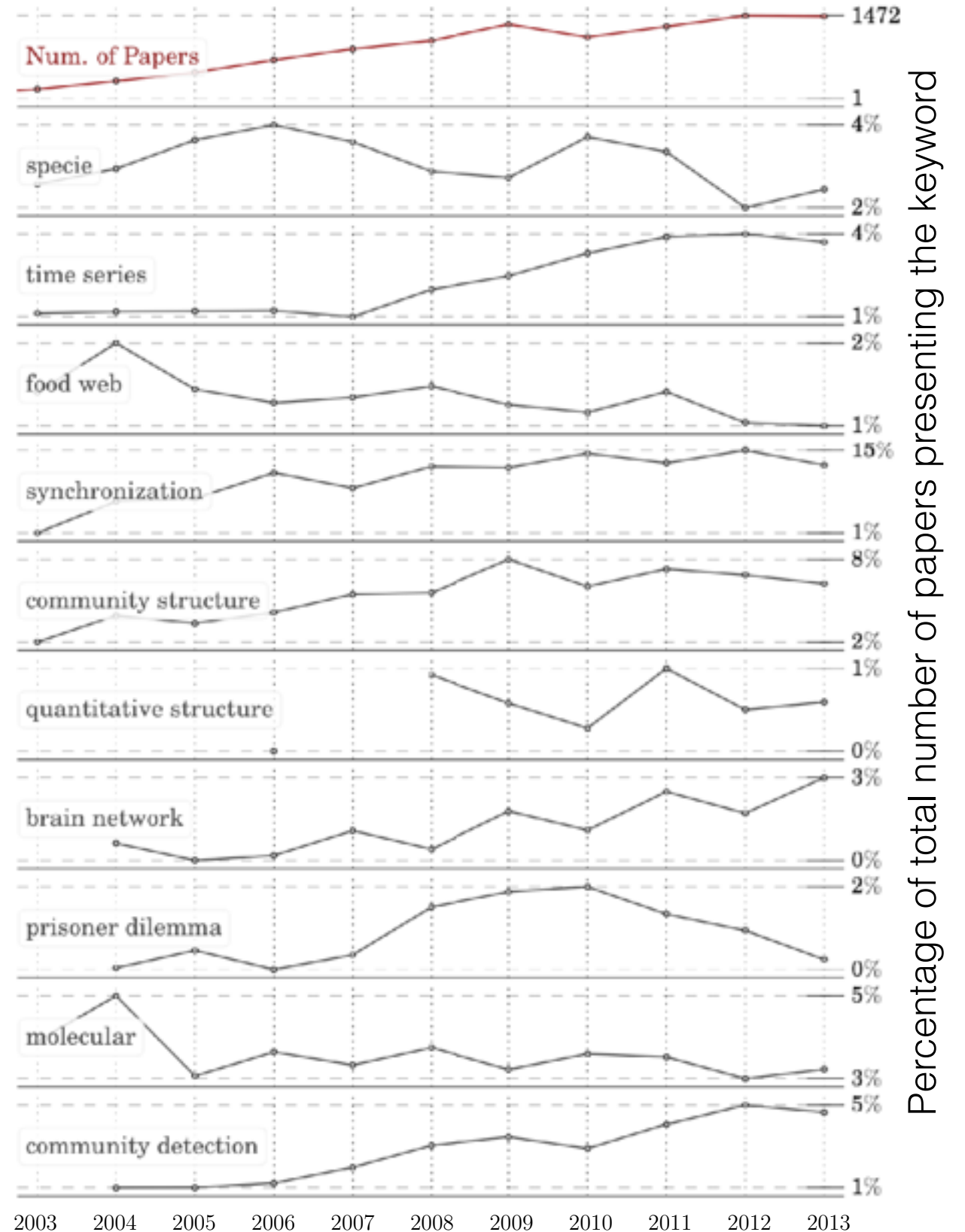
# Complex networks



# Chronological evolution of keywords



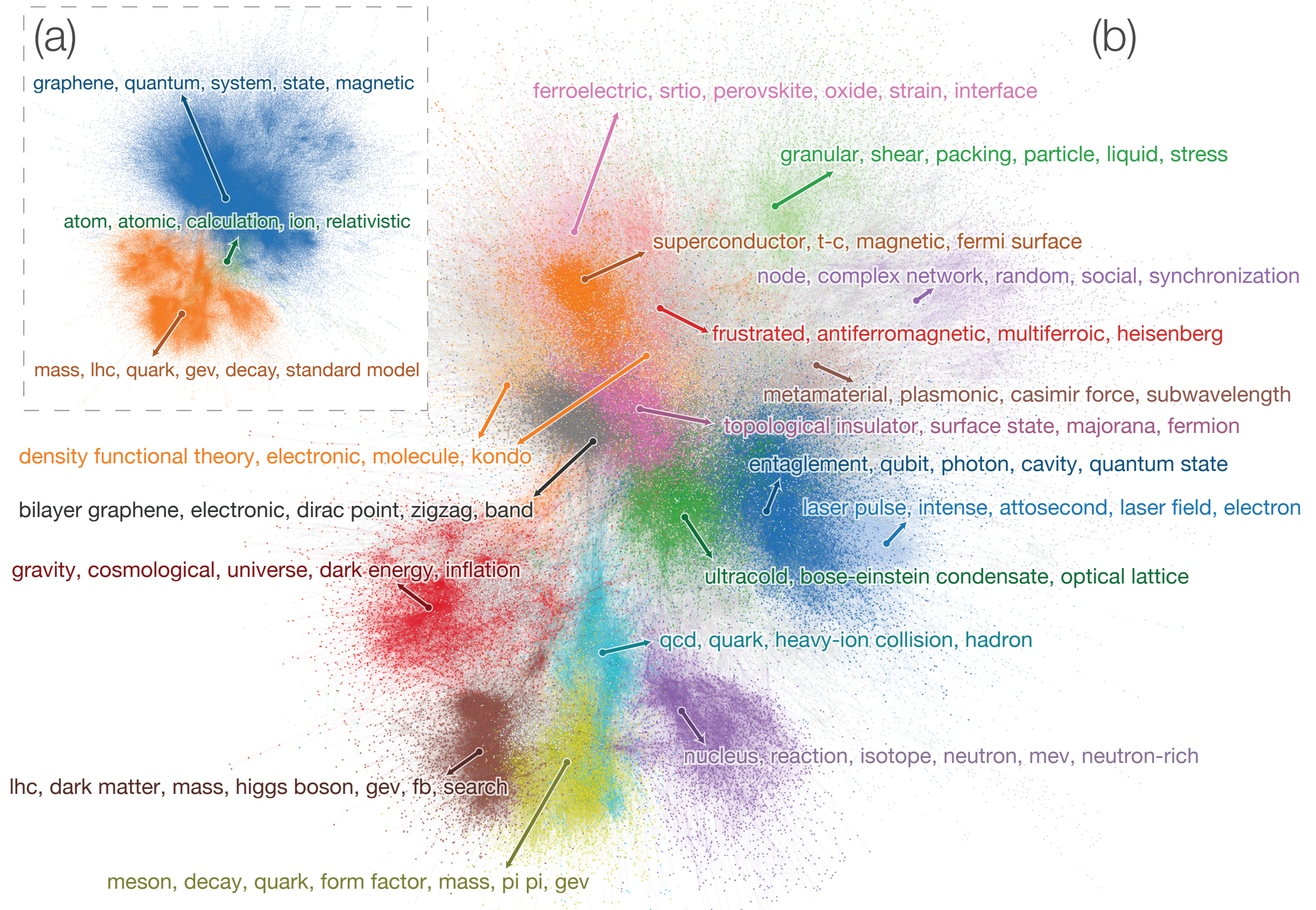
Photonic Crystals



Complex Networks

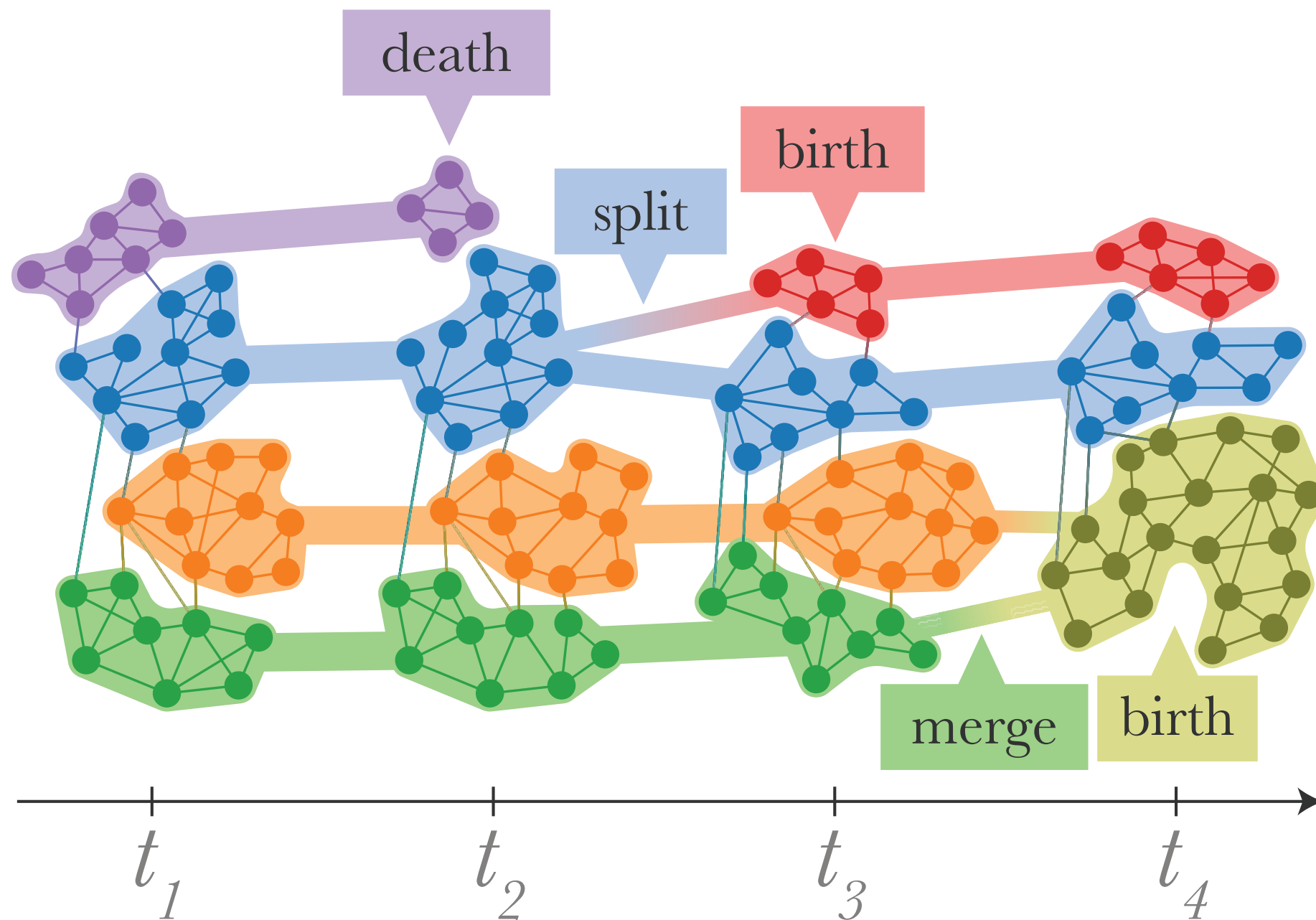


# Dynamics of scientific disciplines





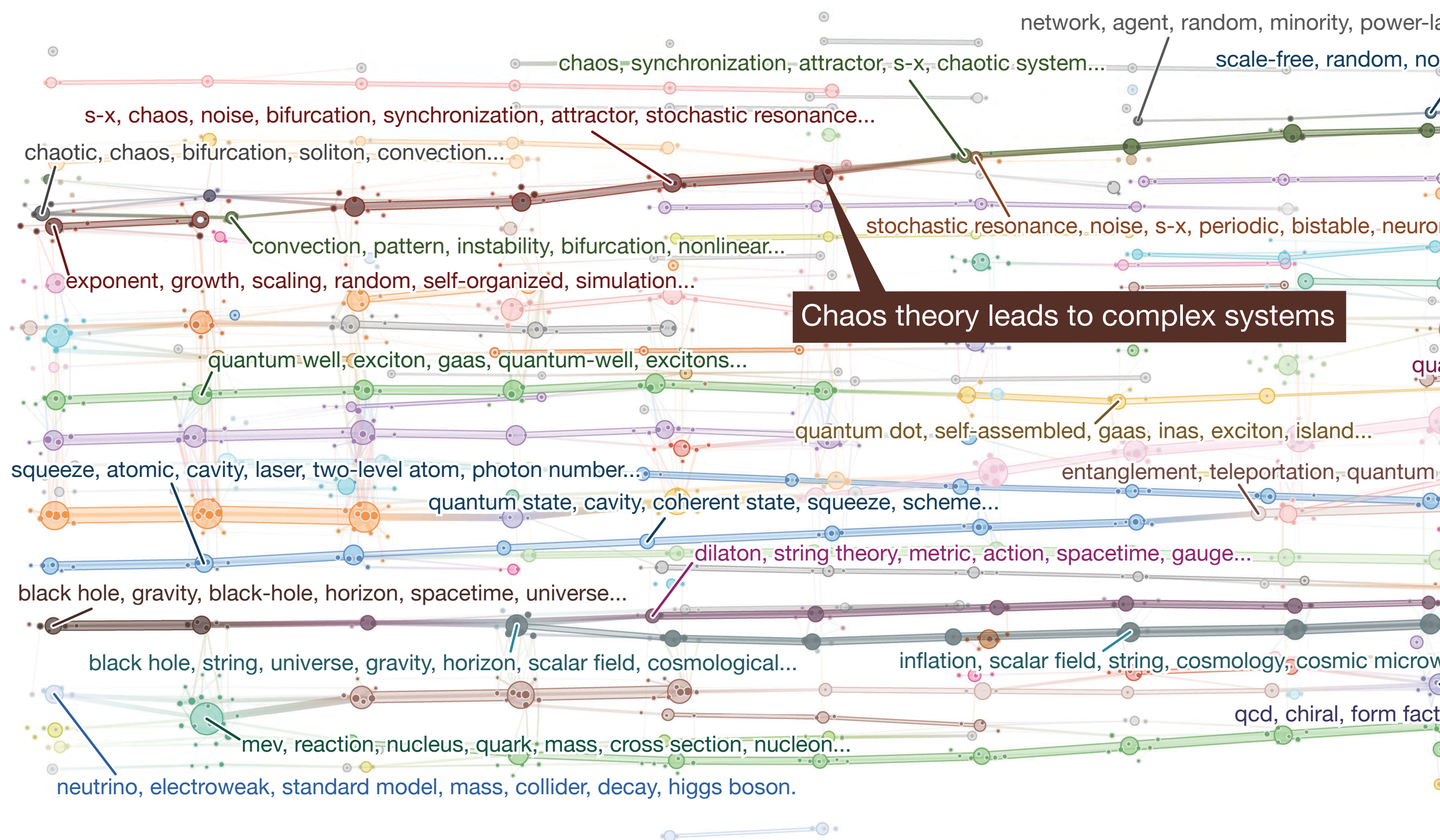
# Dynamics of scientific disciplines





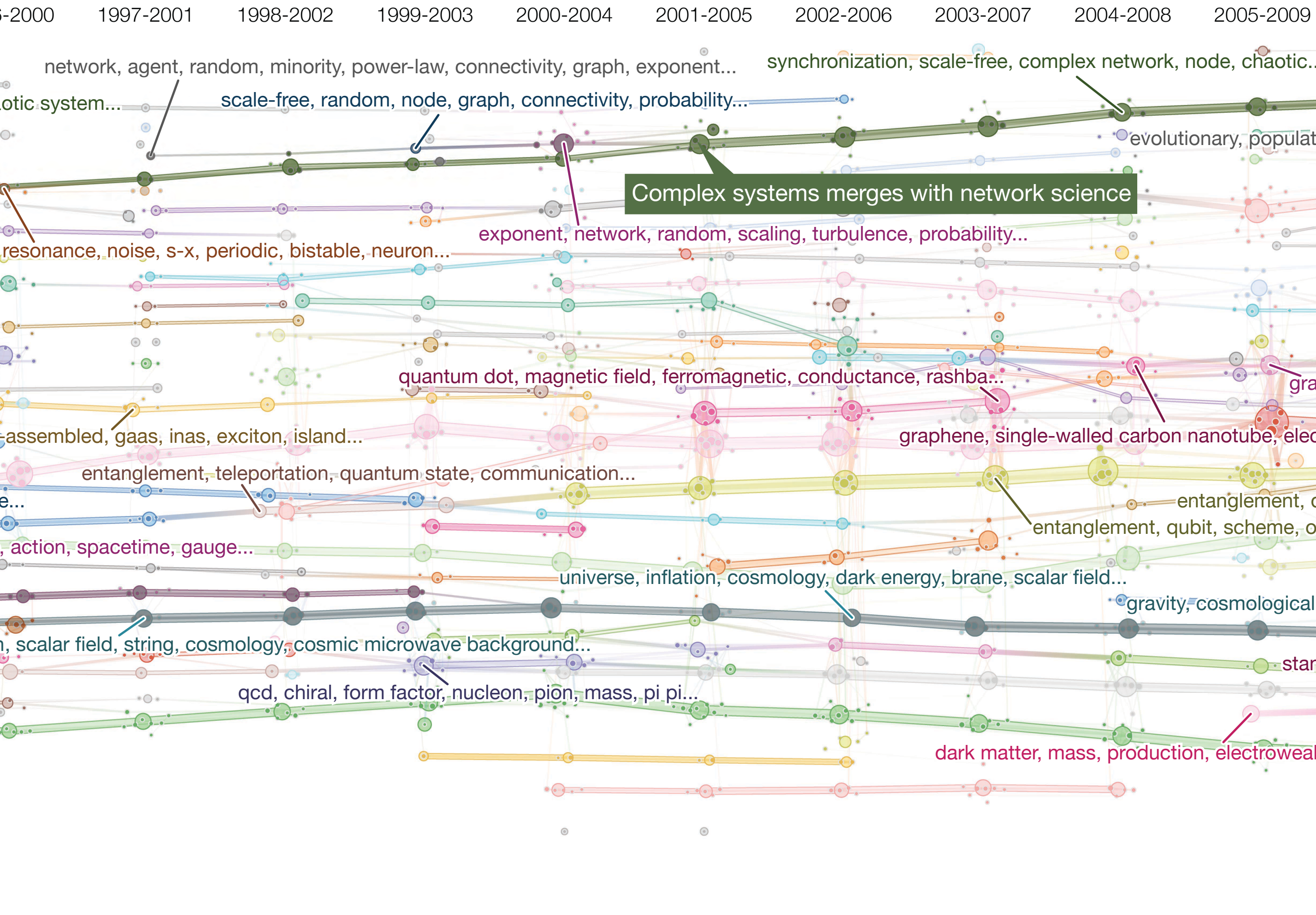


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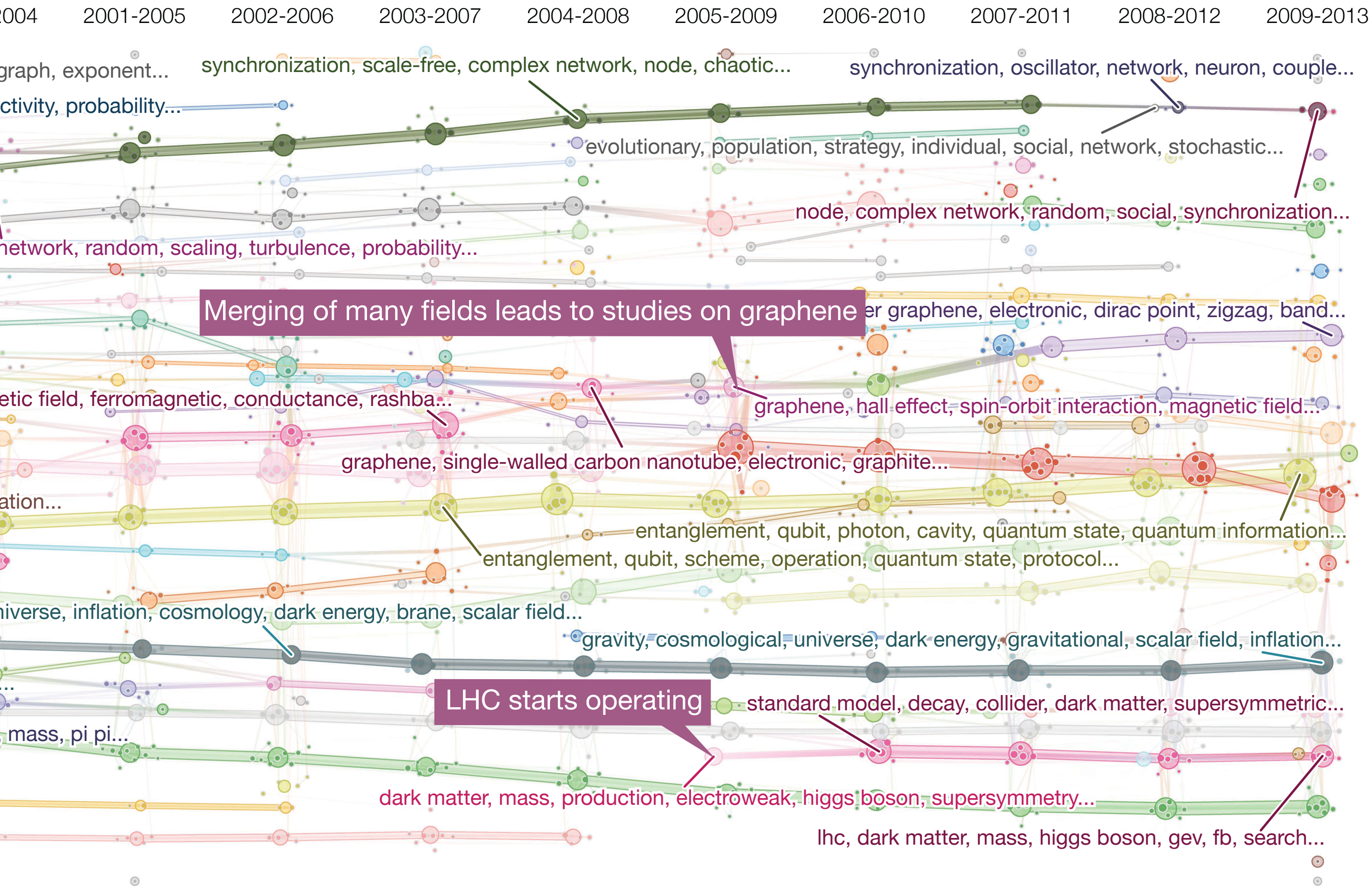


Chaos theory leads to complex systems



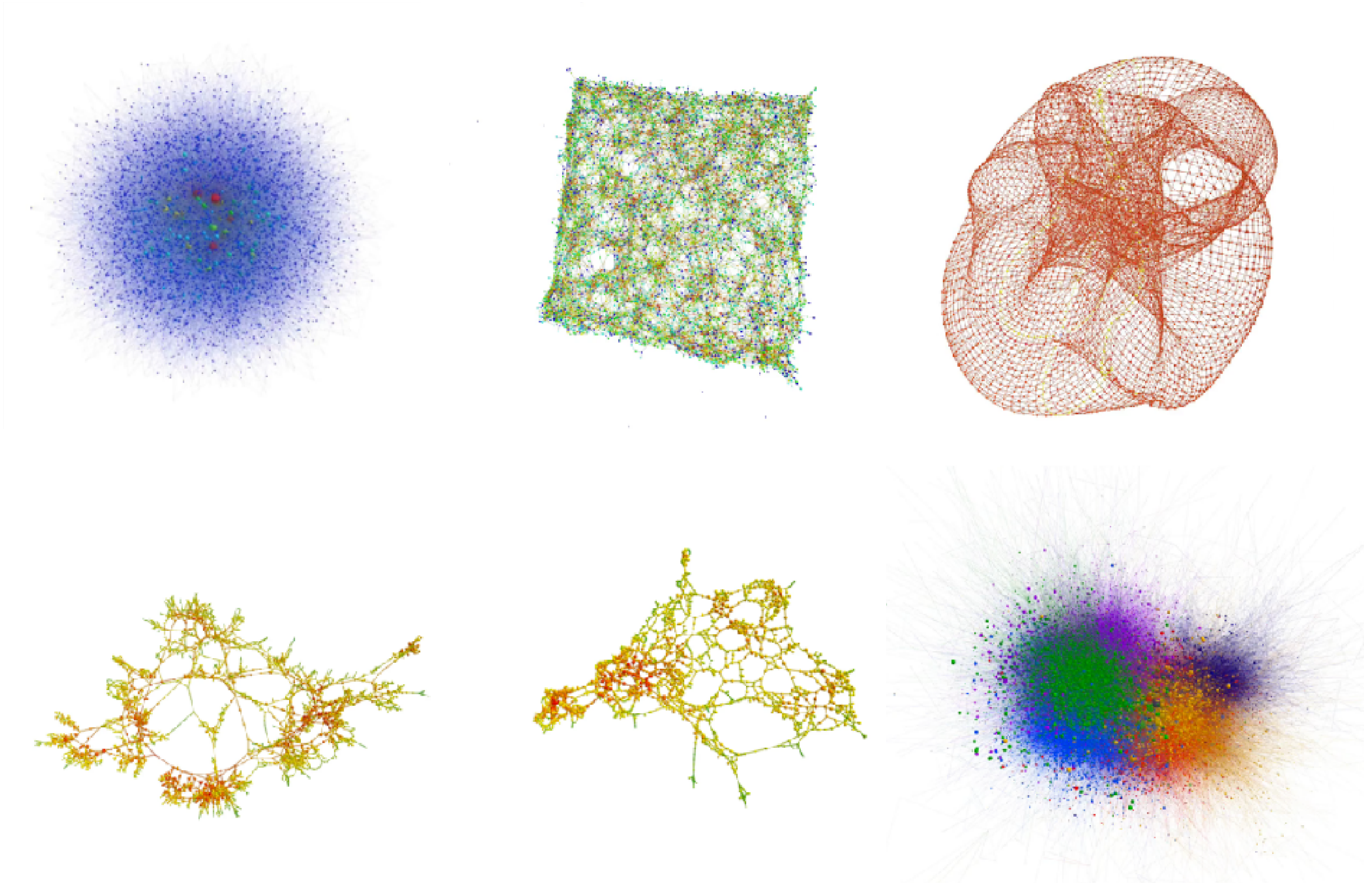






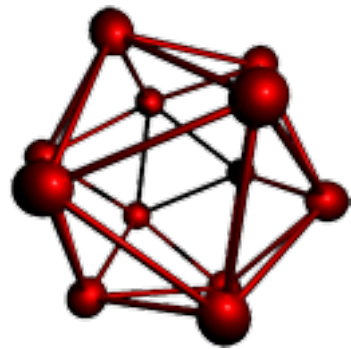
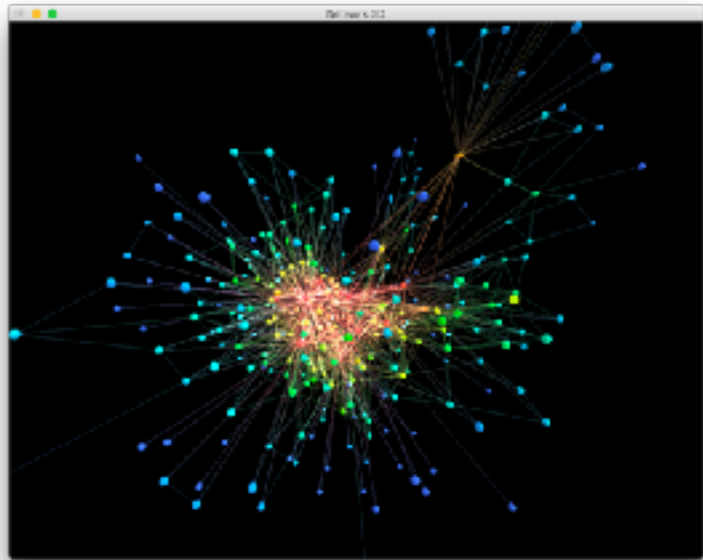
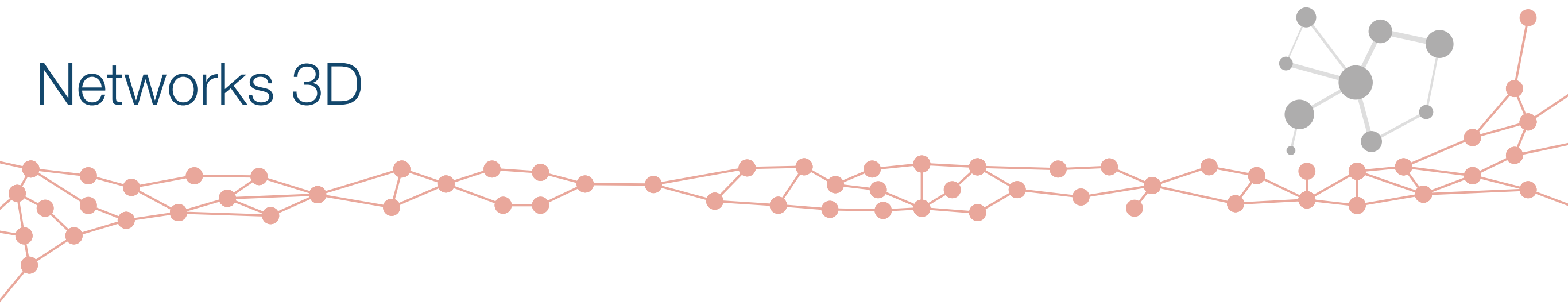


# Complex networks + visualization



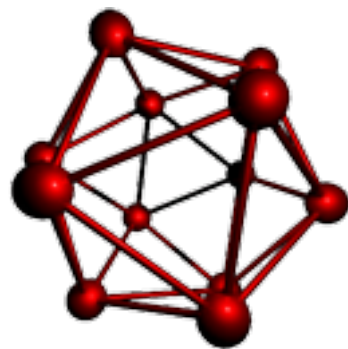
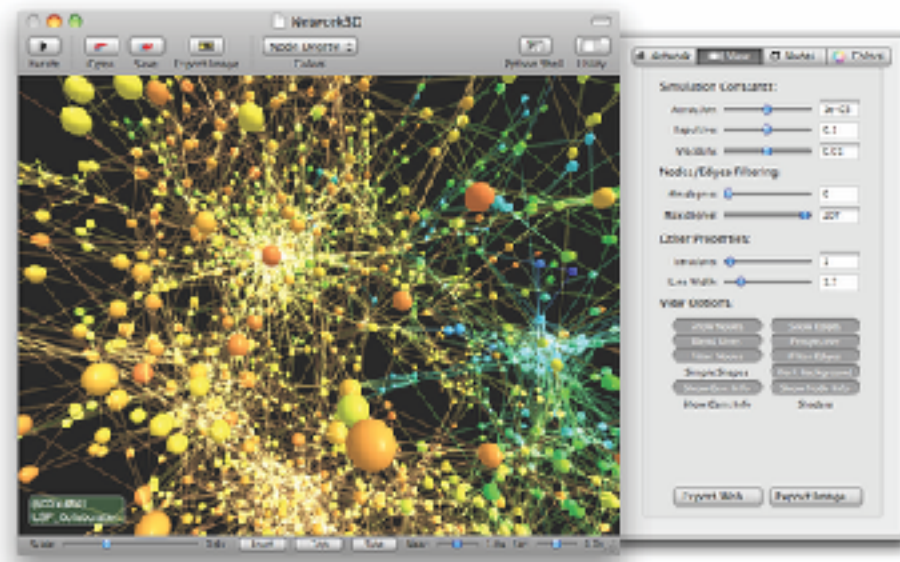
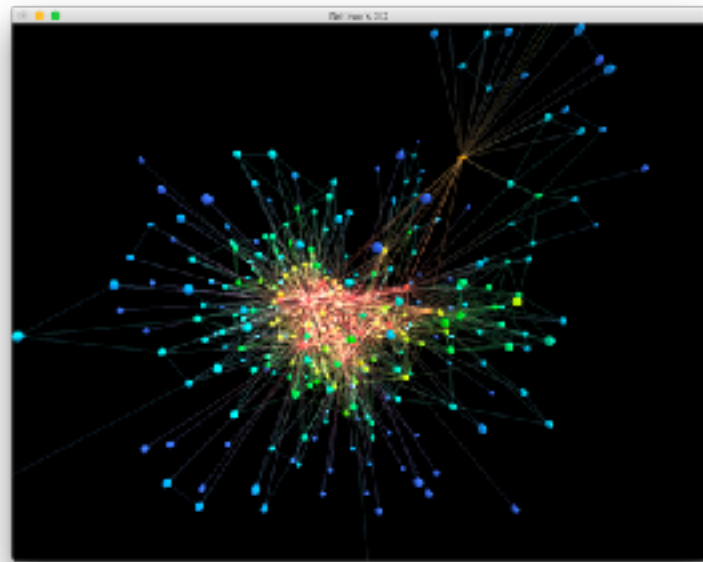
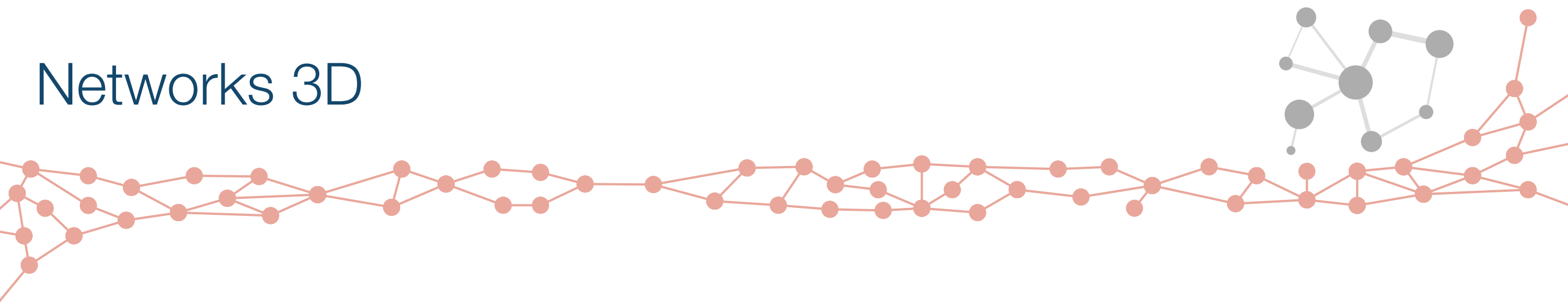


# Networks 3D

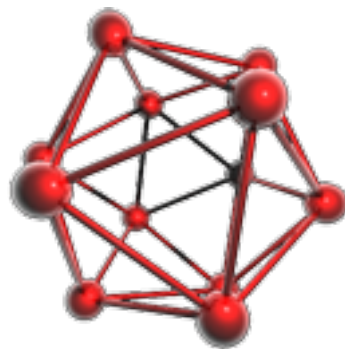


2009

# Networks 3D



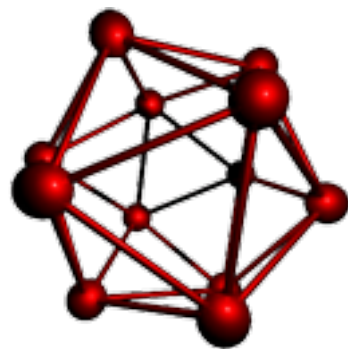
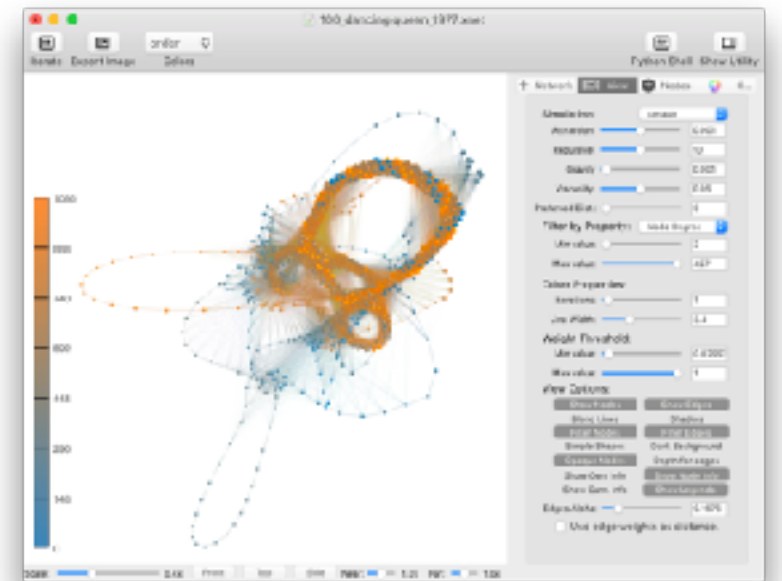
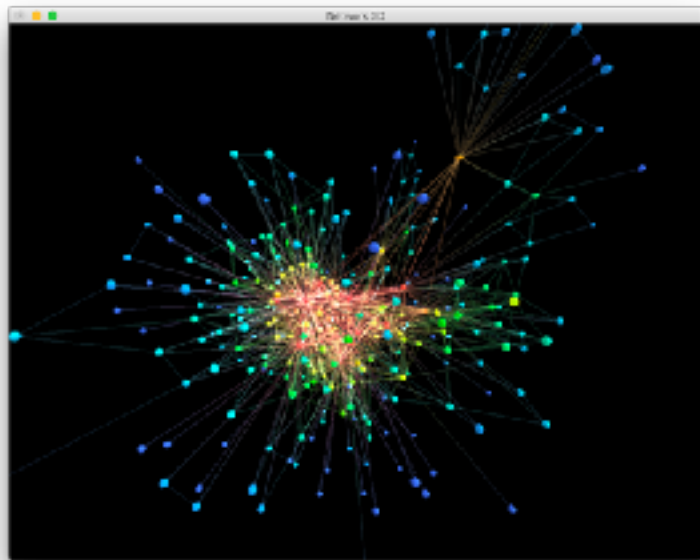
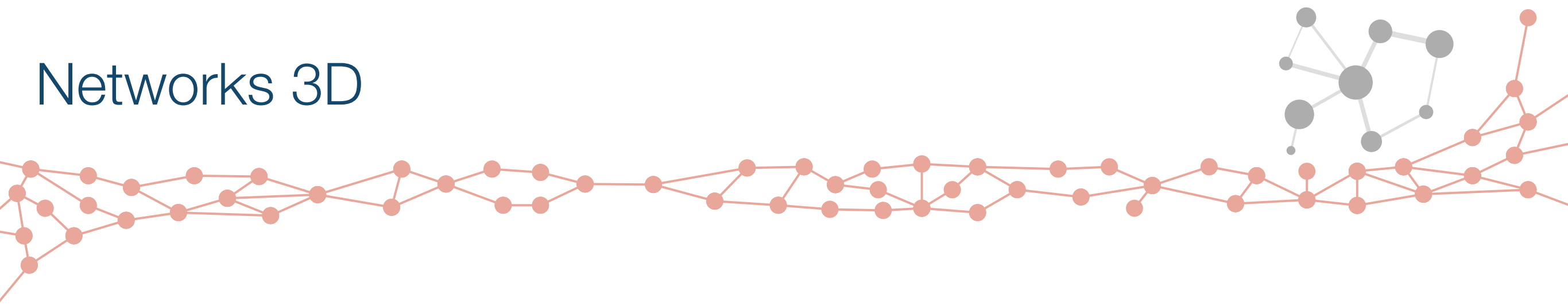
2009



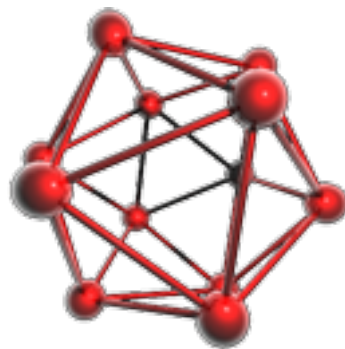
2012



# Networks 3D



2009

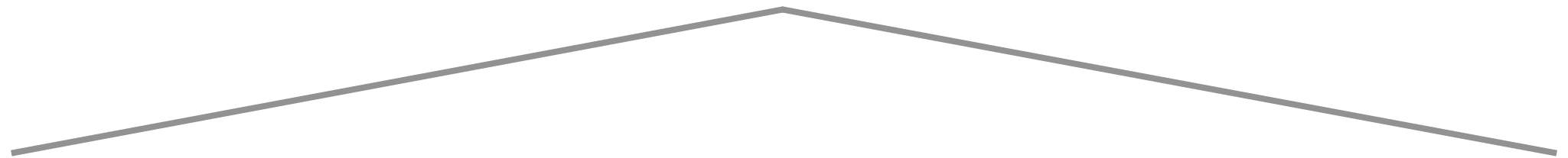
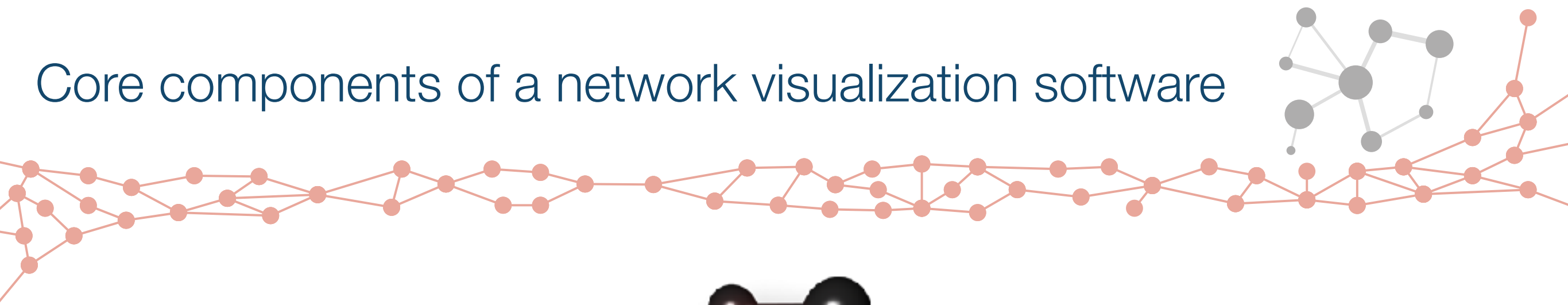


2012

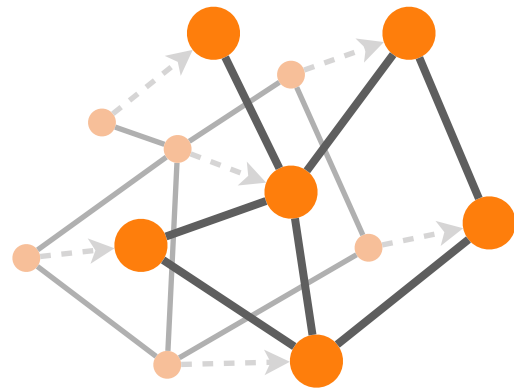


now

# Core components of a network visualization software



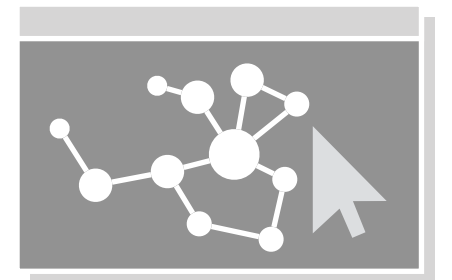
Graph Library



Layout



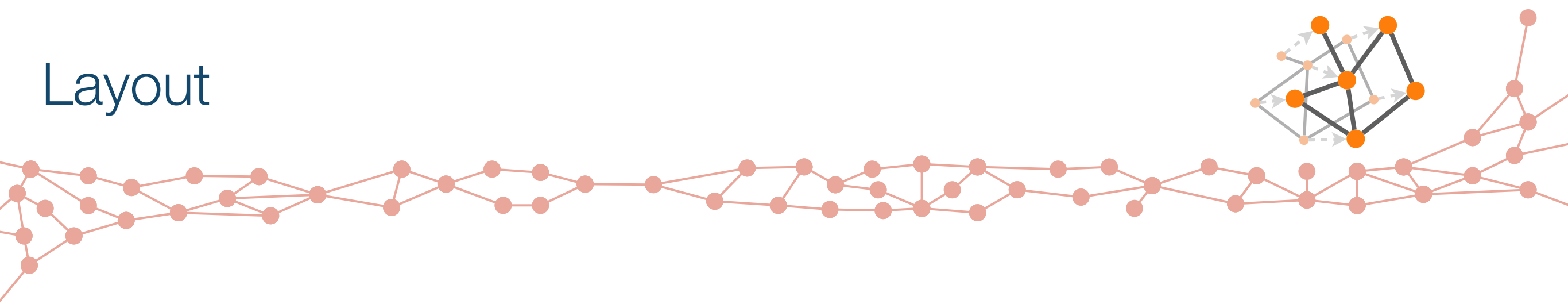
Rendering



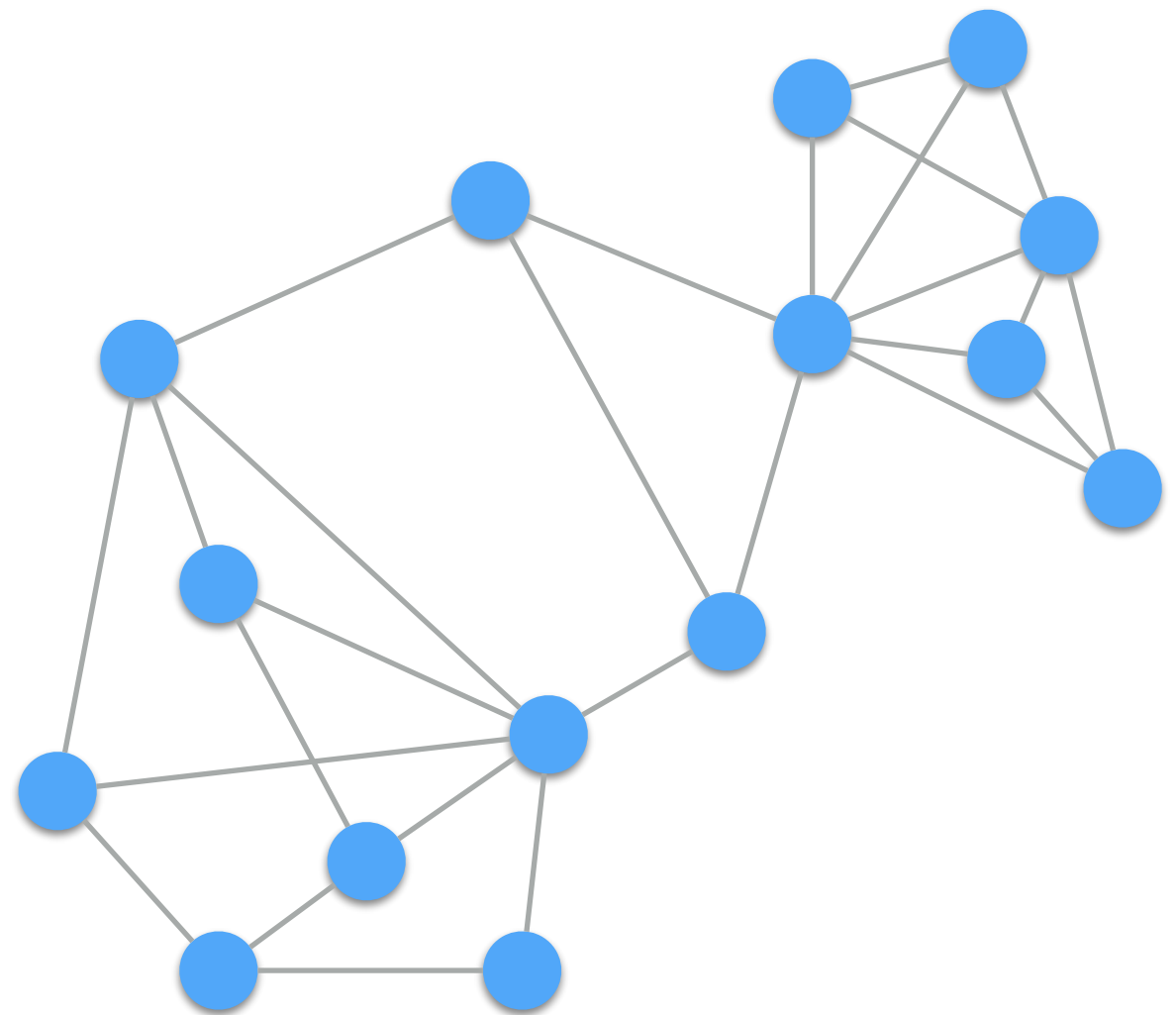
Interface



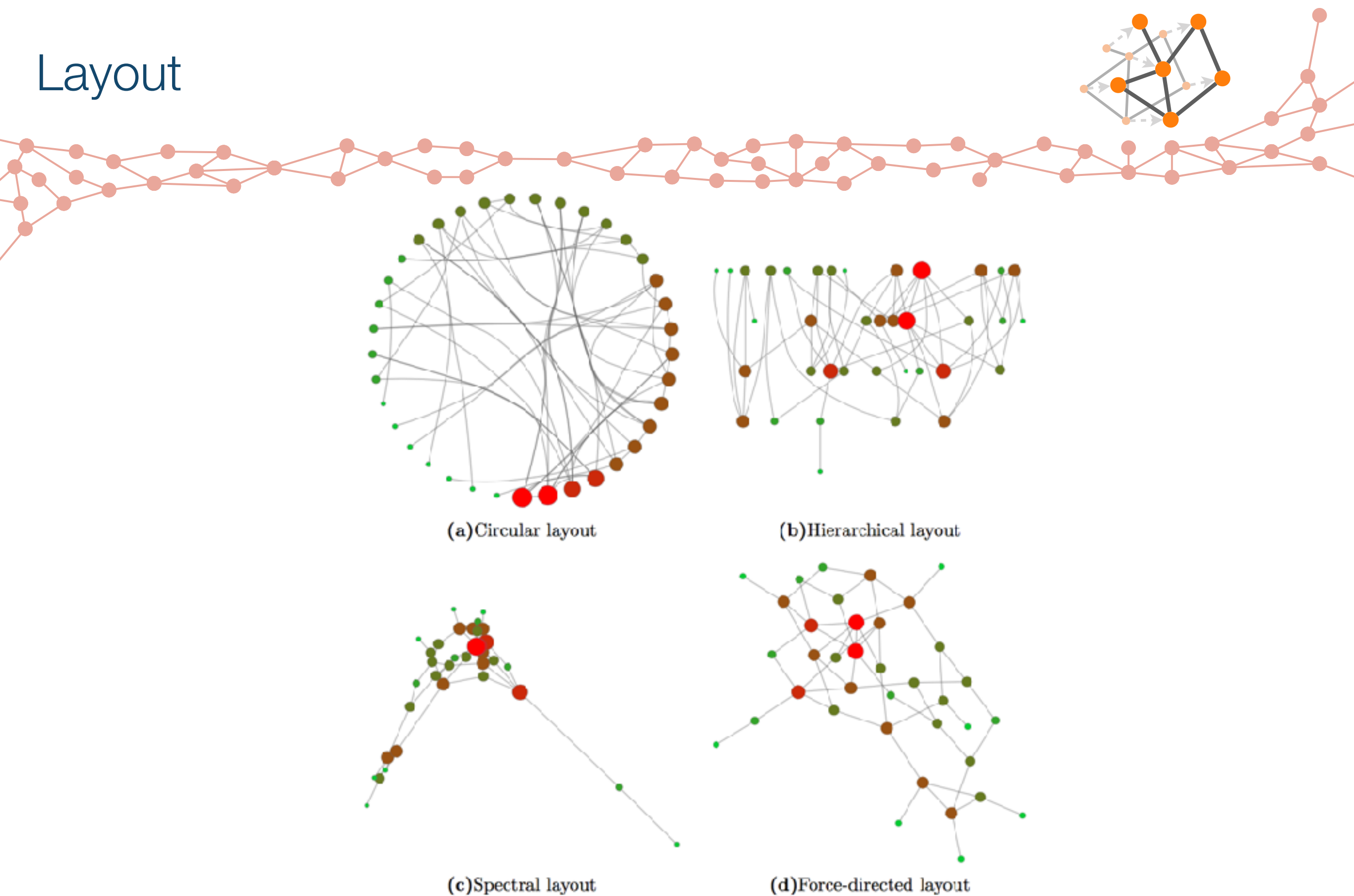
# Layout



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	0				
1		0	1		...
		1	0	1	
1			1	0	
		⋮			⋱



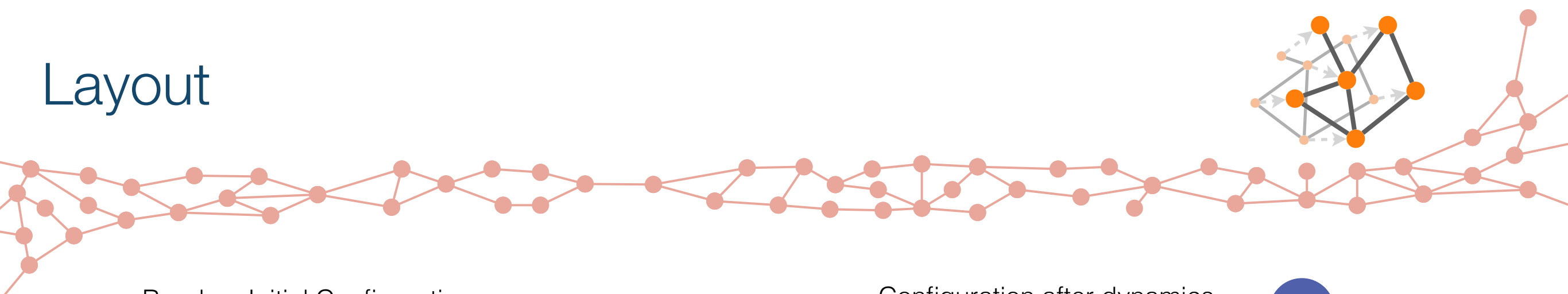
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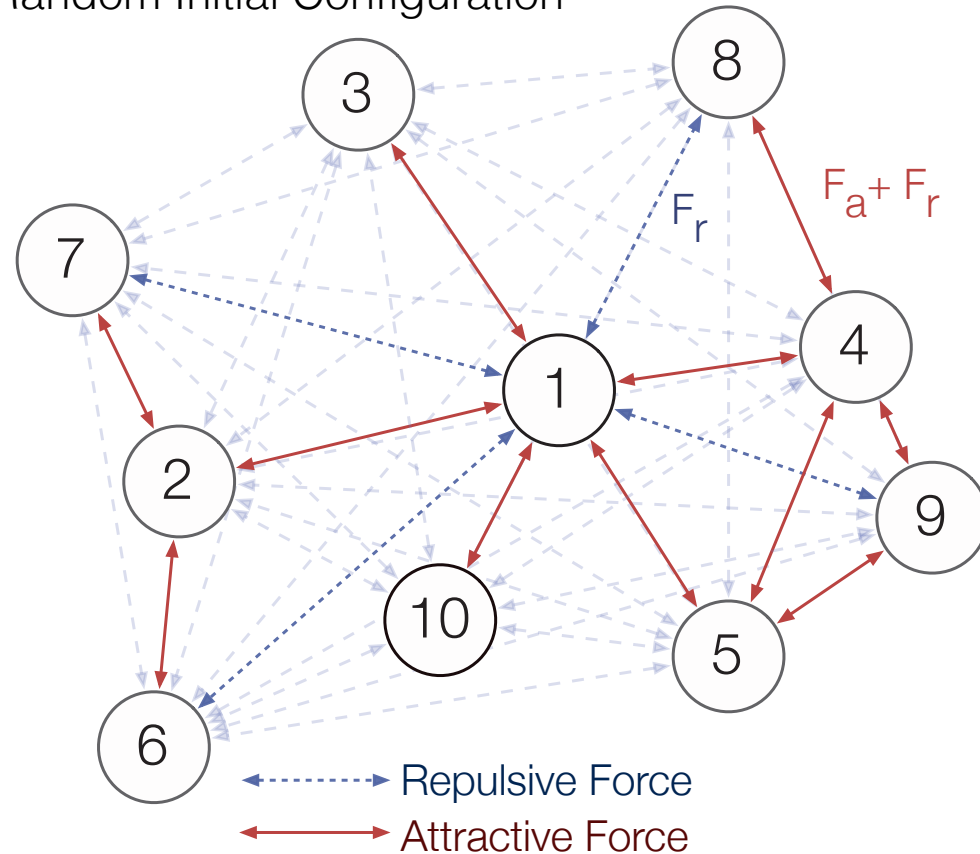
Complex systems: features, similarity and connectivity  
C. H. Comin, T. K. DM. Peron, F. N. Silva, D. R. Amancio, F. A. Rodrigues, L. da F. Costa  
<https://arxiv.org/abs/1606.05400>



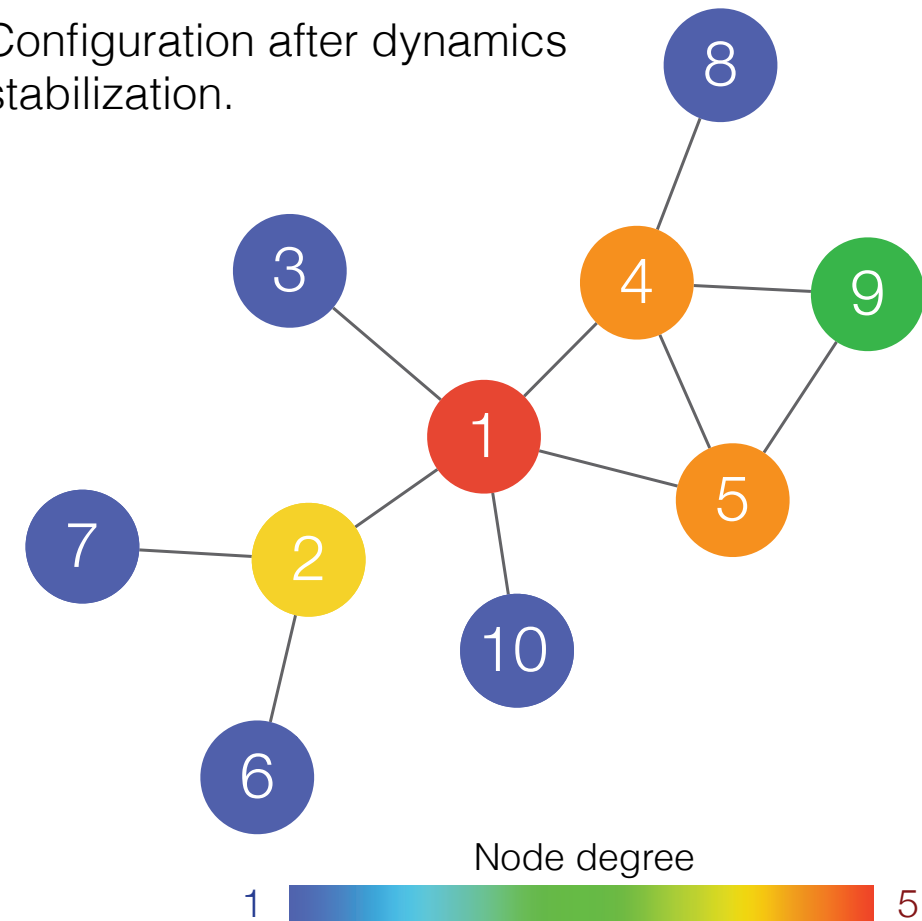
# Layout



Random Initial Configuration



Configuration after dynamics stabilization.



Attractive Force

$$\vec{F}_{(a)j} = \sum_{(i,j) \in \mathcal{E}} a_{ij} (\vec{R}_i - \vec{R}_j)^2 \hat{r}_{ij}$$

Repulsive Force

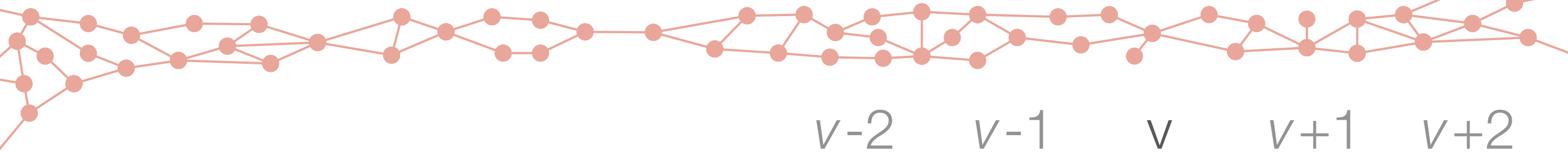
$$\vec{F}_{(r)j} = \sum_{i \in \mathcal{V}} \frac{-b}{(\vec{R}_i - \vec{R}_j)^2} \hat{r}_{ij}$$

Viscosity can be used to cool down the system

$$\frac{d^2 \vec{R}_j}{dt^2} = \vec{F}_{(a)i} + \vec{F}_{(r)j} - \mu \frac{d\vec{R}_j}{dt}$$

Runge-Kutta or Verlet can be used

# Layout

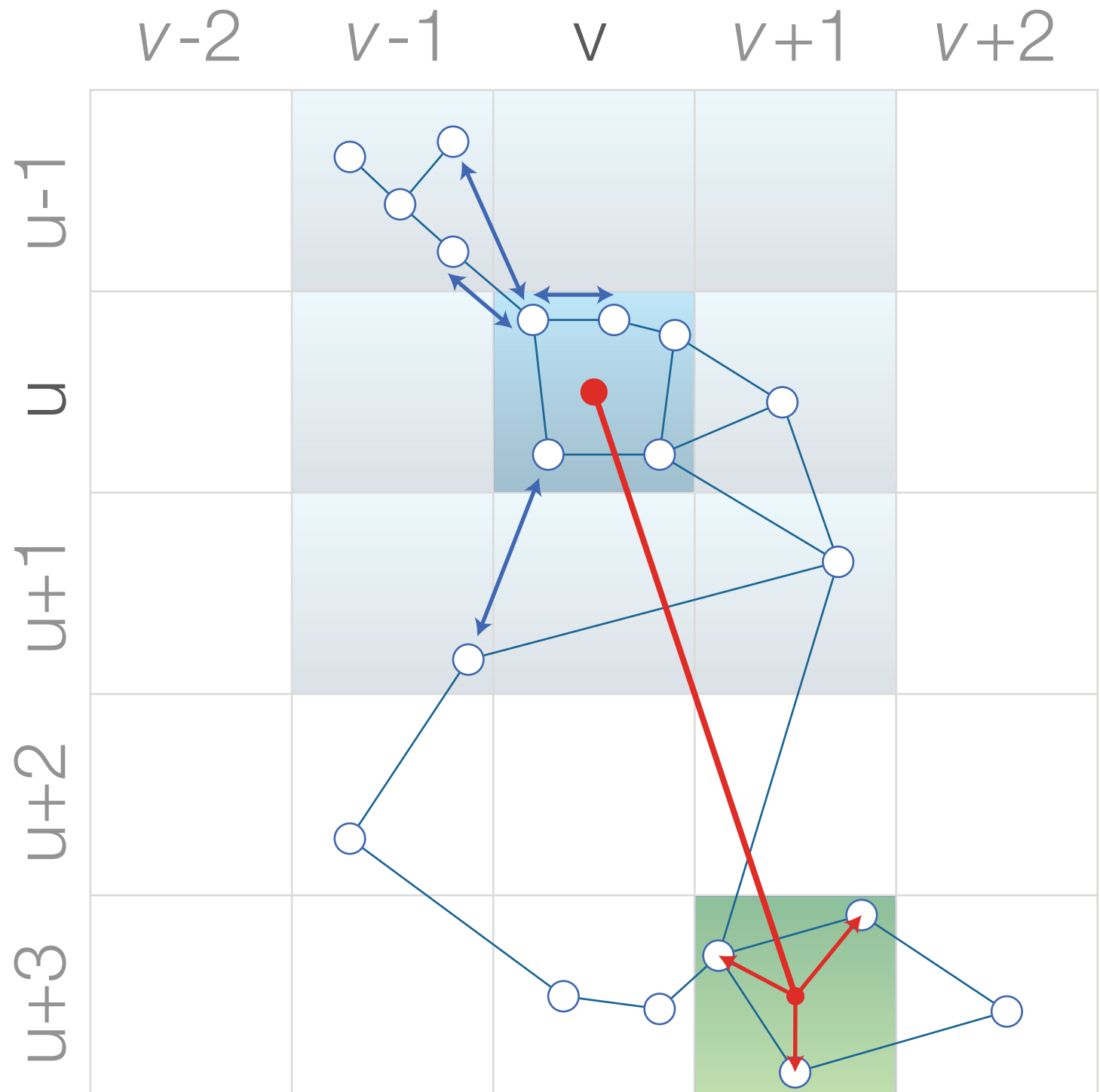


- Molecular dynamics simulation is  $O(N^2)$ .
- We can use multipole expansion:

$$\sum_{i \in \mathcal{V}} \frac{\hat{r}_{ij}}{(\vec{R}_i - \vec{R}_j)^2} = -\vec{\nabla} \sum_{i \in \mathcal{V}} \frac{1}{|\vec{R}_i - \vec{R}_j|} = -\vec{\nabla} \phi(\vec{R}_j)$$

$$\phi(\vec{R}_j) \propto \frac{N_{u,v}}{|\vec{R}_j|} + \frac{\vec{p}_{u,v} \cdot \vec{R}_j}{|\vec{R}_j|^3} + \frac{1}{2} \sum_m^3 \sum_n^3 \frac{(Q_{u,v})_{mn} (R_j)_m (R_j)_n}{|\vec{R}_j|^5} + \dots$$

- Where  $N_{u,v}$ ,  $\vec{p}_{u,v}$  e  $Q_{u,v}$  are the monopole, dipole and quadrupole moments on box  $(u,v)$ .
- Quadrupole is OK for most of networks.











Waxman model



Visualizing Complex Networks (CDT-5)

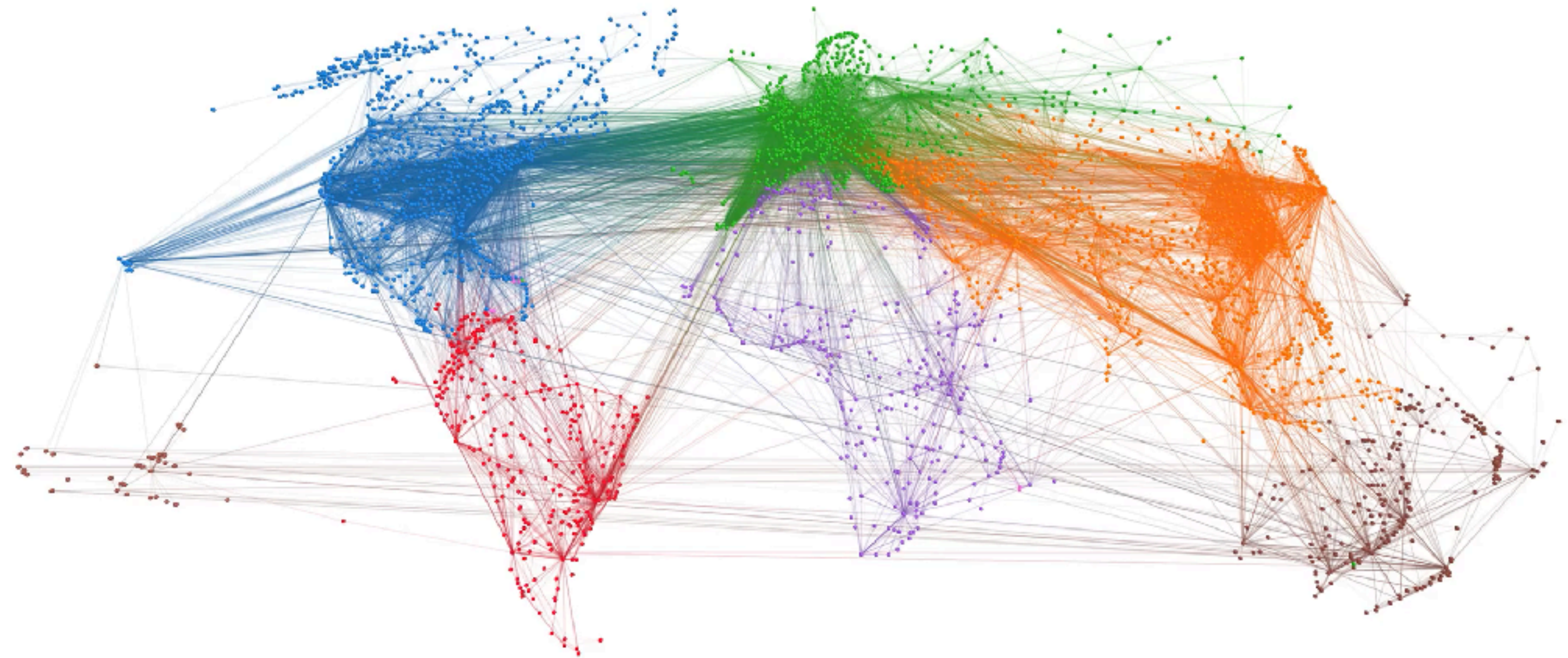
Silva, F. N. and Costa, L. da F.

<http://dx.doi.org/10.13140/RG.2.2.21310.74567/1>





# Airport network of direct flights



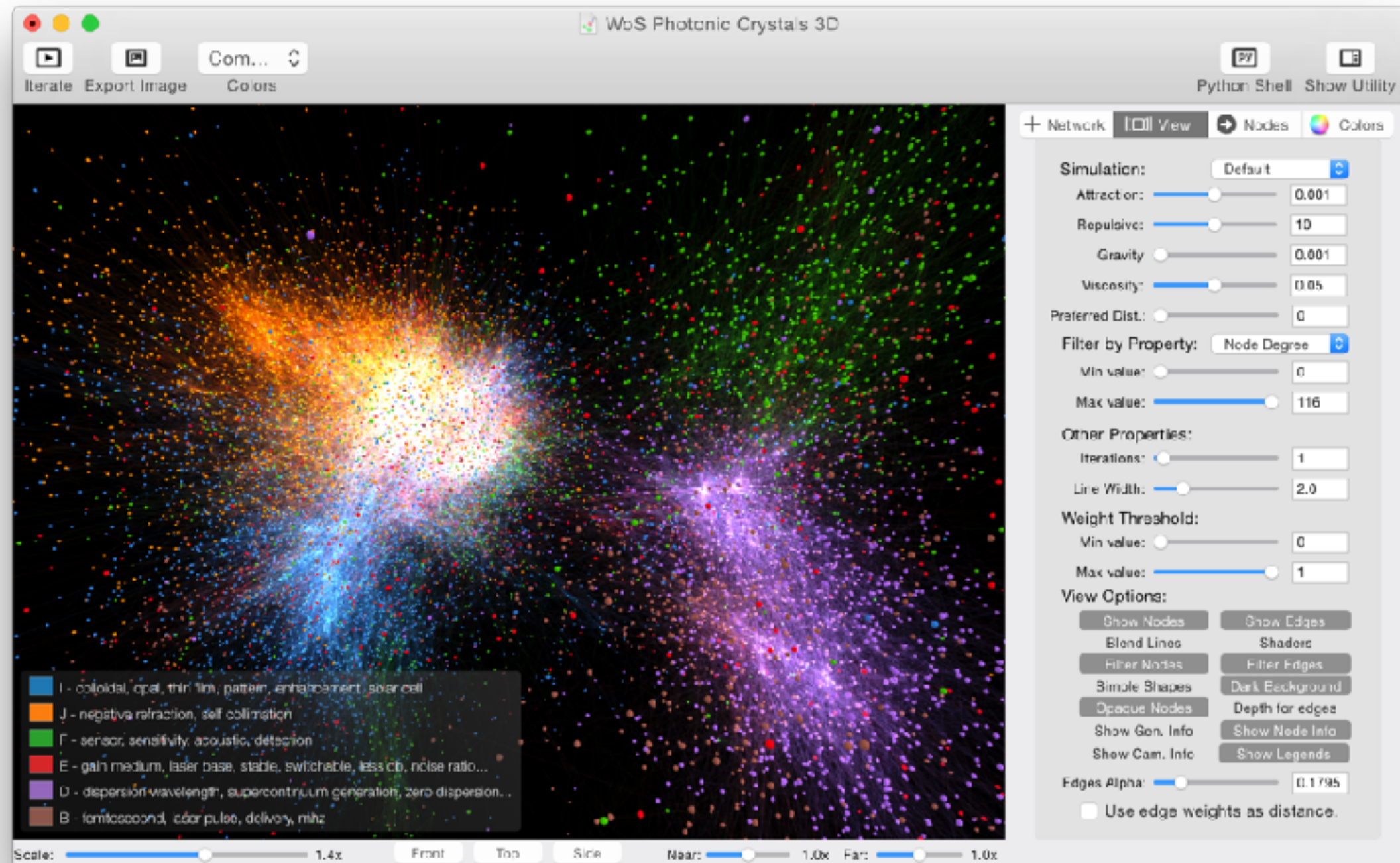
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<http://dx.doi.org/10.13140/RG.2.2.21310.74567/1>



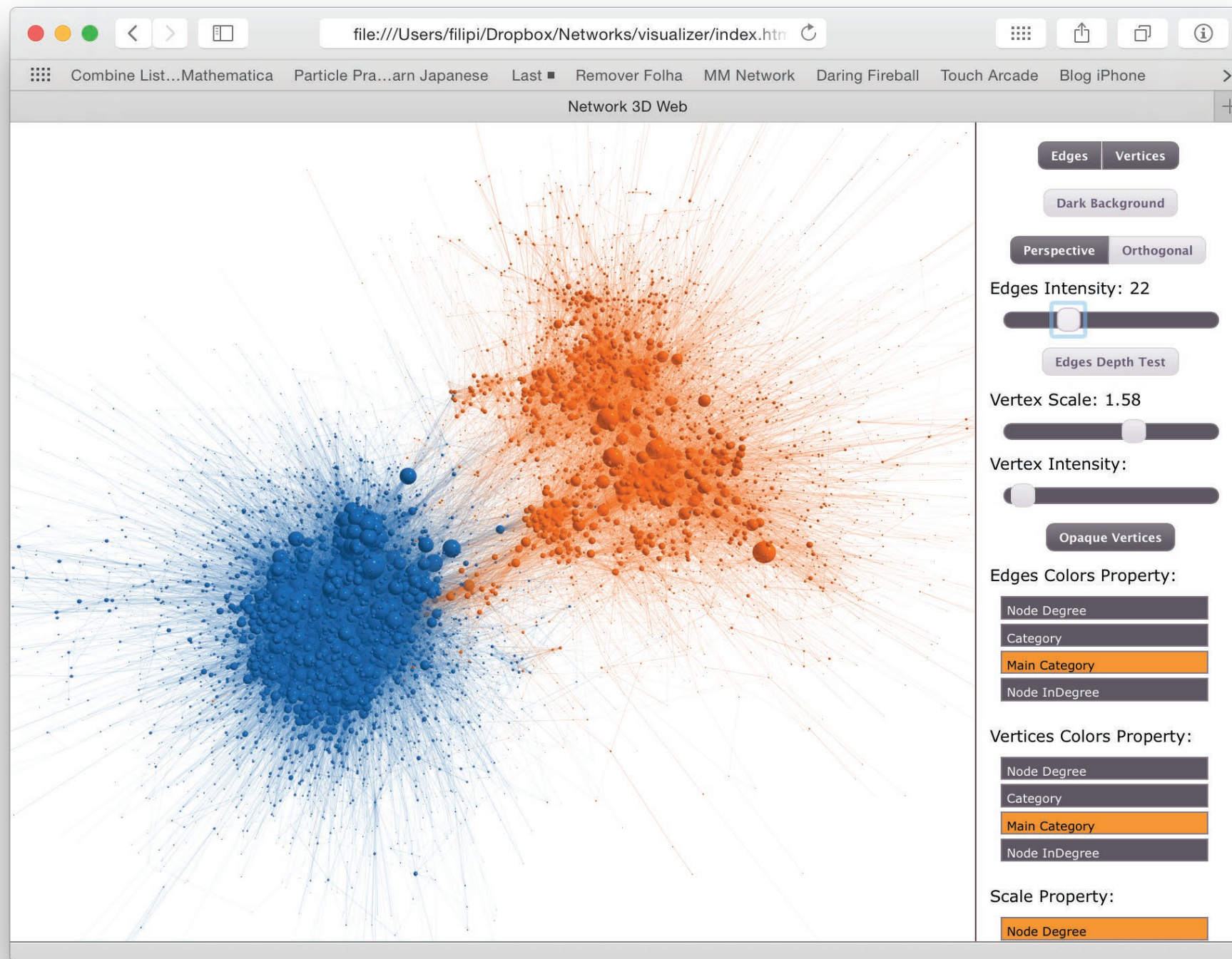
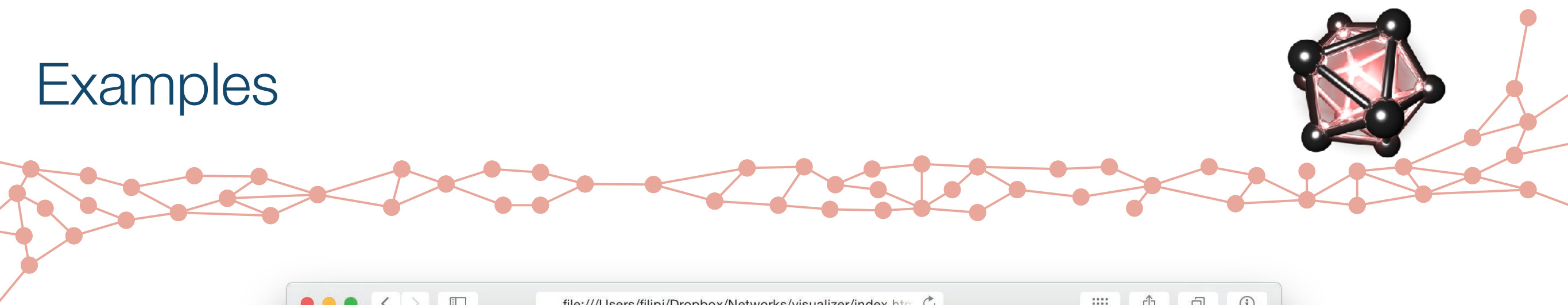
# Examples



Software Interface



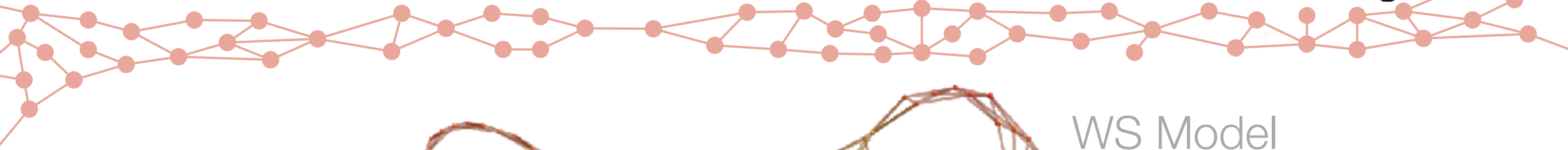
# Examples



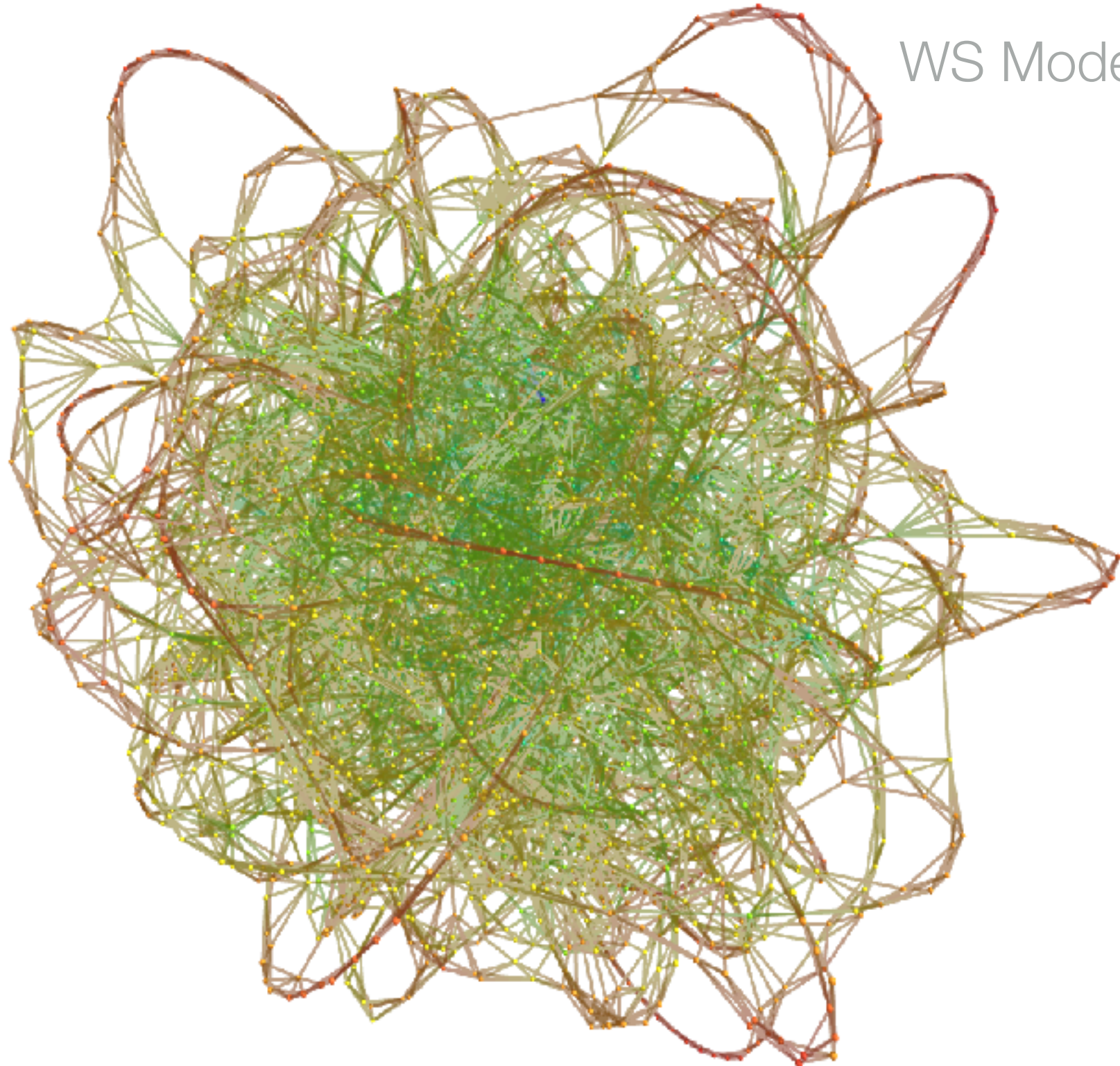
Web interface



# Examples

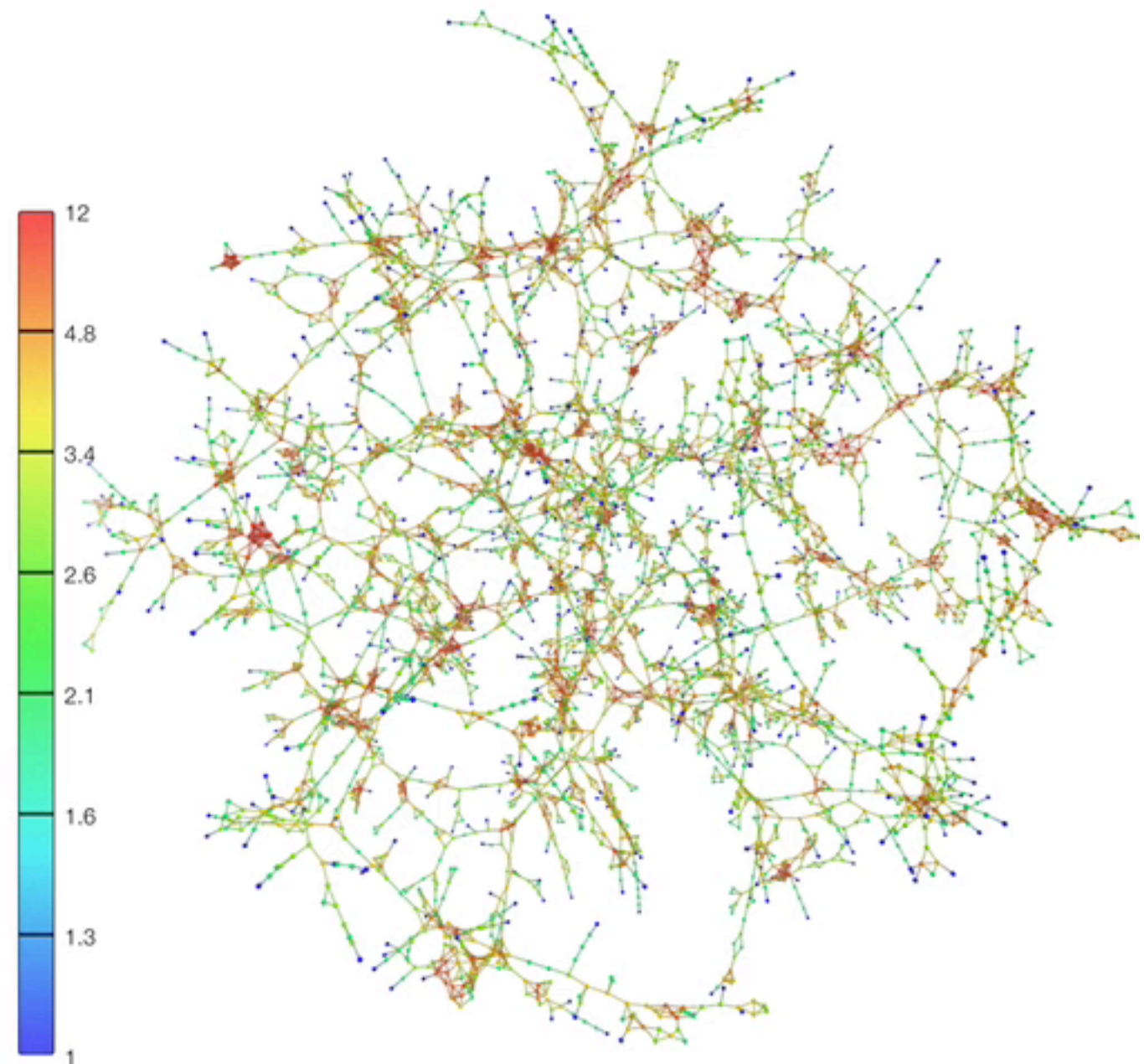
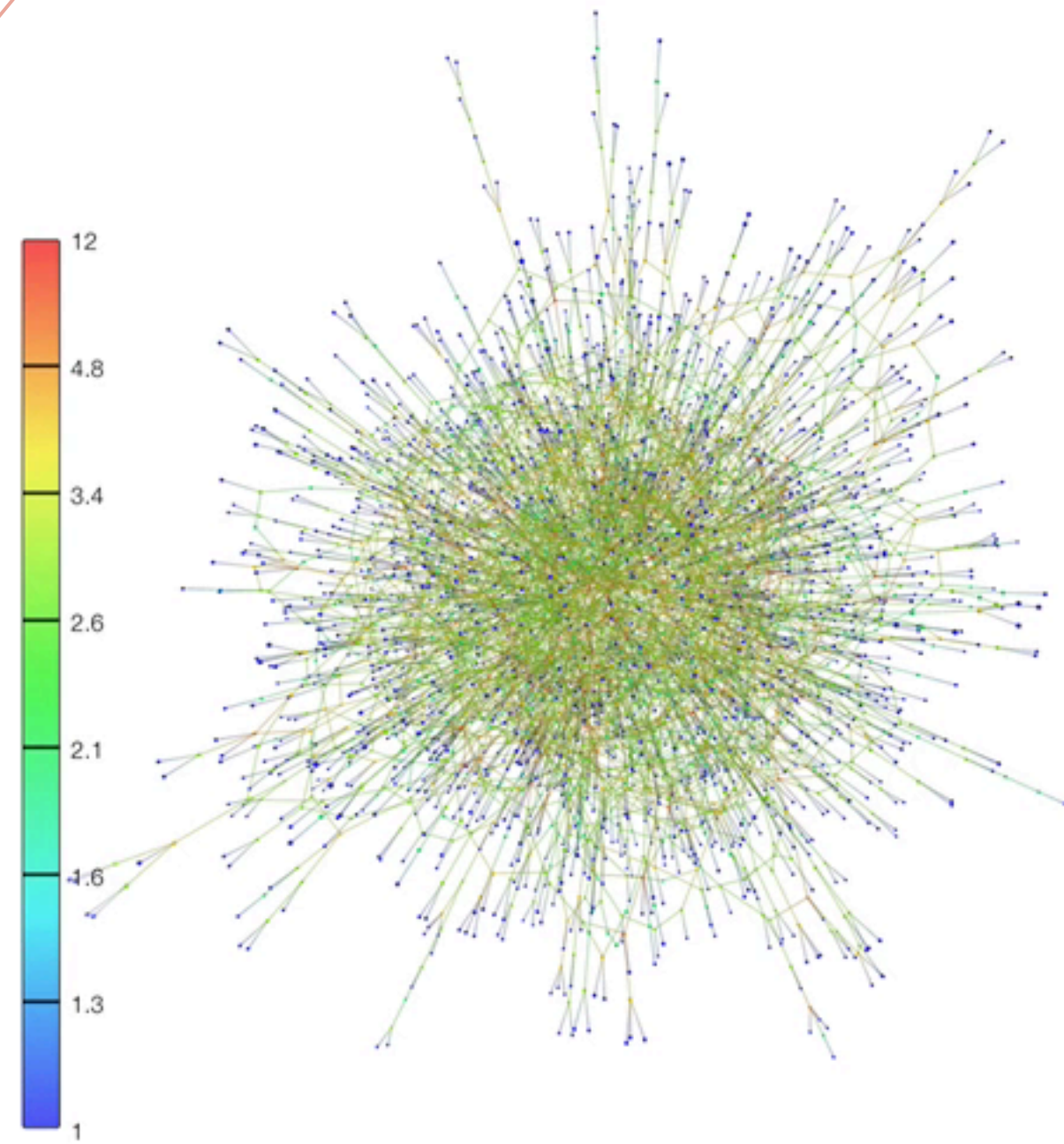
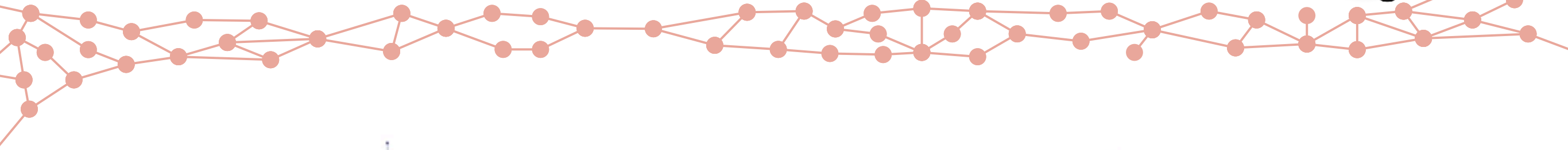


WS Model

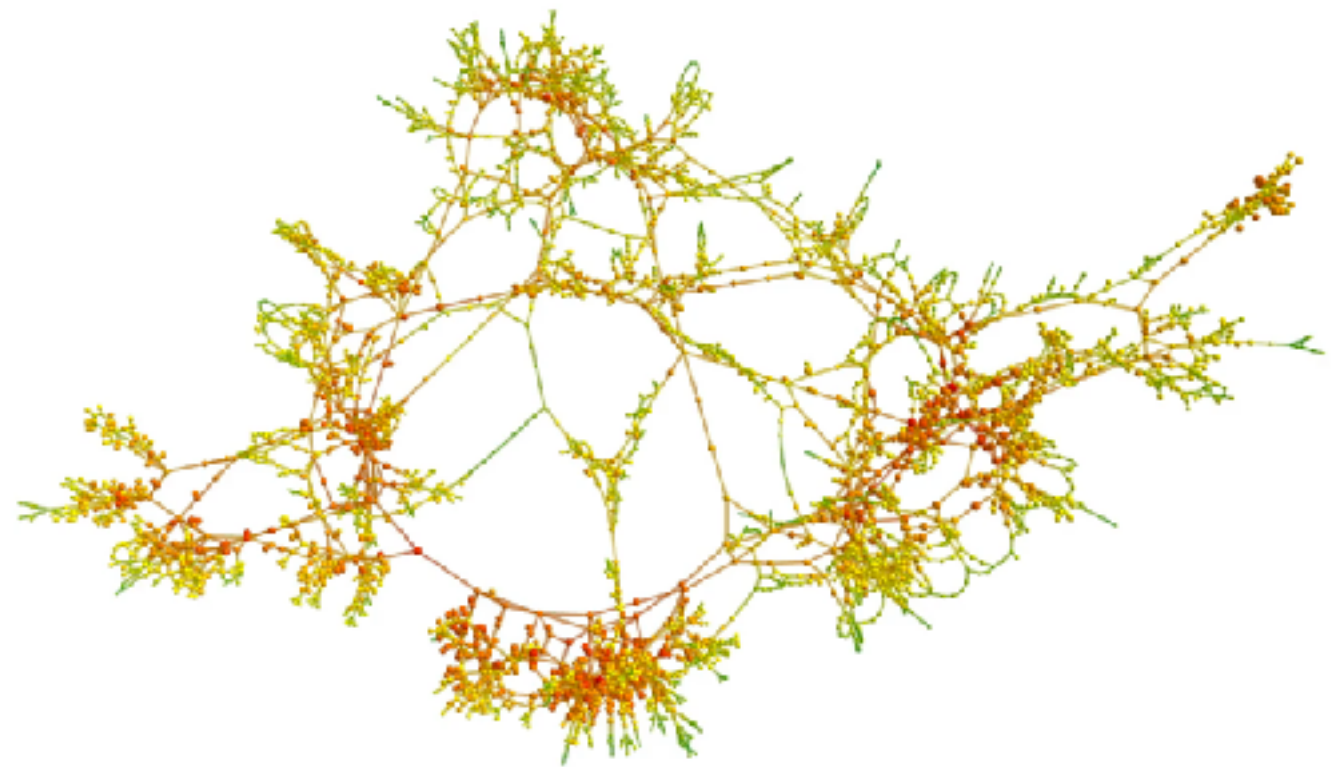
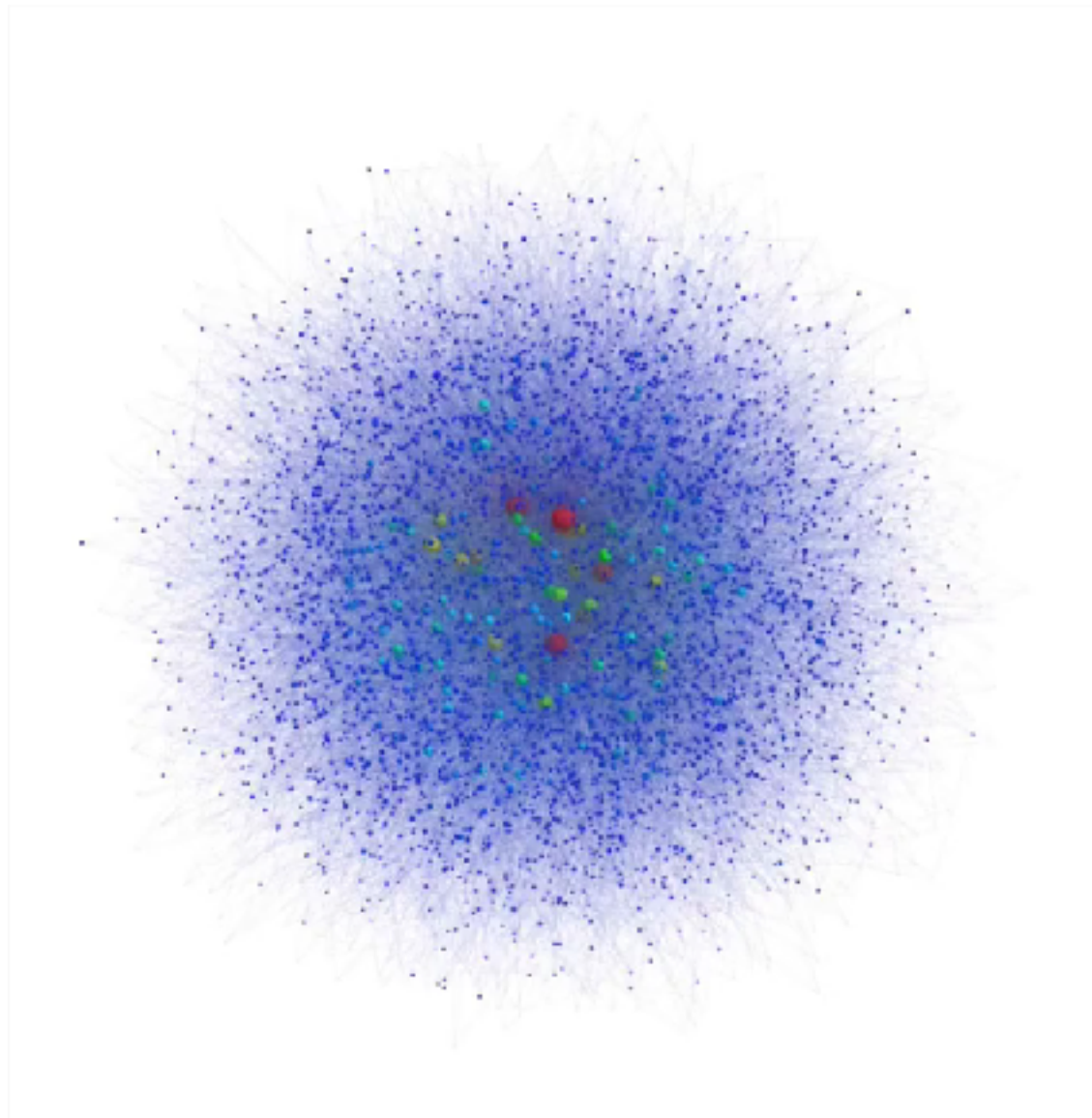
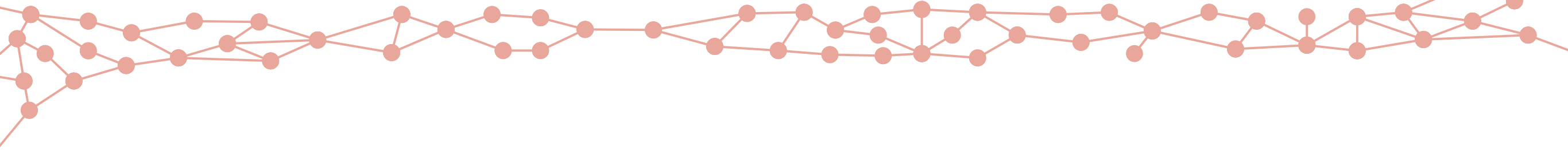




# Examples

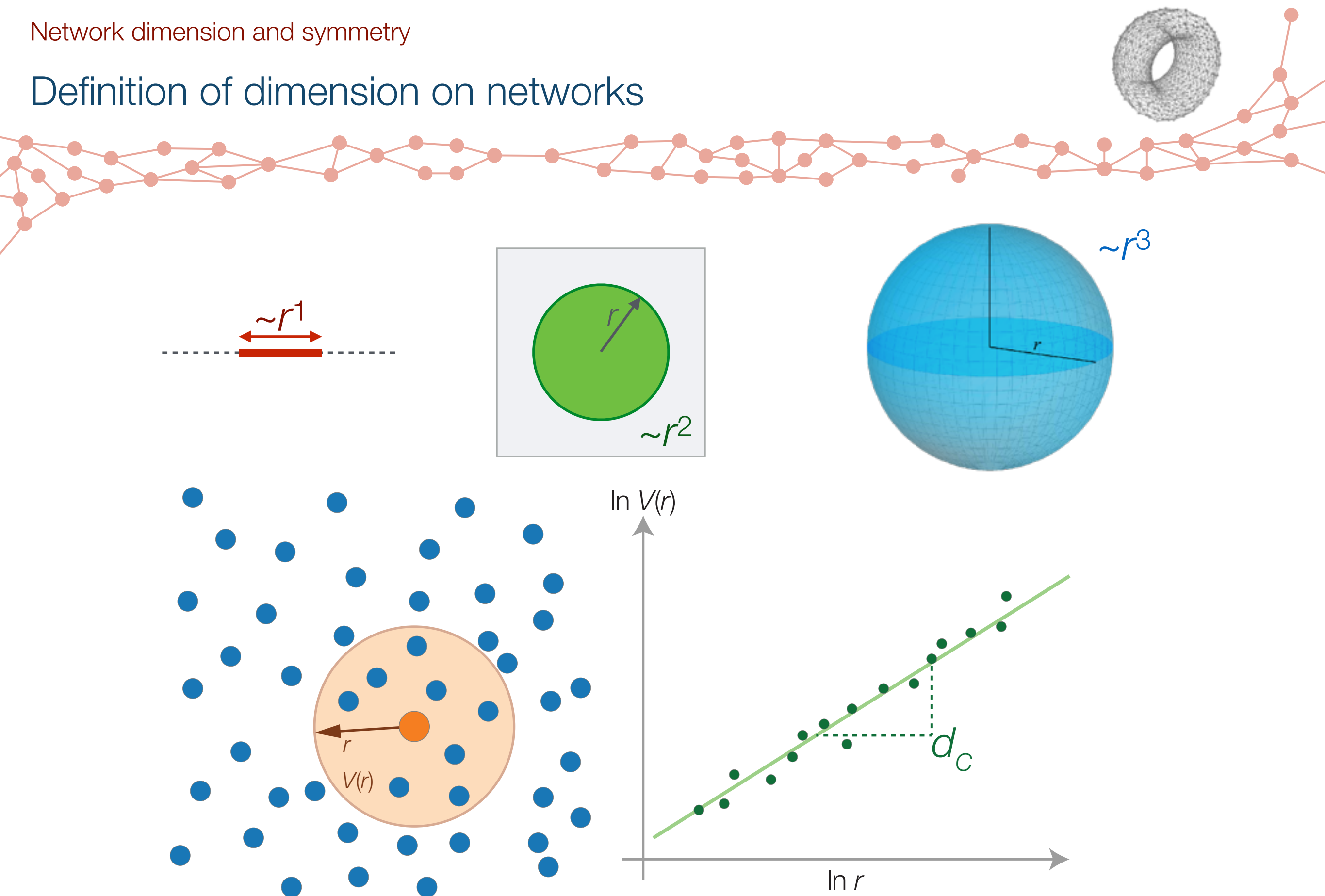


## Network dimension



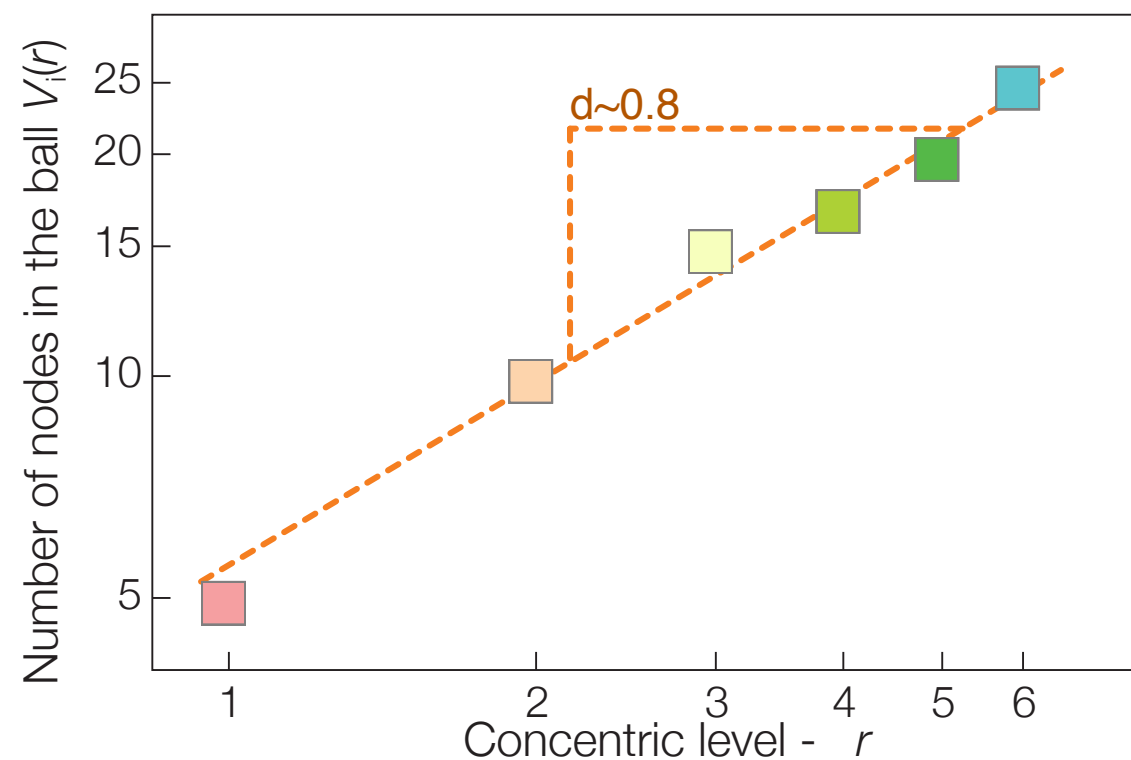
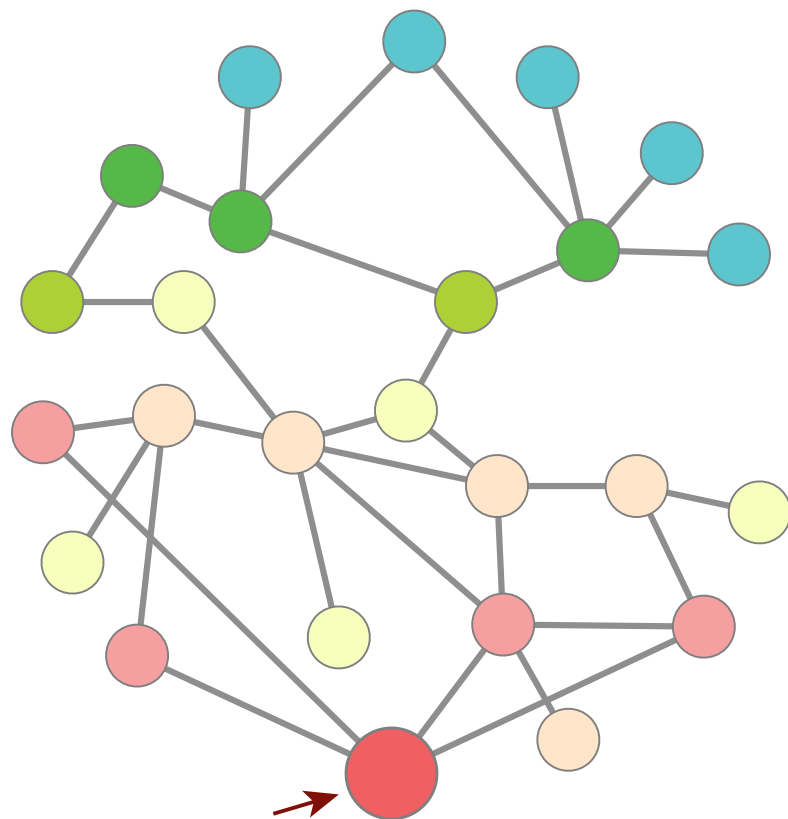
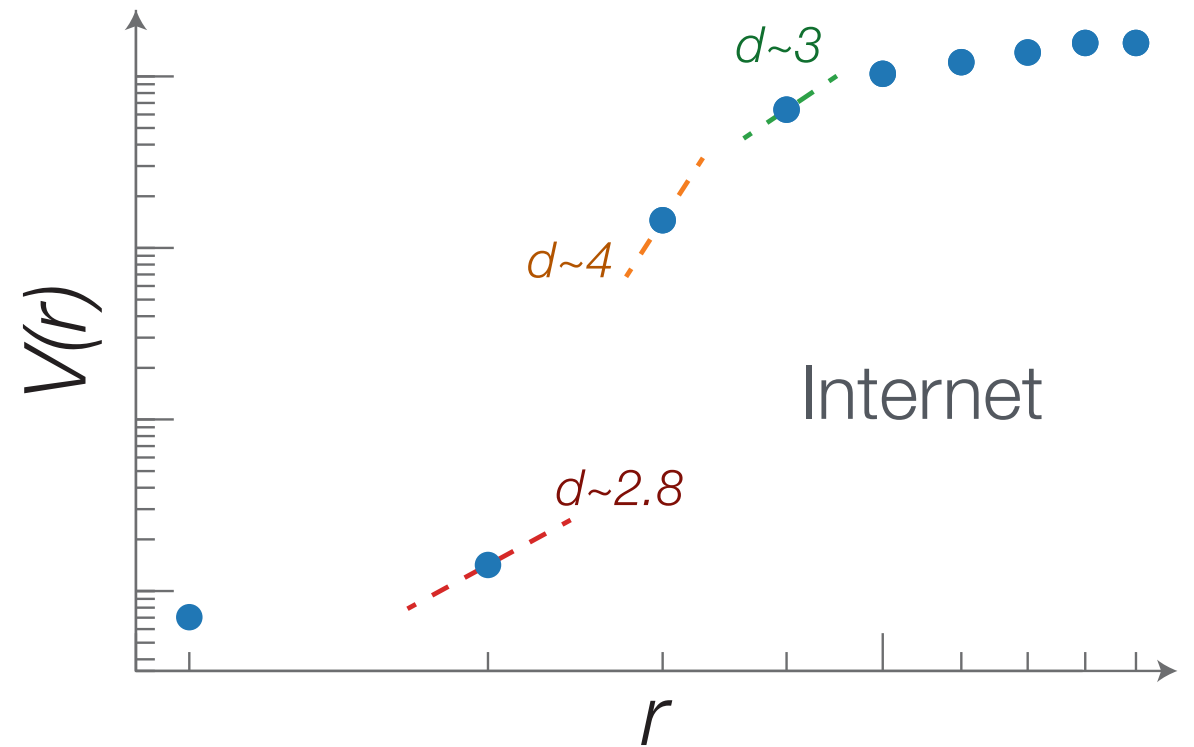
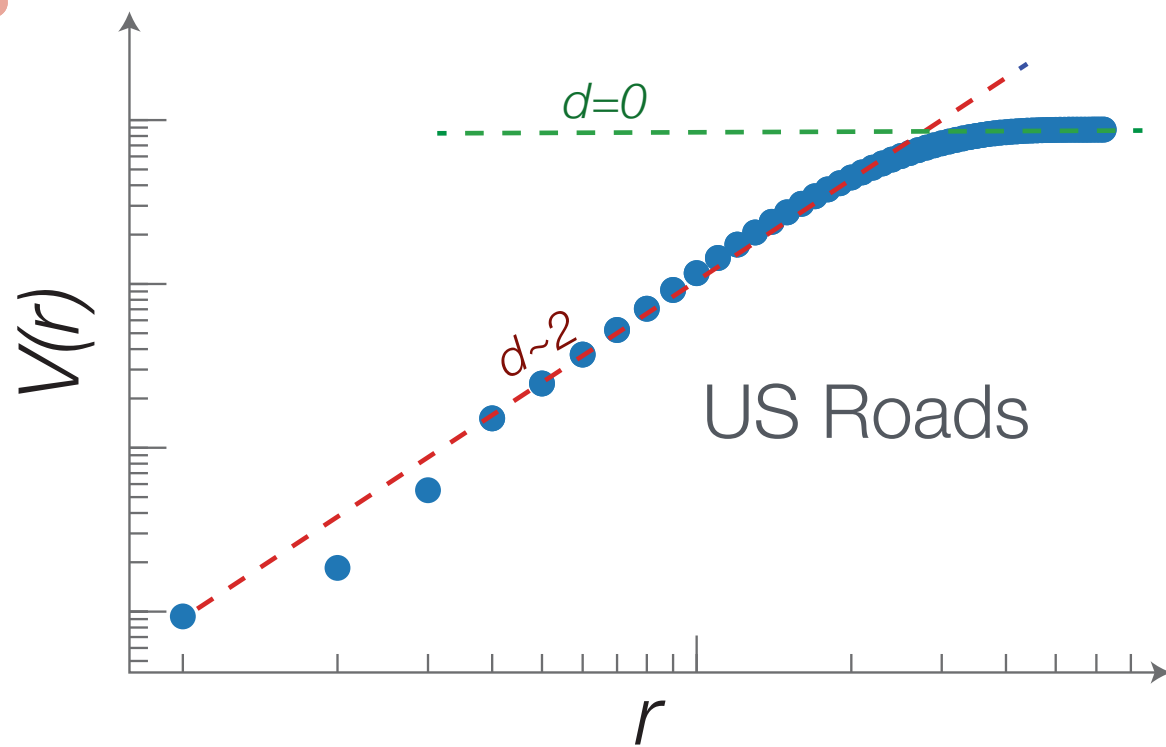
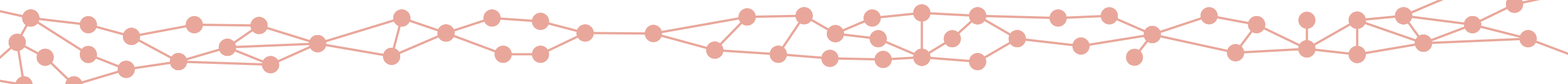


# Definition of dimension on networks

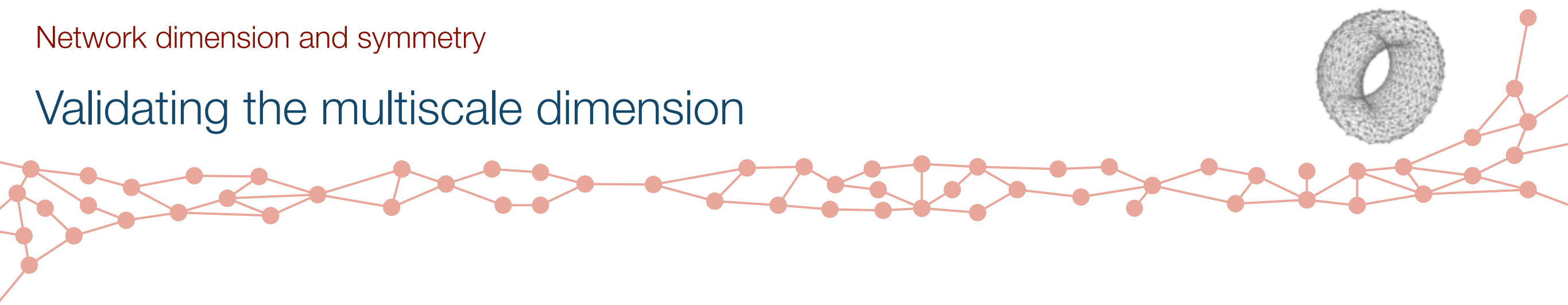




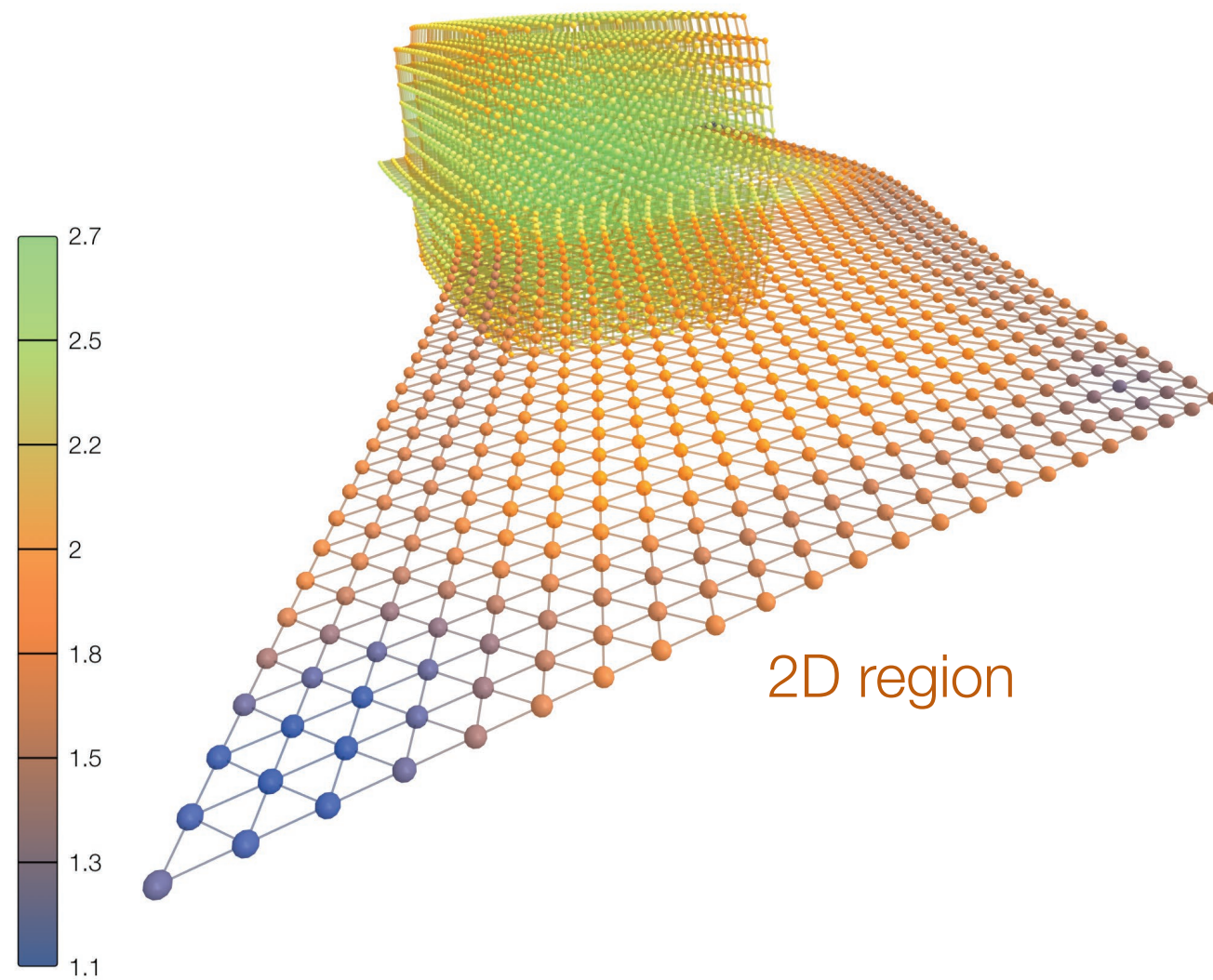
# Problems



# Validating the multiscale dimension



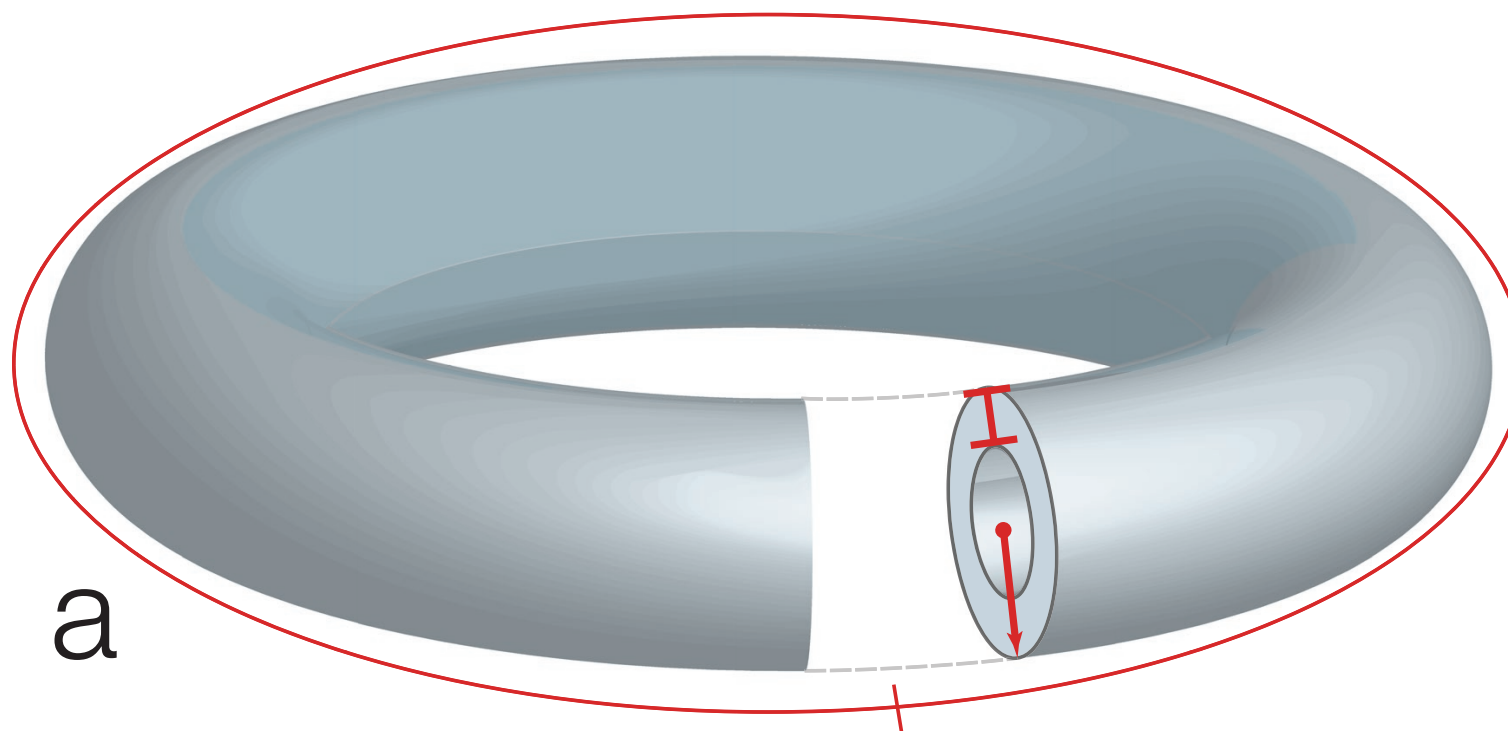
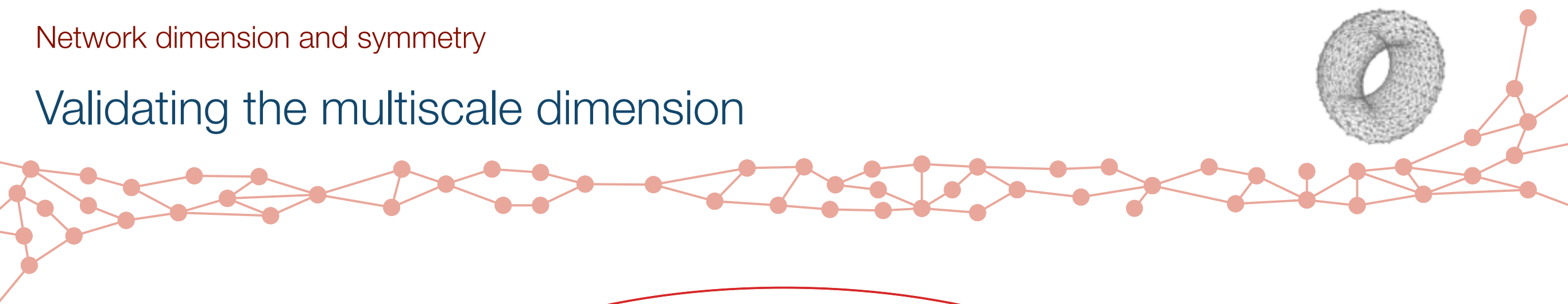
3D region



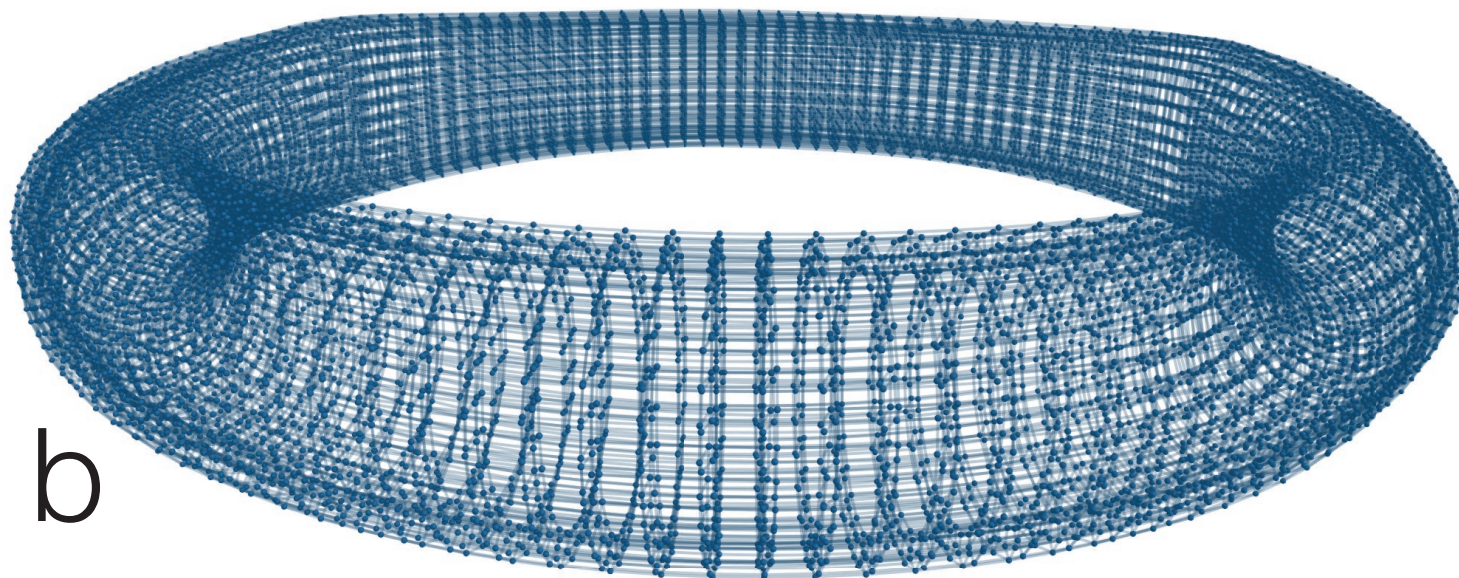
Local dimension  $r=4$ .



## Validating the multiscale dimension

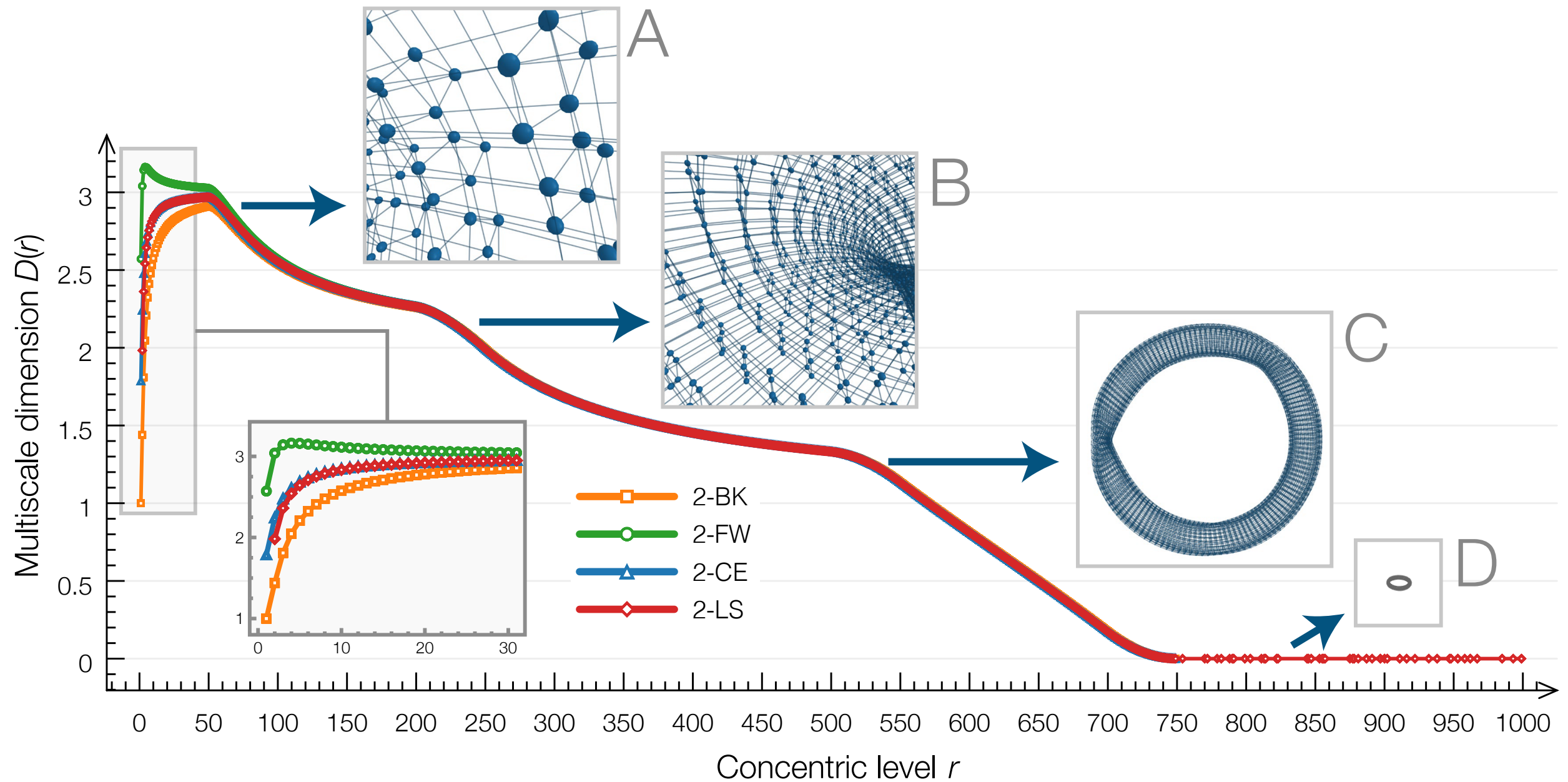


a



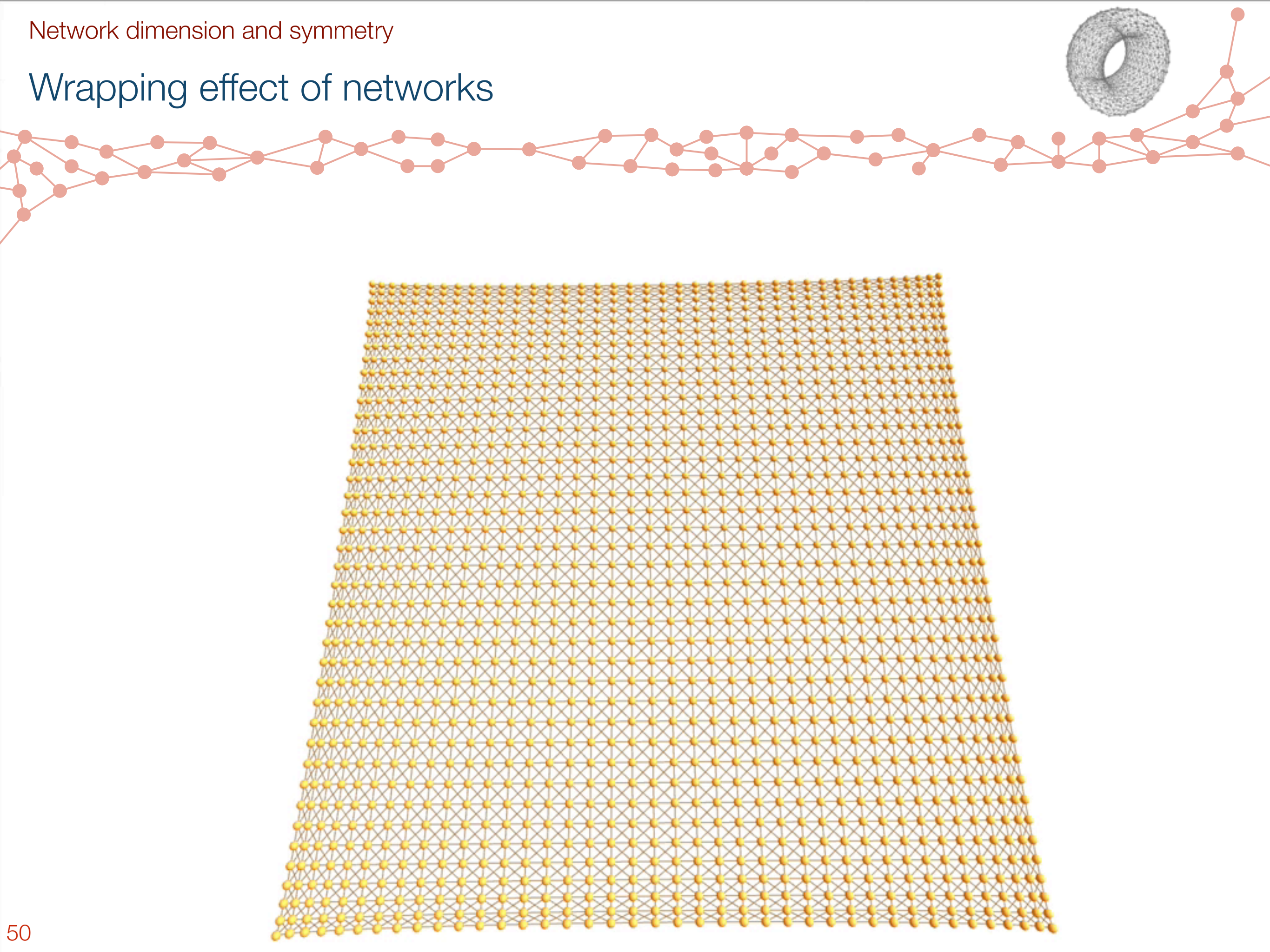
b

# Validating the multiscale dimension



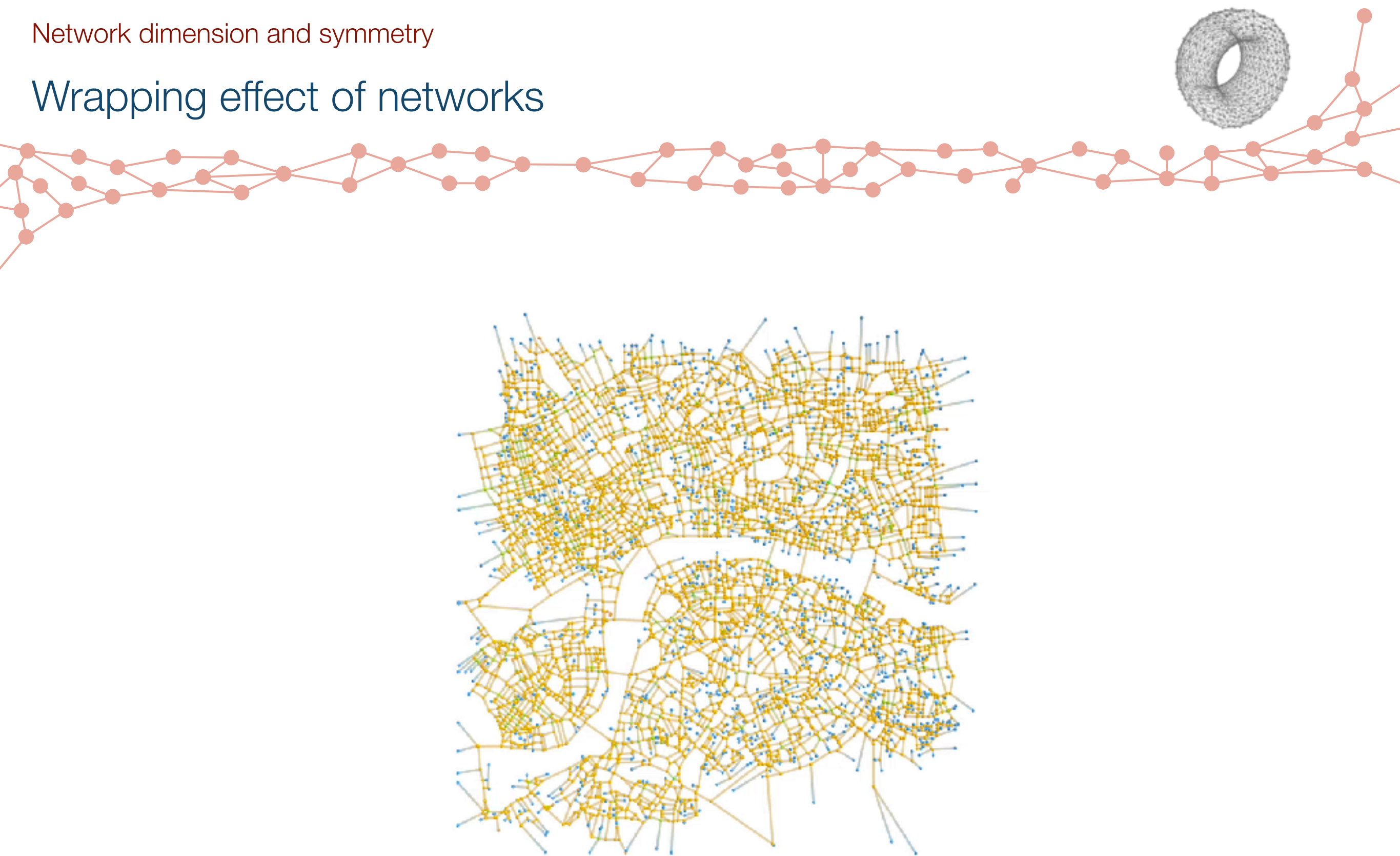


## Wrapping effect of networks



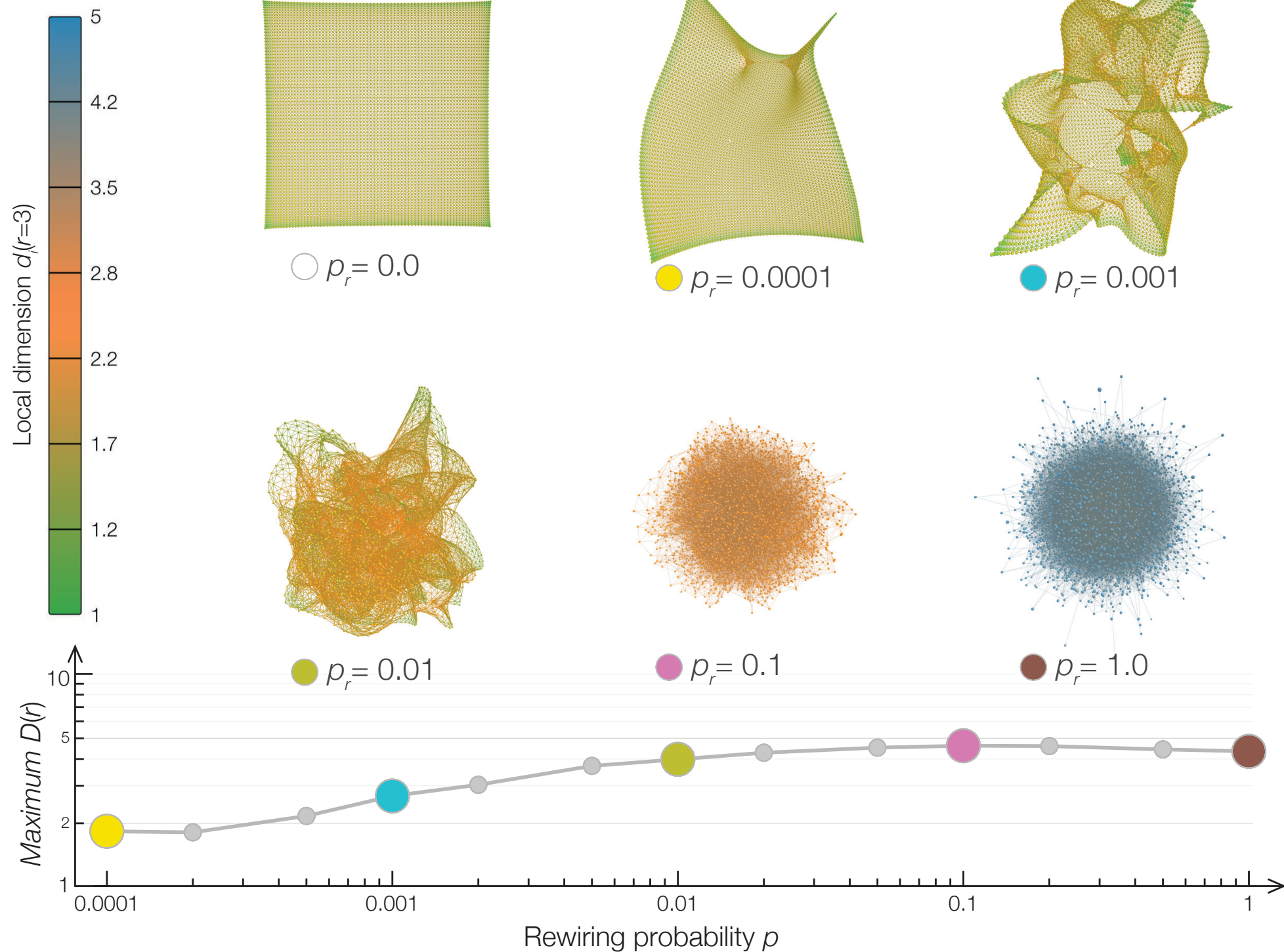


## Wrapping effect of networks





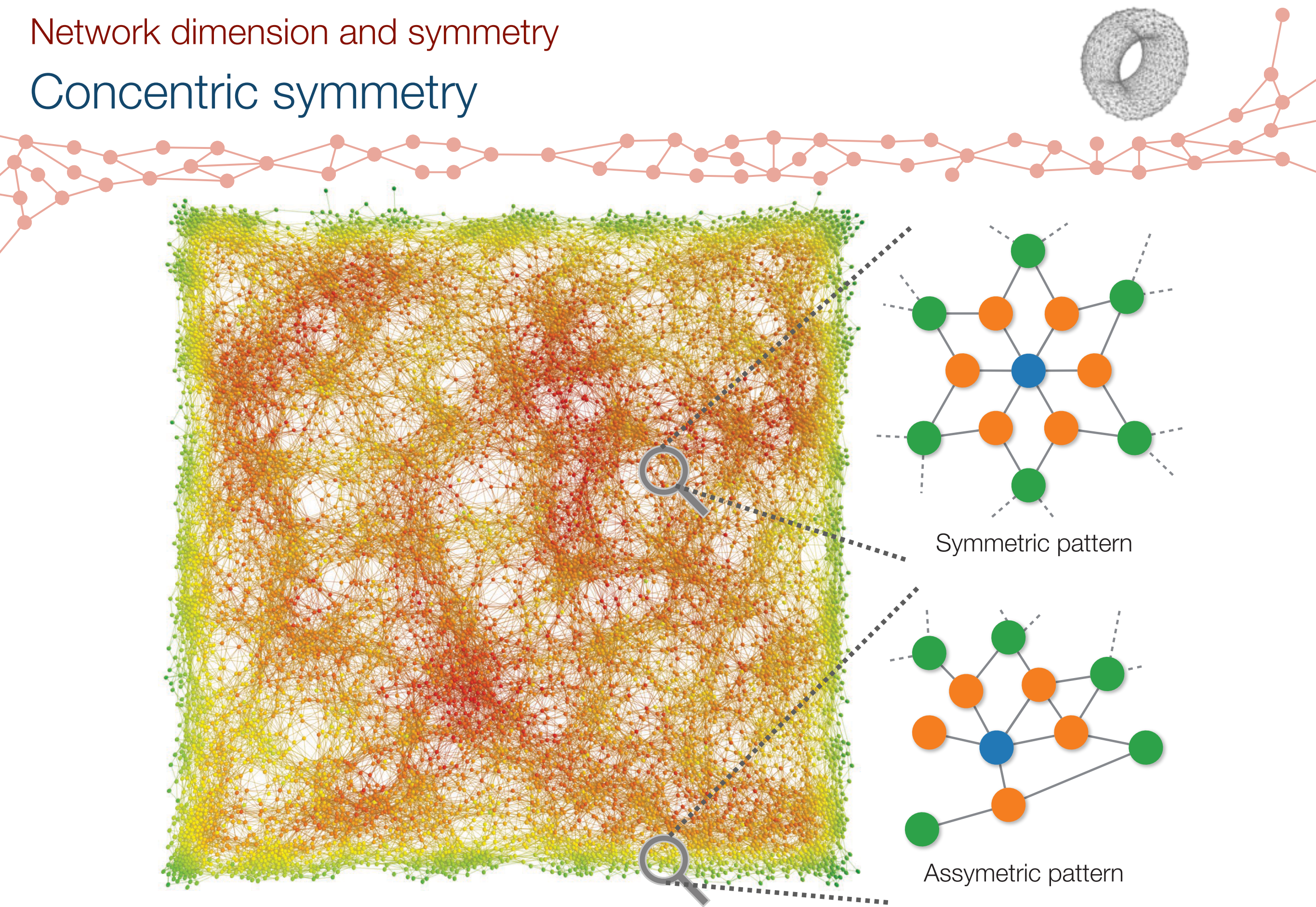
# Wrapping effect of networks





# Network dimension and symmetry

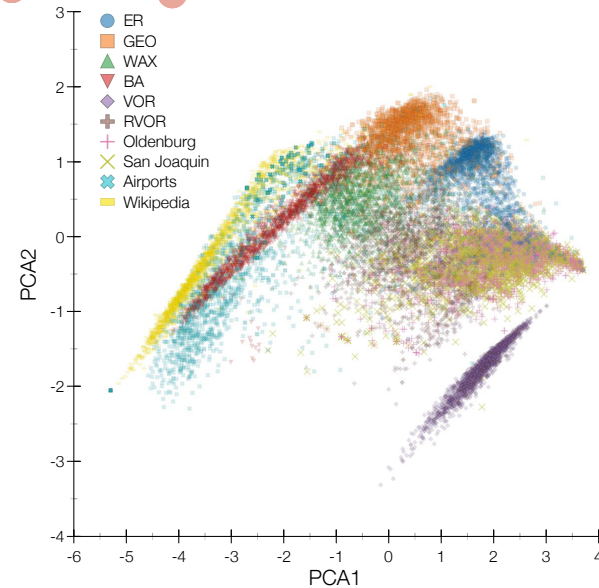
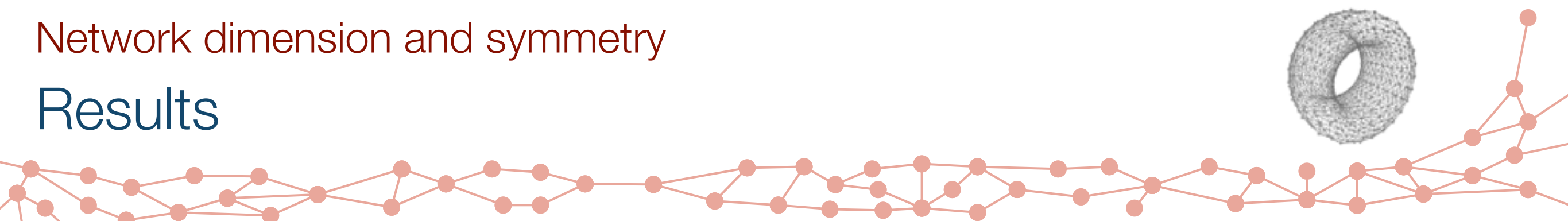
## Concentric symmetry





# Network dimension and symmetry

## Results



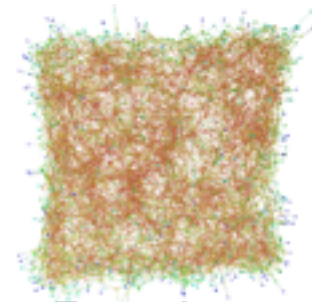
- Concentric symmetries
- Do not correlate with traditional network measurements.
- Discriminate between a diverse range of models and real networks.
- Allowed us to rank networks by their "average" symmetry.



Cities  
(Oldenburg)



ER



Random  
Geographic



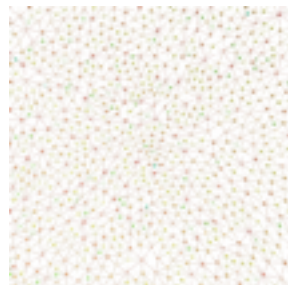
BA



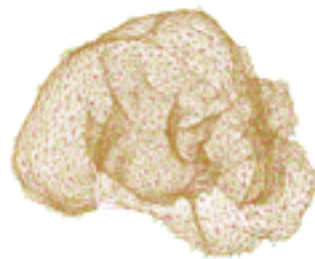
Wikipedia



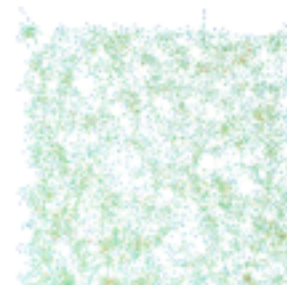
Voronoi



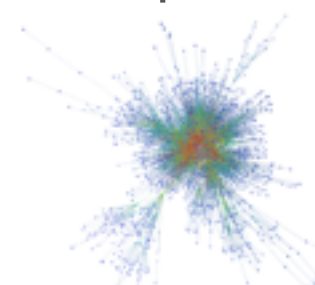
Rewired  
Voronoi



Waxman

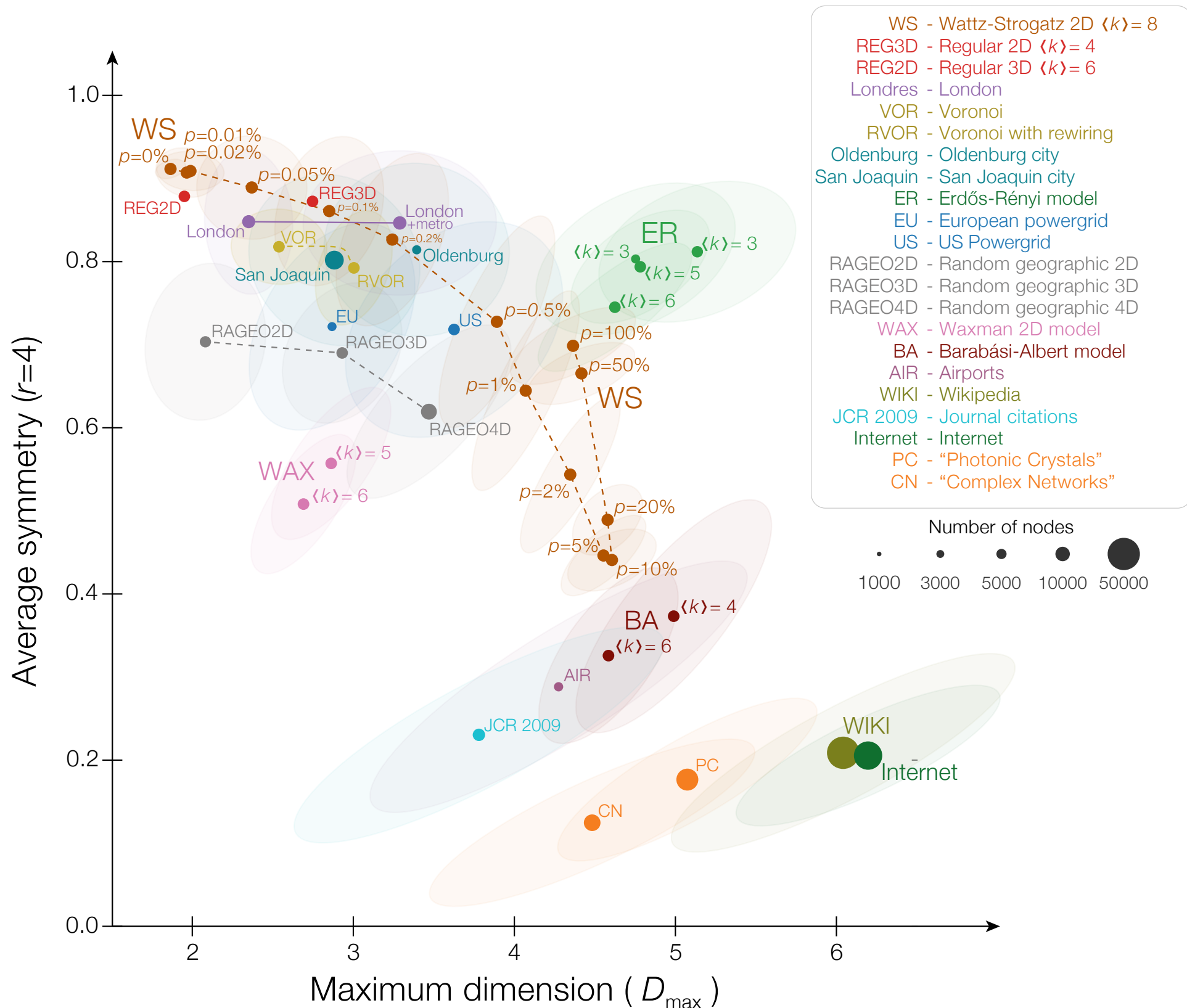


Airports



# Network dimension and symmetry

## Dimension and symmetry



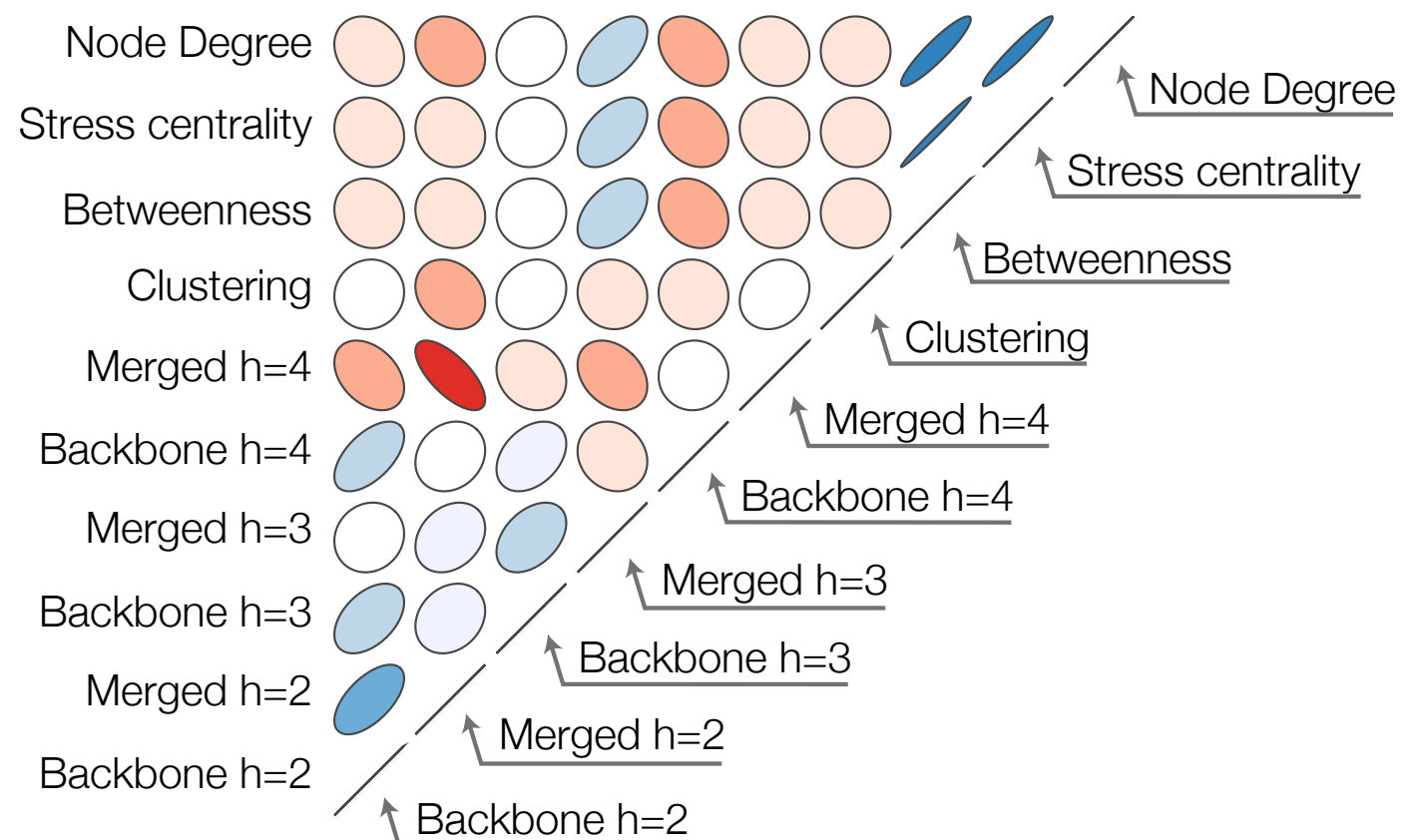


# Symmetry in word adjacency networks

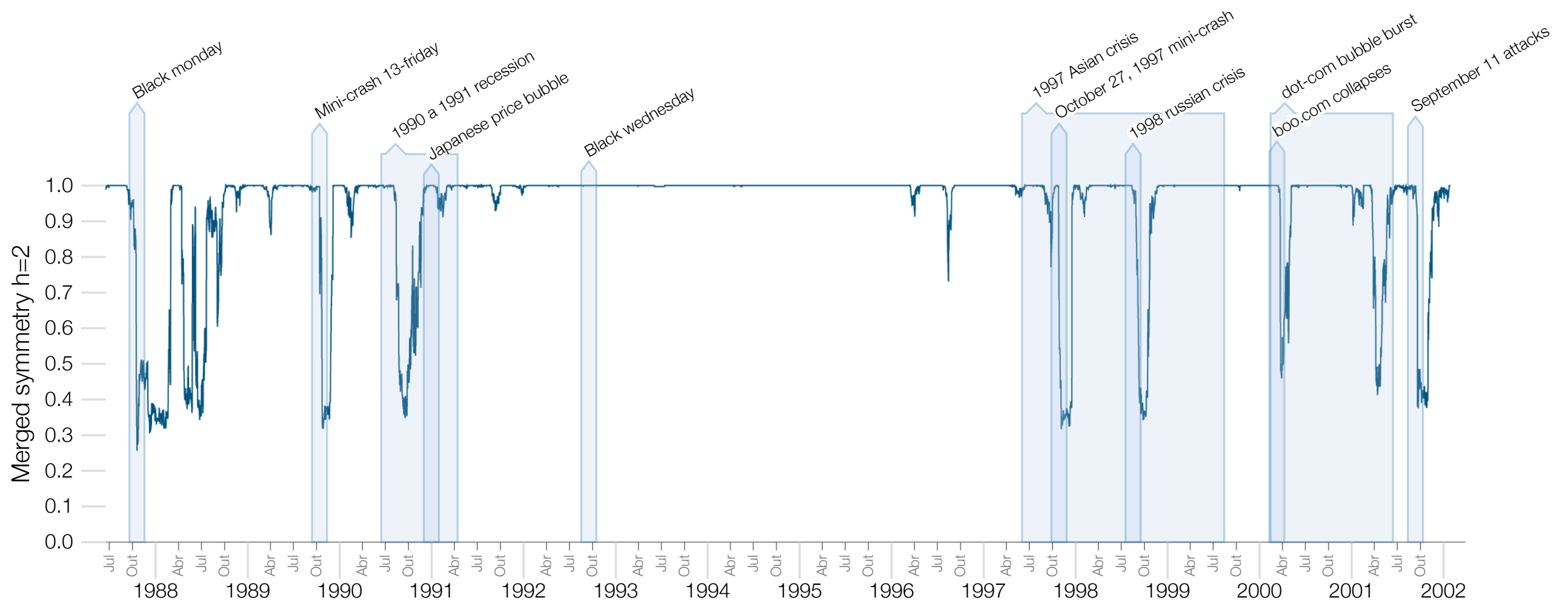
Symmetry	SVM	MLP	KNN	NBY
Merged $h = 2$	75.0%	72.5%	55.0%	42.5%
Merged $h = 3$	70.0%	62.5%	65.0%	40.0%
Merged $h = 4$	82.5%	82.5%	57.5%	42.5%
Backbone $h = 2$	32.5%	32.5%	20.0%	20.0%
Backbone $h = 3$	70.0%	72.5%	57.5%	27.5%
Backbone $h = 4$	70.0%	82.5%	57.5%	42.5%

Accuracy rates found for the authorship detection task.

Pearson correlation coefficients between symmetry and other traditional network measurements

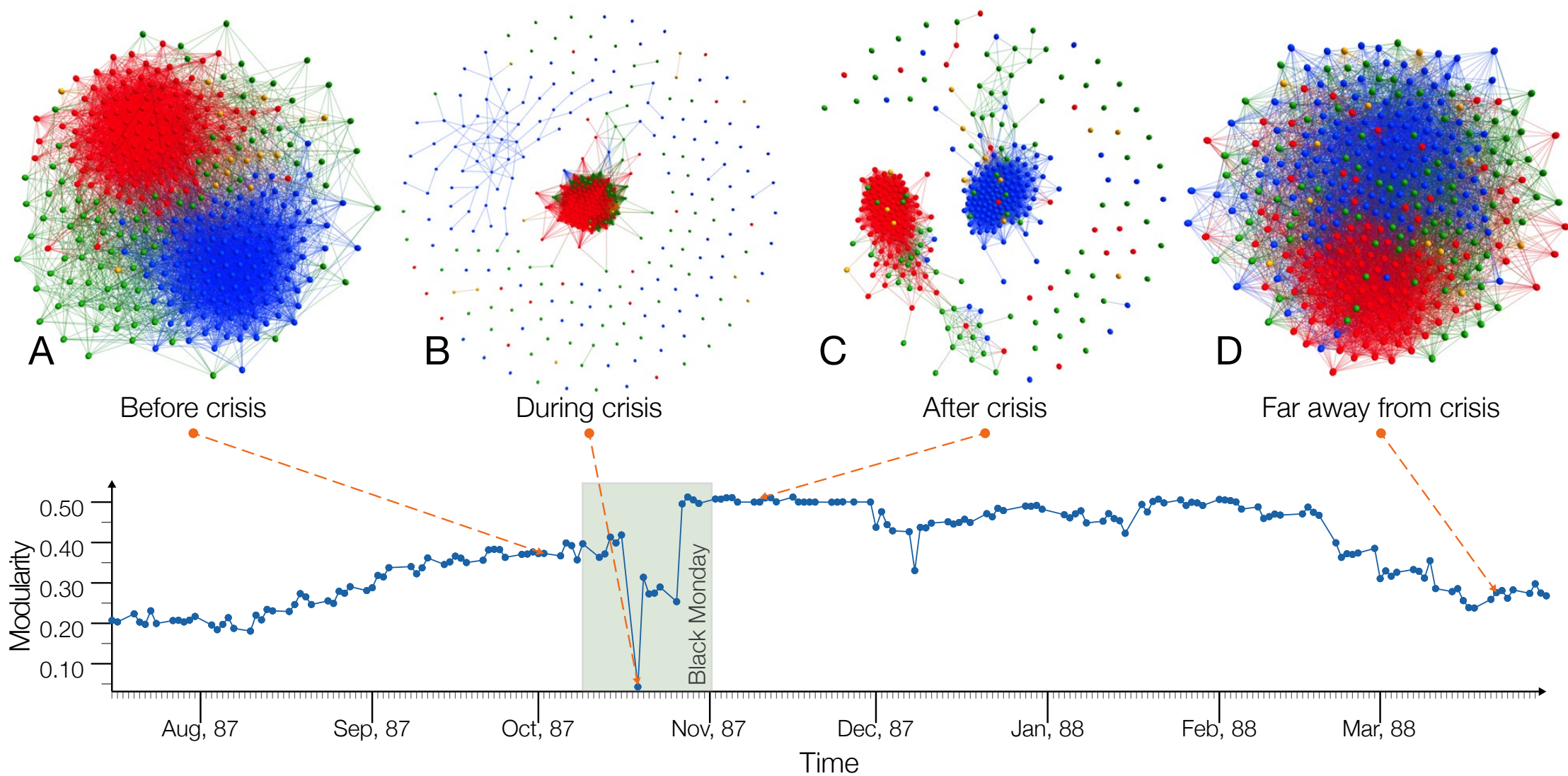


# Symmetry applied to the financial market network

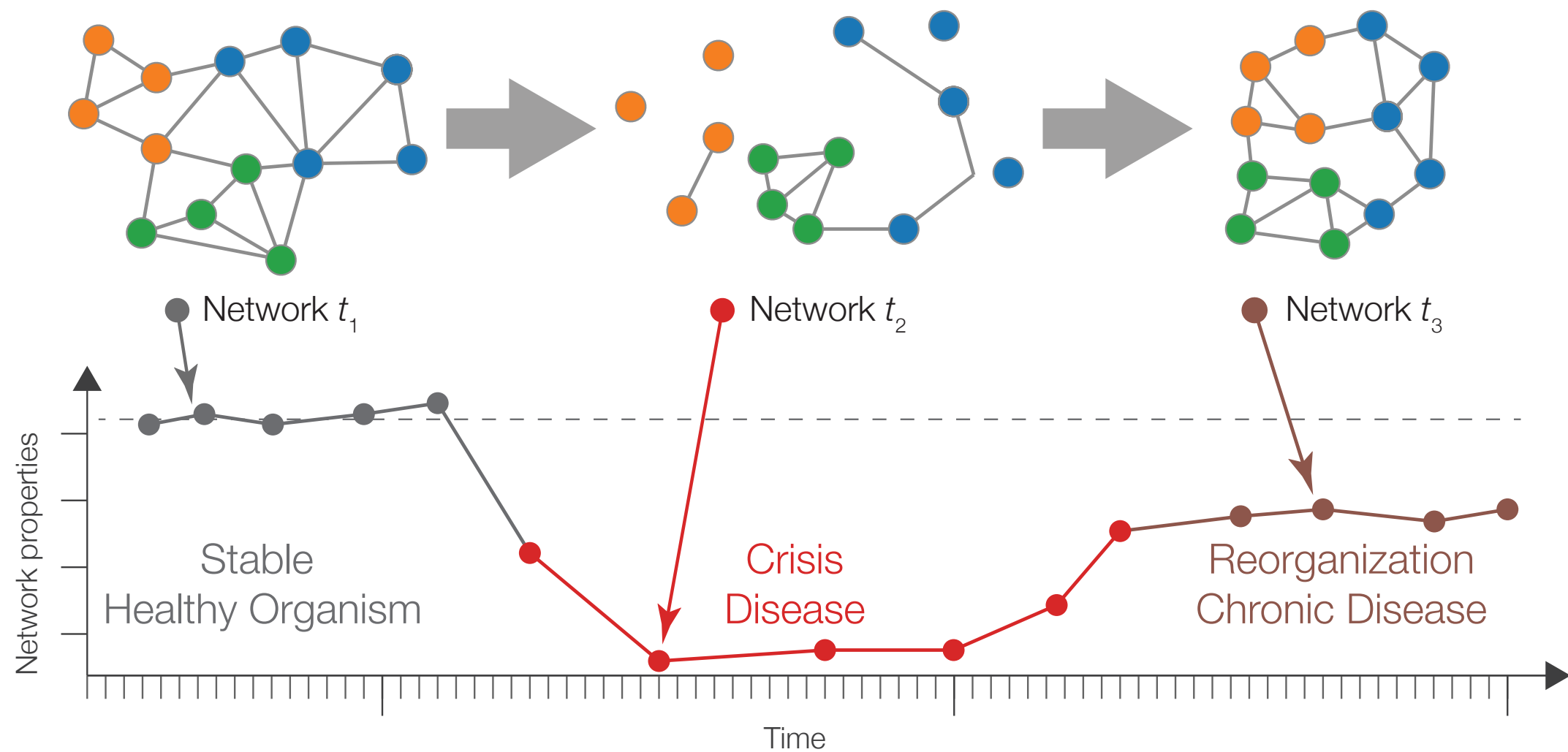




# Financial market networks

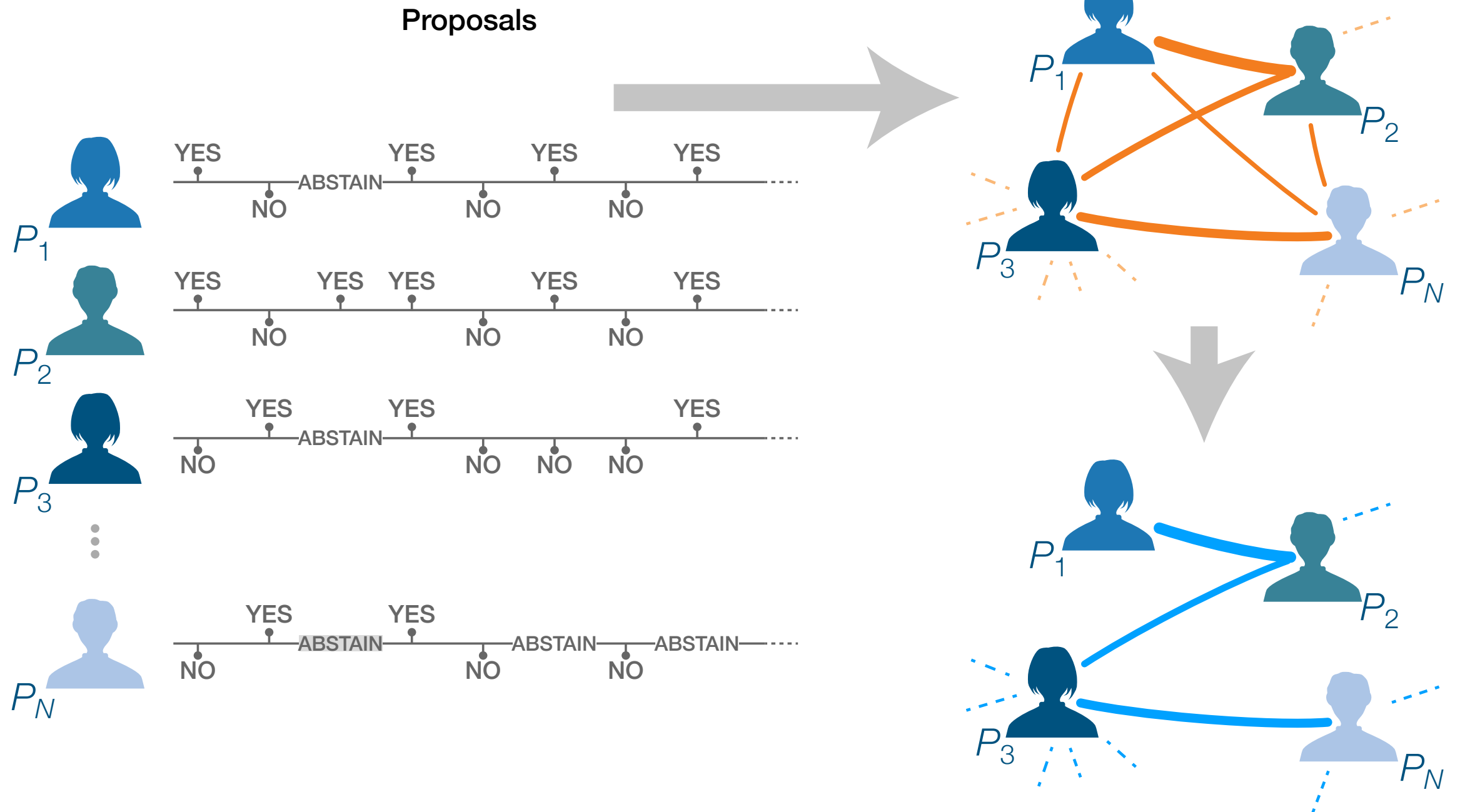


# Time evolving network during crisis

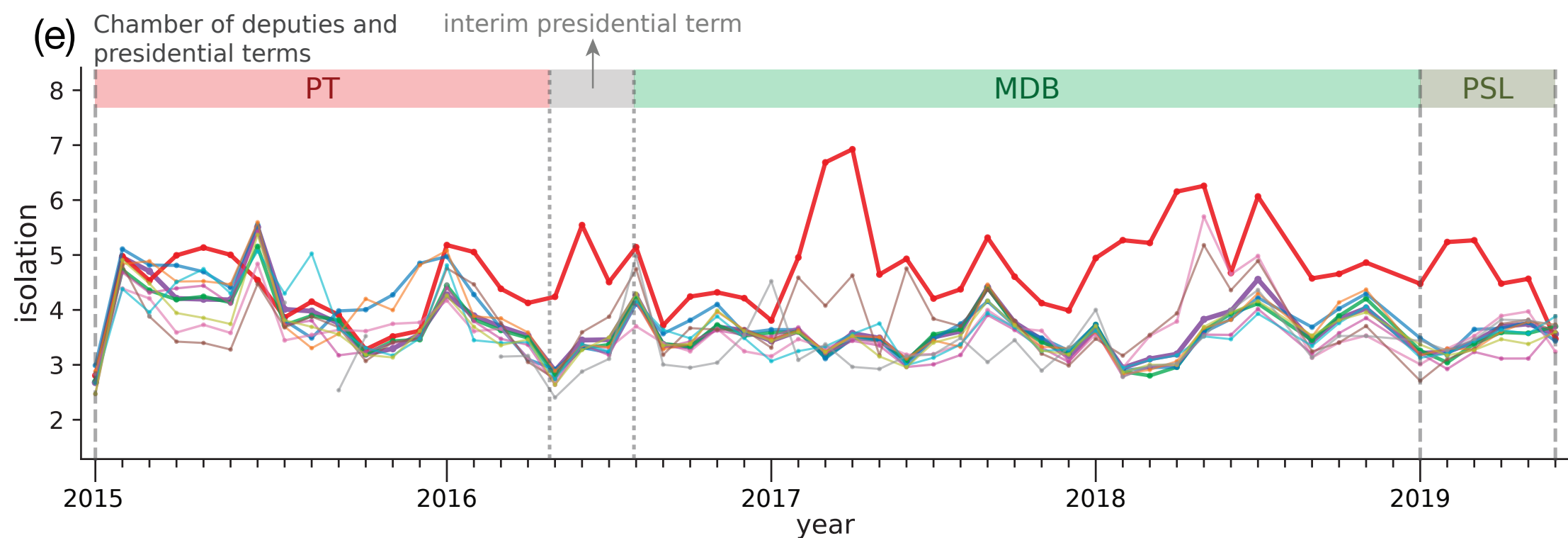
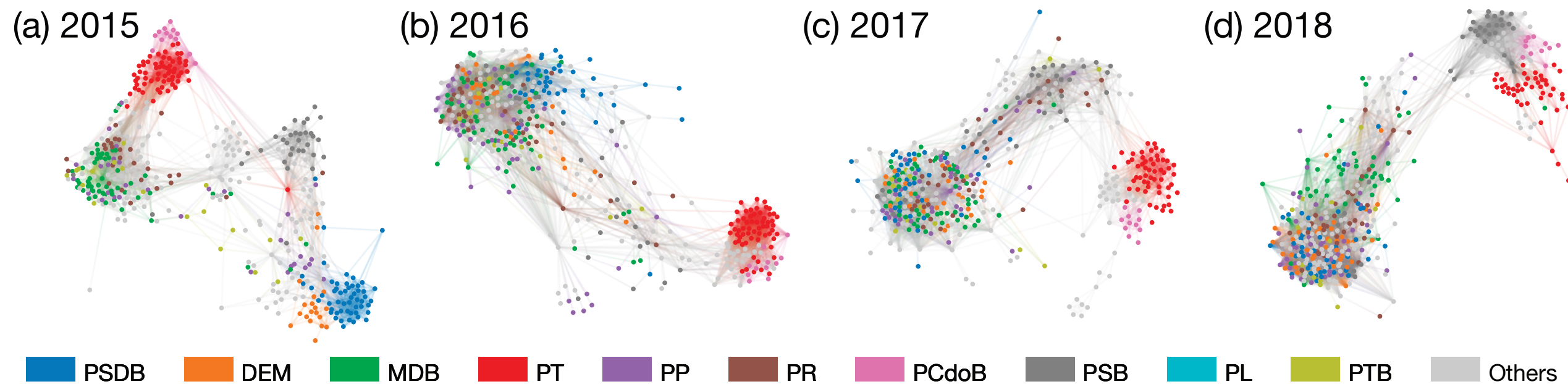




# Political networks

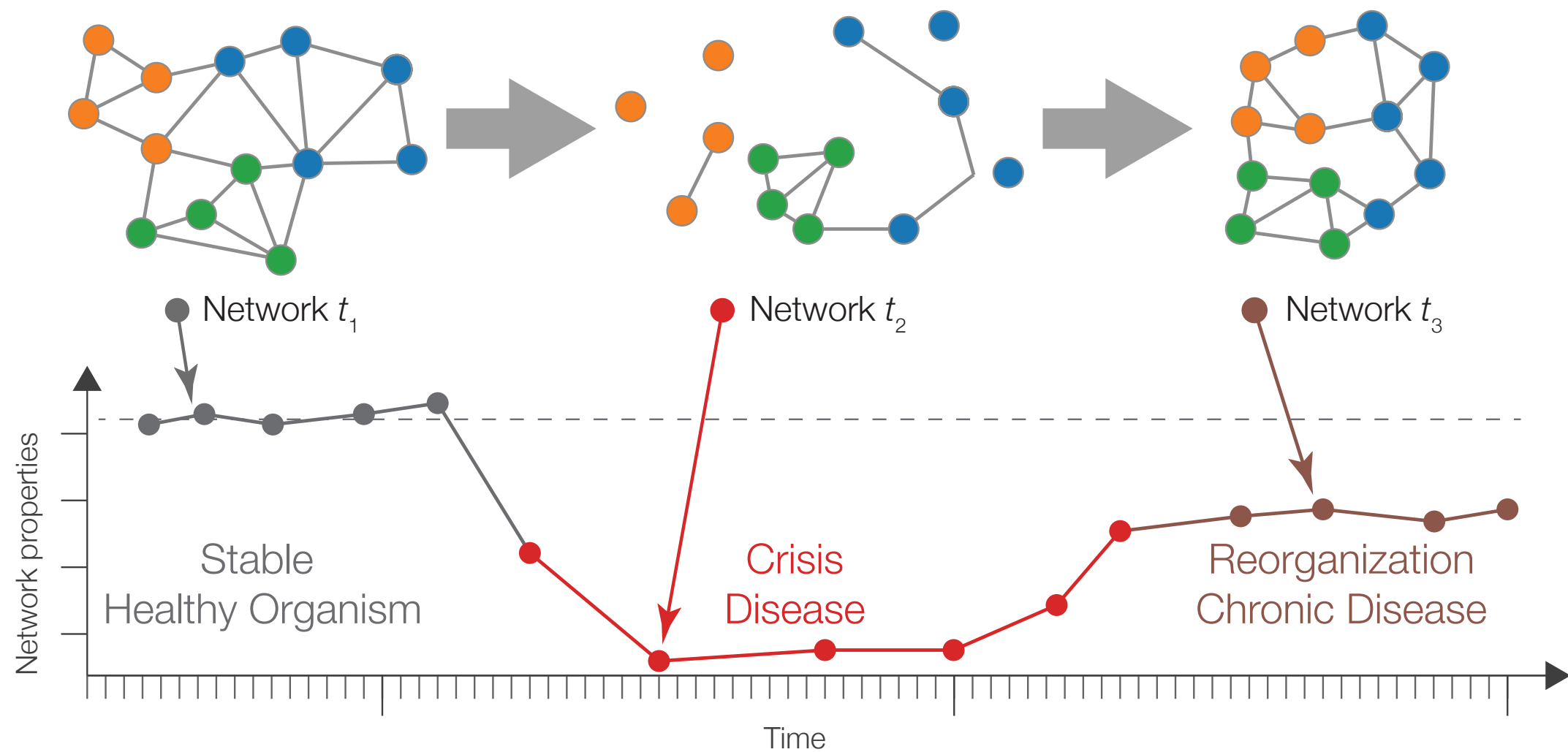


# Political networks

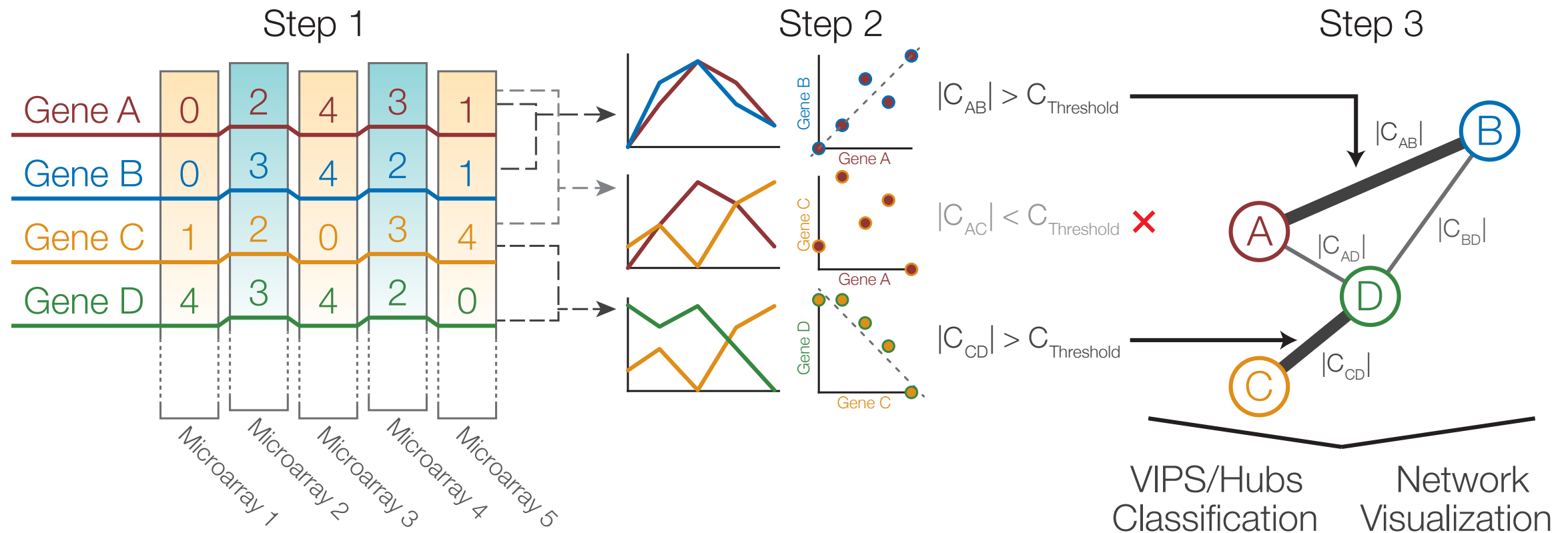




# Time evolving network during crisis



# Gene co-expression networks

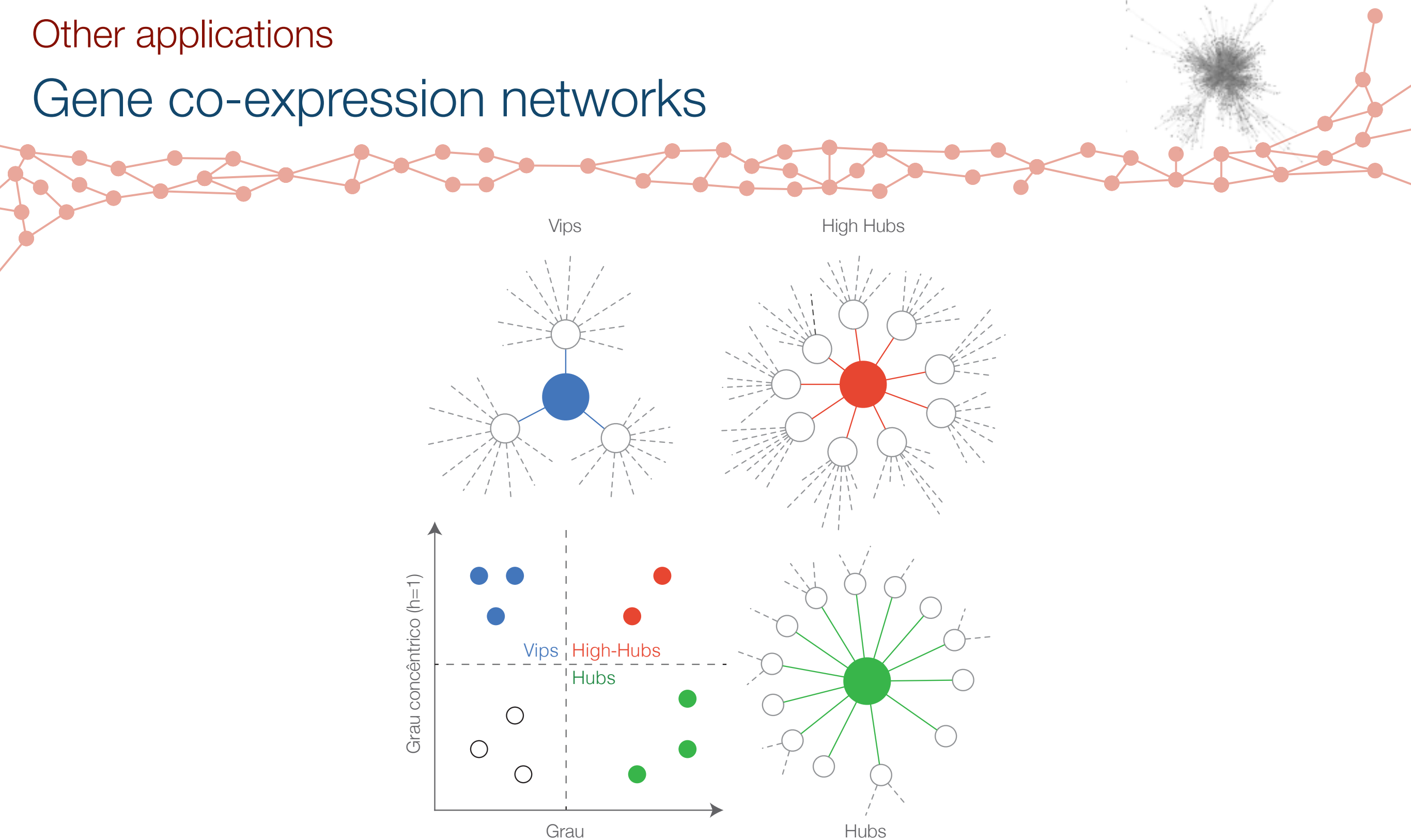


BANDO, S. Y.; SILVA, F. N.; COSTA, L. da F.; SILVA, A. V.; PIMENTEL-SILVA, L. R.; CASTRO, L. H. M.; WEN, H.-T.; AMARO JUNIOR, E.; MOREIRA-FILHO, C. A. Complex network analysis of CA3 transcriptome reveals pathogenic and compensatory pathways in refractory temporal lobe epilepsy. *PLoS ONE*, v. 8, n. 11, p. e79913, 2013.

MOREIRA-FILHO, C. A.; BANDO, S. Y.; BERTONHA, F. B.; SILVA, F. N.; COSTA, L. da F. Methods for gene coexpression network visualization and analysis. In: PASSOS, G. A. (Ed.). *Transcriptomics in health and disease*. Berlin: Springer, 2014. cap. 4, p. 79–94.



# Gene co-expression networks



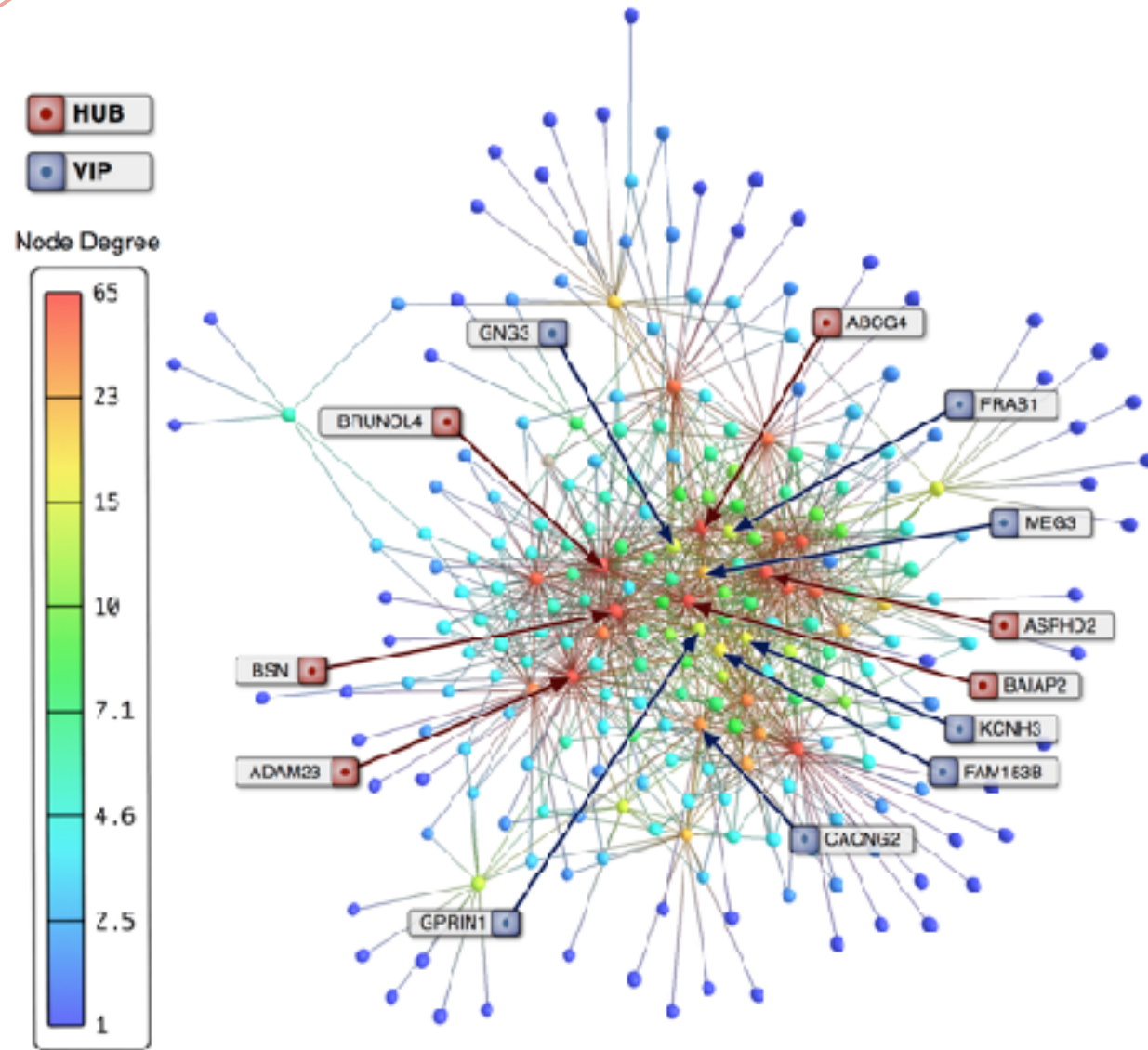
MOREIRA-FILHO, C. A.; BANDO, S. Y.; BERTONHA, F. B.; IAMASHITA, P.; SILVA, F. N.; COSTA, L. da F.; SILVA, A. V.; CASTRO, L. H. M.; WEN, H.-T. Community structure analysis of transcriptional networks reveals distinct molecular pathways for early- and late-onset temporal lobe epilepsy with childhood febrile seizures. *PLoS ONE*, v. 10, n. 5, p. e0128174, 2015.

BANDO, S. Y.; BERTONHA, F. B.; SILVA, F. N.; COSTA, L. da F.; FERREIRA, L.; FURLANETTO, G.; CHACUR, P.; ZERBINI, M. C.; CARNEIRO-SAMPAIO, M.; MOREIRA-FILHO, C. A. Modular Transcriptional Repertoire and MicroRNA target Analyses Characterize Genomic Dysregulation in the Thymus of Down Syndrome Infants. Submetido à *Oncotarget*.

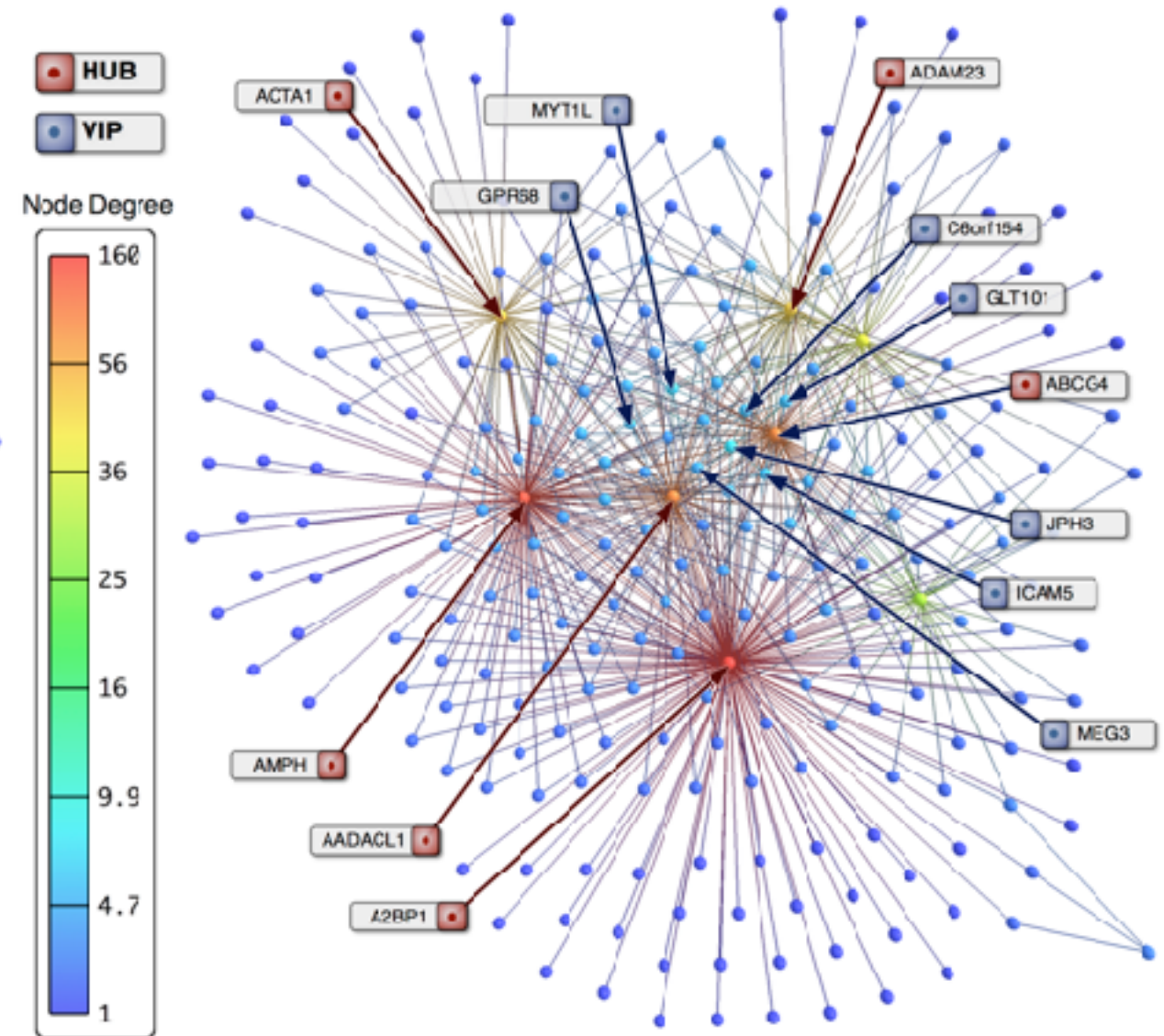
## Other applications

# Gene co-expression networks

DE Networks of CA3 Transcriptome



Febrile



Afebrile



Other applications

## Gene co-expression networks



microorganisms



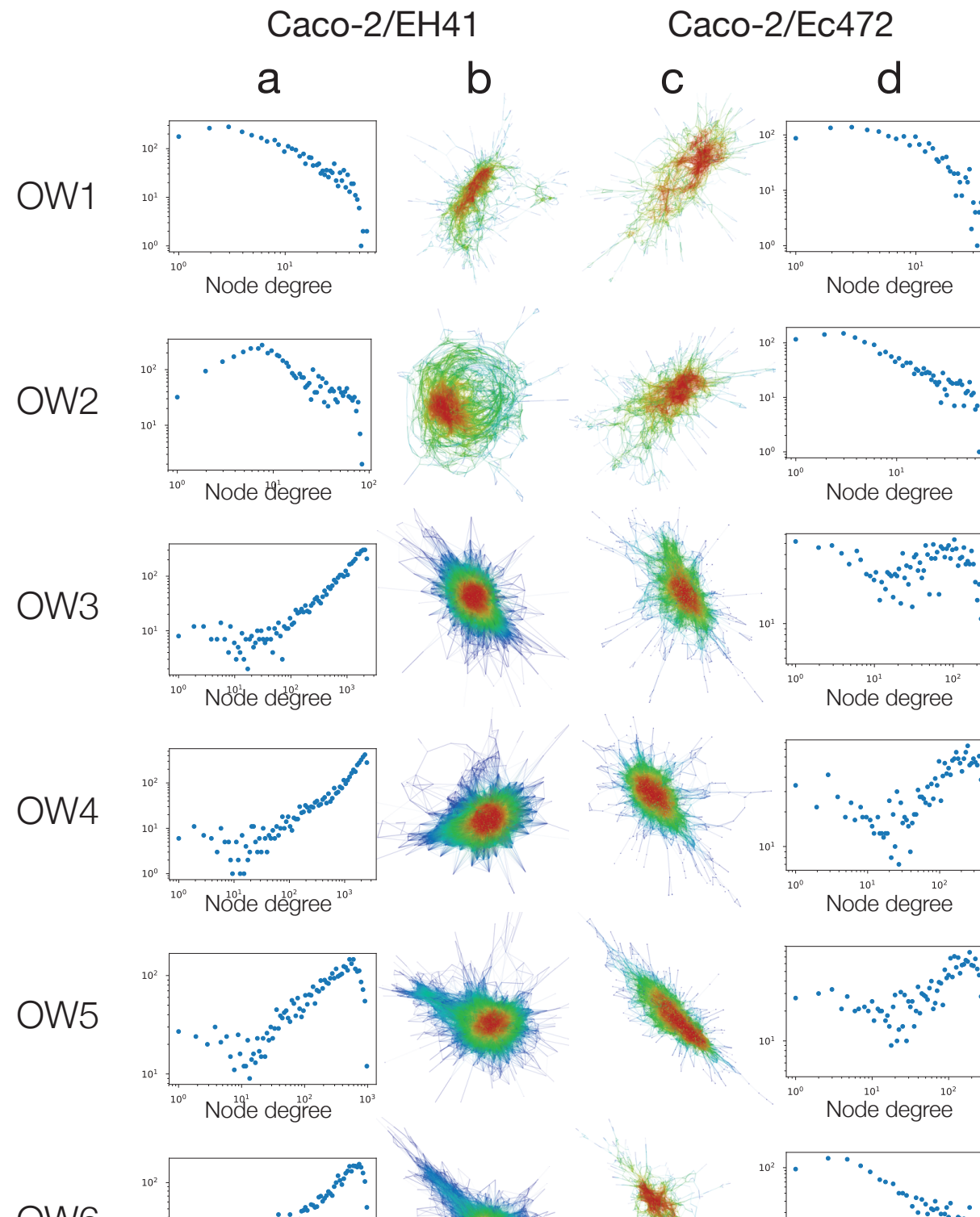
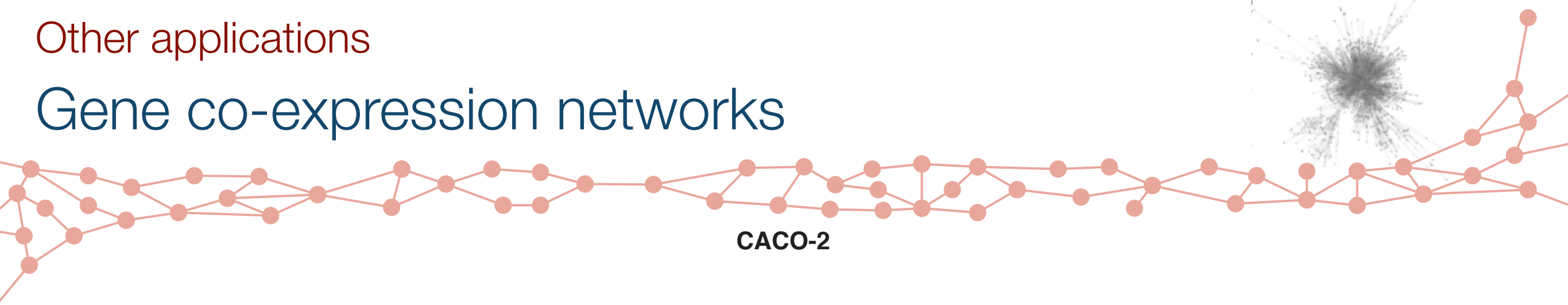
Article

# Dynamic Gene Network Analysis of Caco-2 Cell Response to Shiga Toxin-Producing *Escherichia coli*-Associated Hemolytic–Uremic Syndrome

Silvia Y. Bando <sup>1,†</sup>, Priscila Iamashita <sup>1,†</sup>, Filipi N. Silva <sup>2</sup>, Luciano da F. Costa <sup>2</sup>, Cecilia M. Abe <sup>3</sup>, Fernanda B. Bertonha <sup>1</sup>, Beatriz E. C. Guth <sup>4</sup>, André Fujita <sup>5</sup>, and Carlos A. Moreira-Filho <sup>1,\*</sup>

## Other applications

# Gene co-expression networks





# Gene co-expression



OW8

OW9

OW10

# Narrative

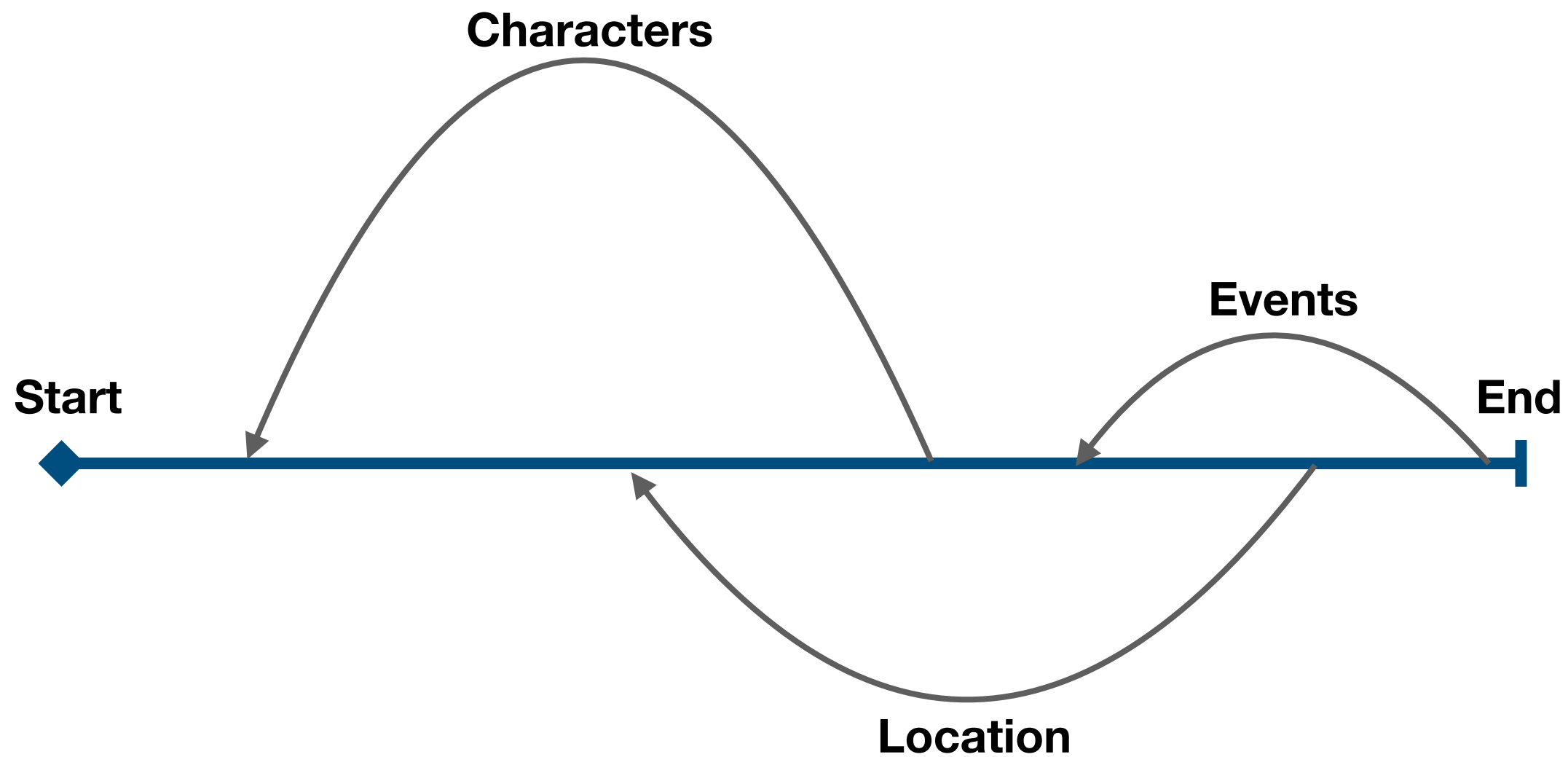
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**End**

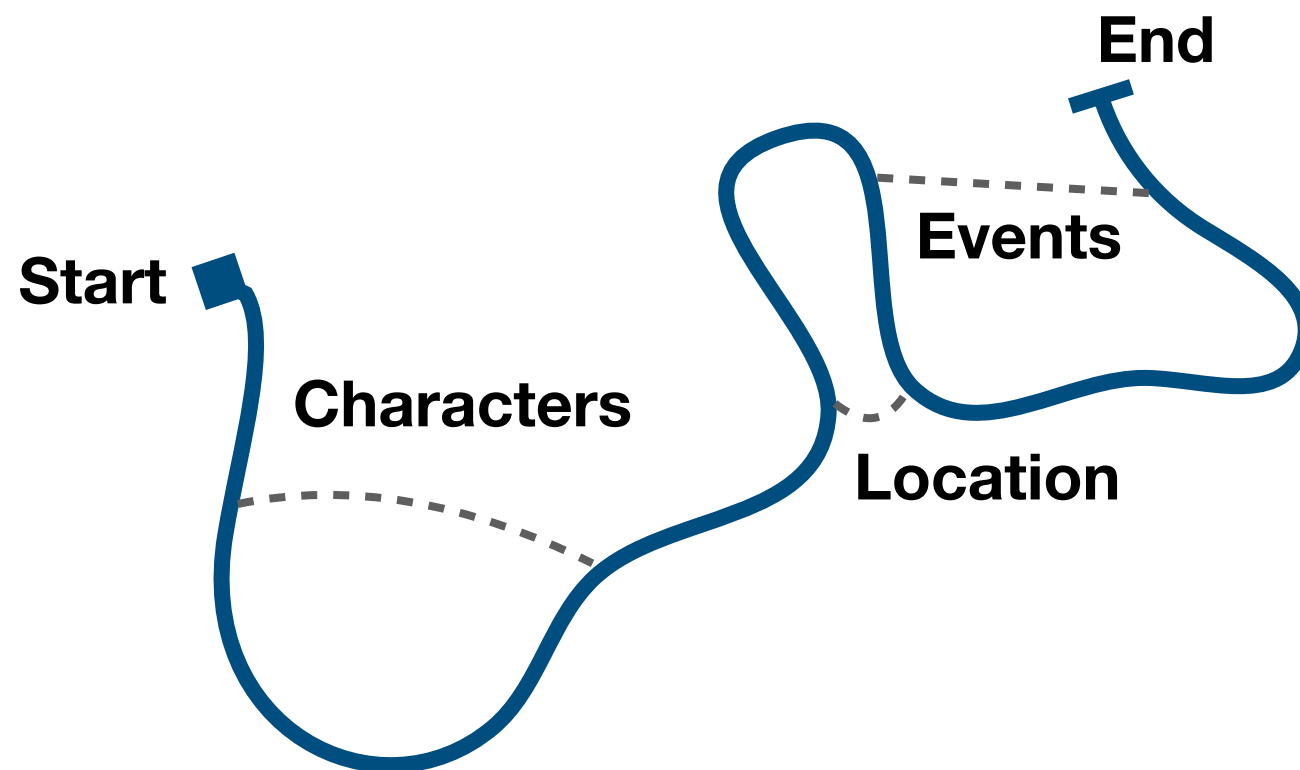




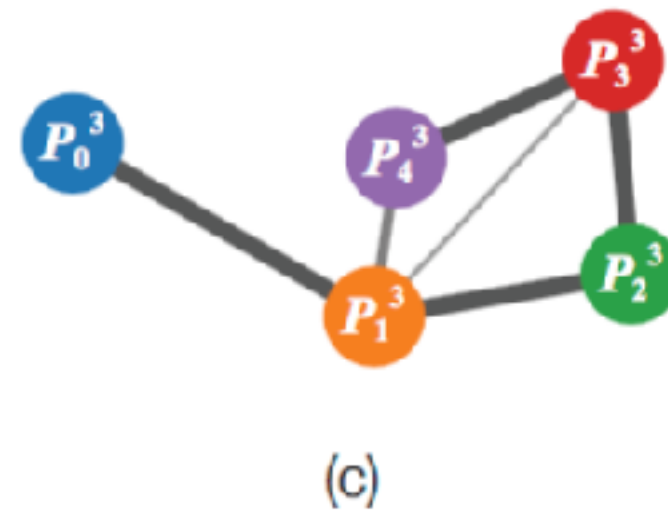
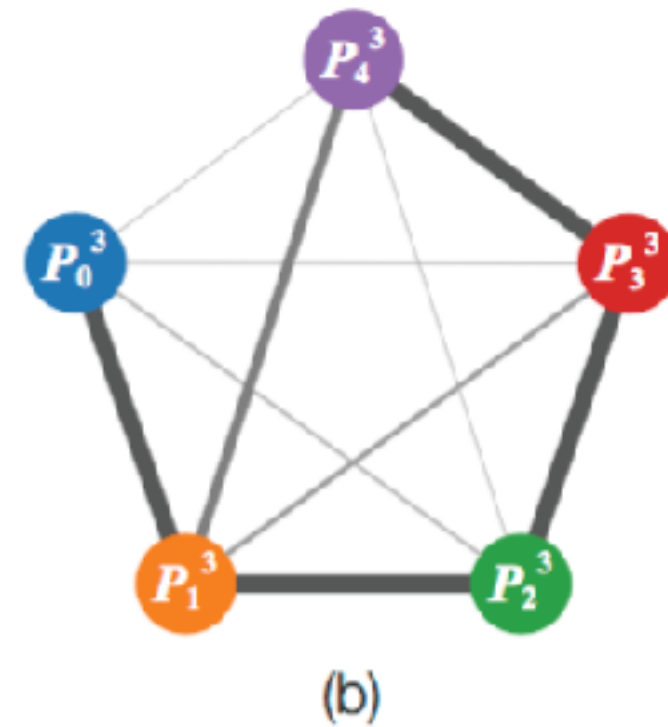
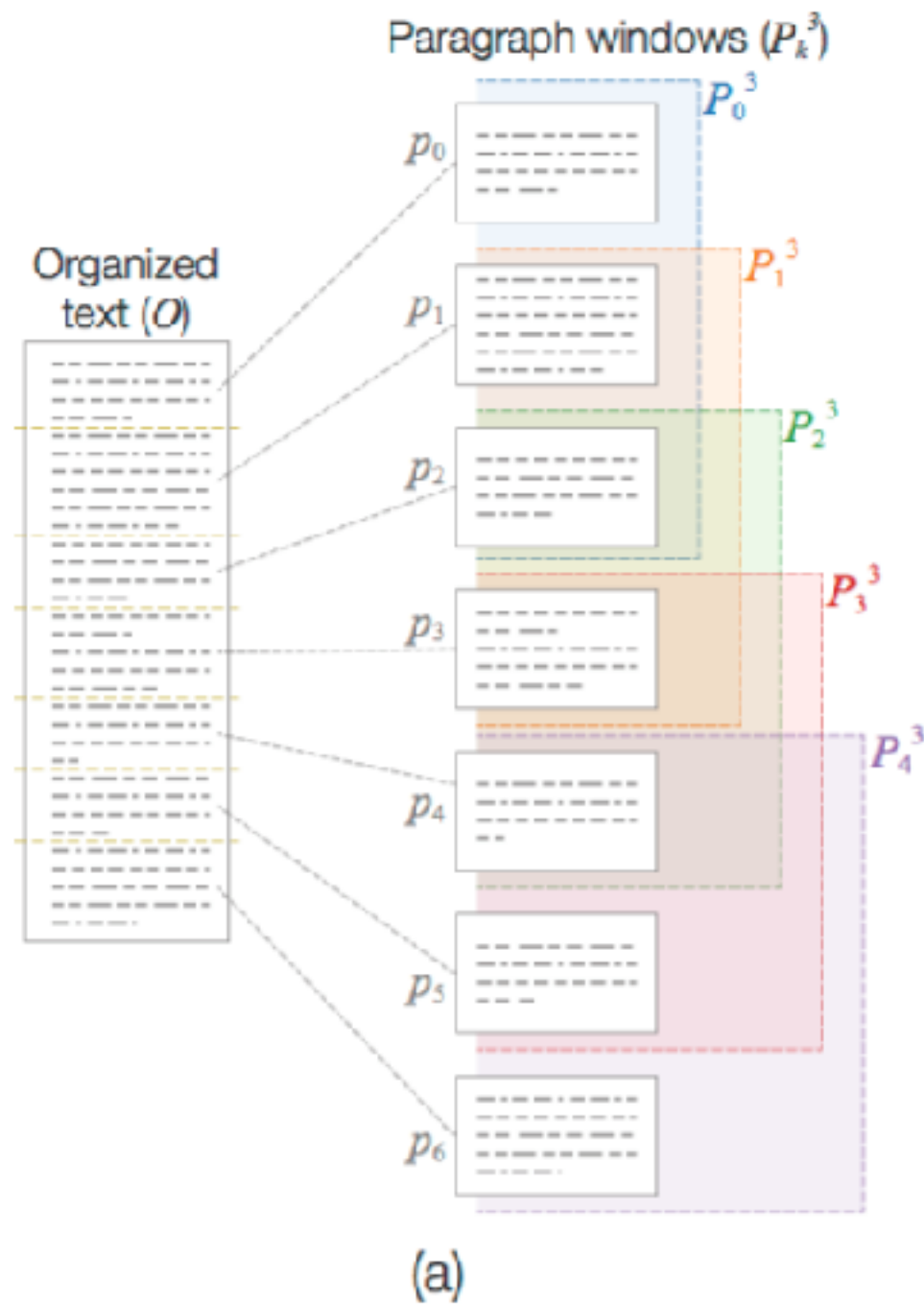
# Narrative



# Narrative

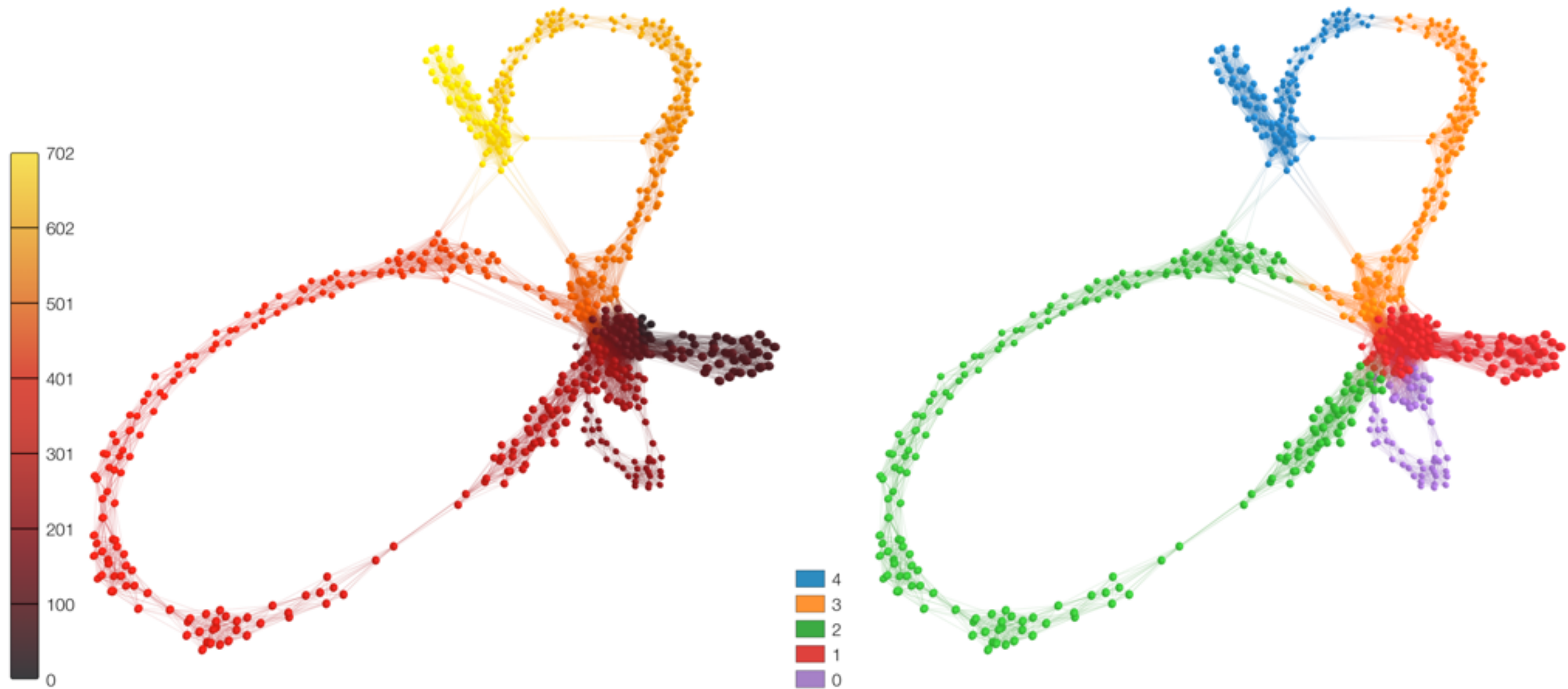






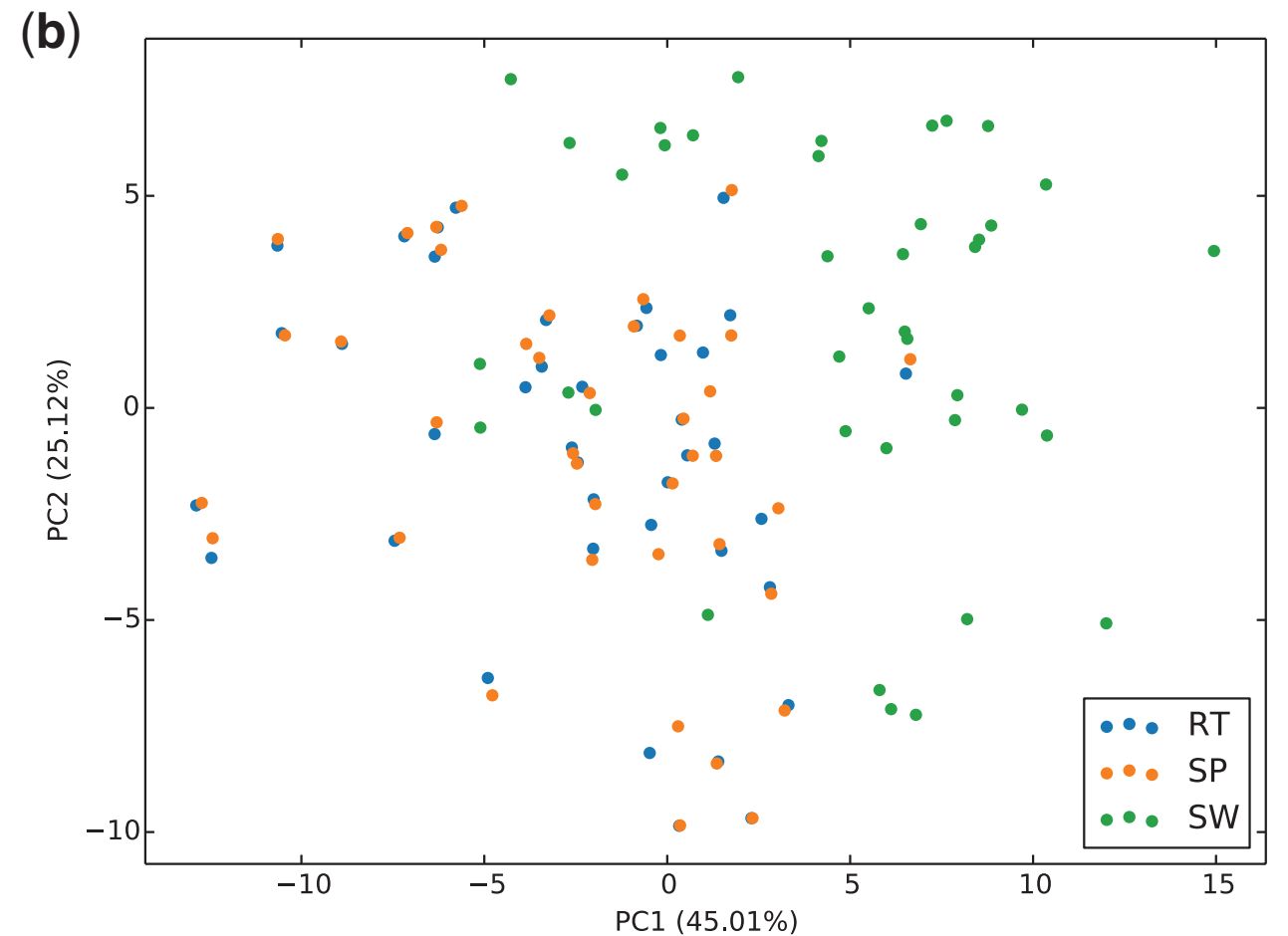
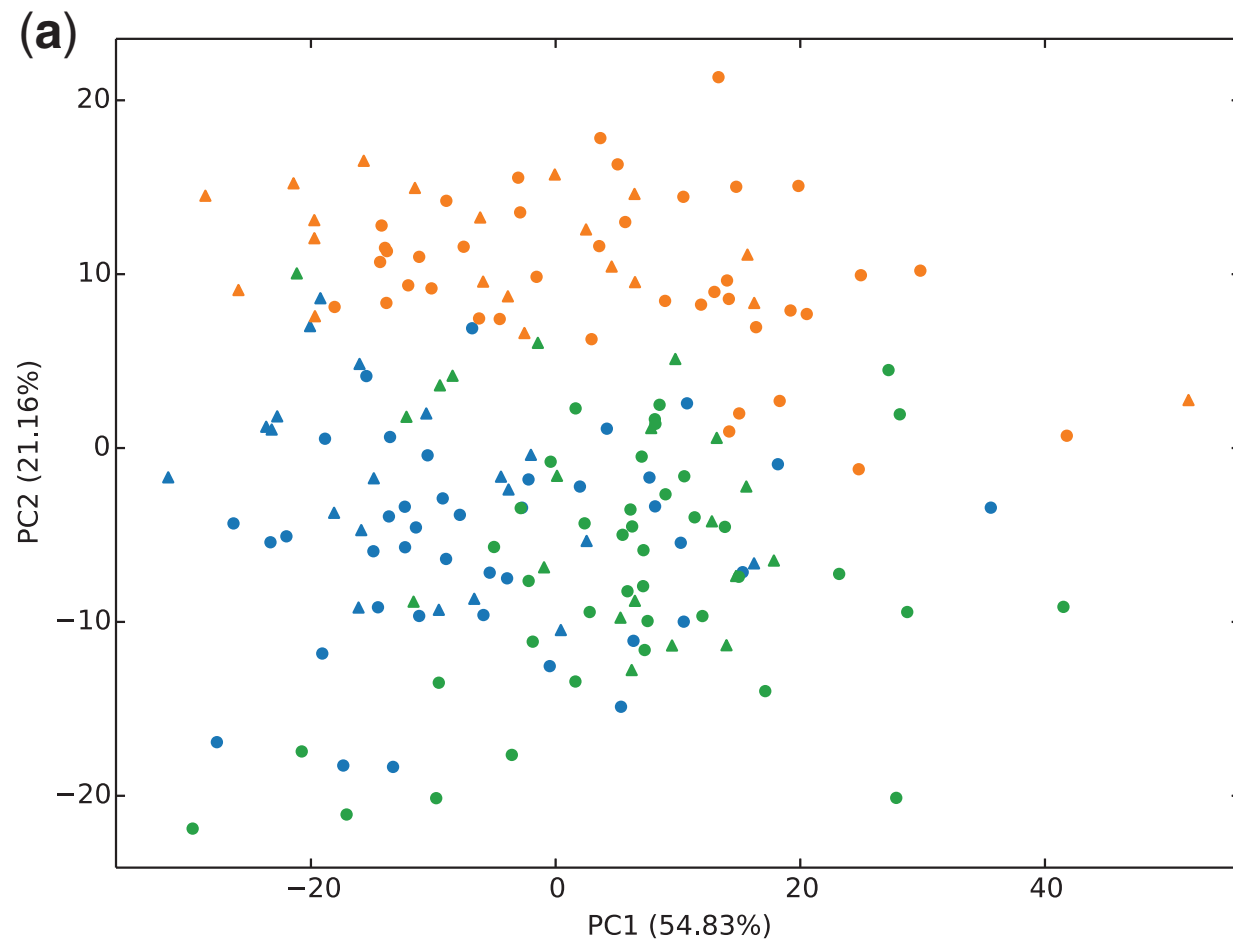
Mesoscopic representation of texts as complex networks  
H. F. de Arruda, F. N. Silva, V. Q. Marinho, D. R. Amancio, L. da F. Costa  
<https://arxiv.org/abs/1606.09636>

# Alice in Wonderland



Mesoscopic representation of texts as complex networks  
H. F. de Arruda, F. N. Silva, V. Q. Marinho, D. R. Amancio, L. da F. Costa  
<https://arxiv.org/abs/1606.09636>

# Classification using mesoscopic representation

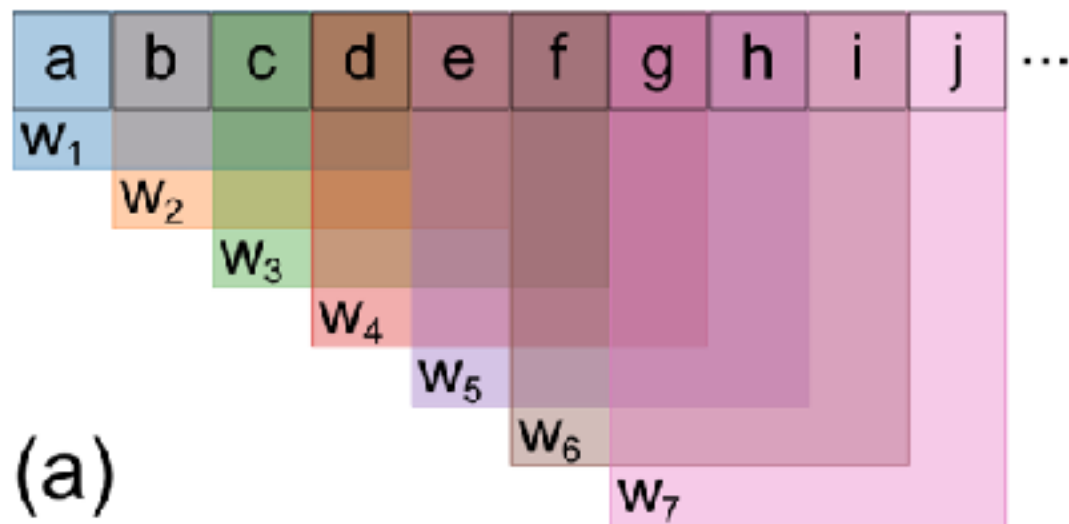


Mesosopic representation of texts as complex networks  
H. F. de Arruda, F. N. Silva, V. Q. Marinho, D. R. Amancio, L. da F. Costa

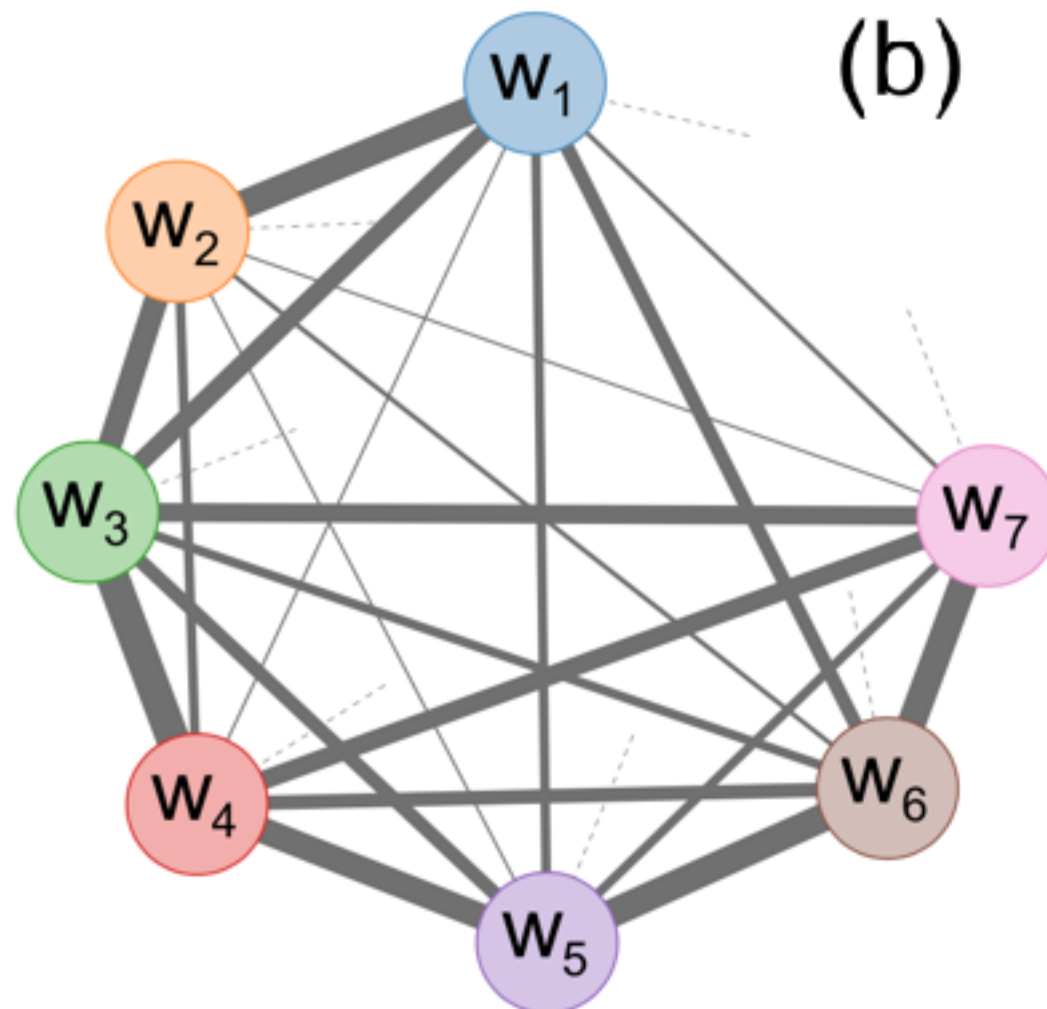
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# Lyrics

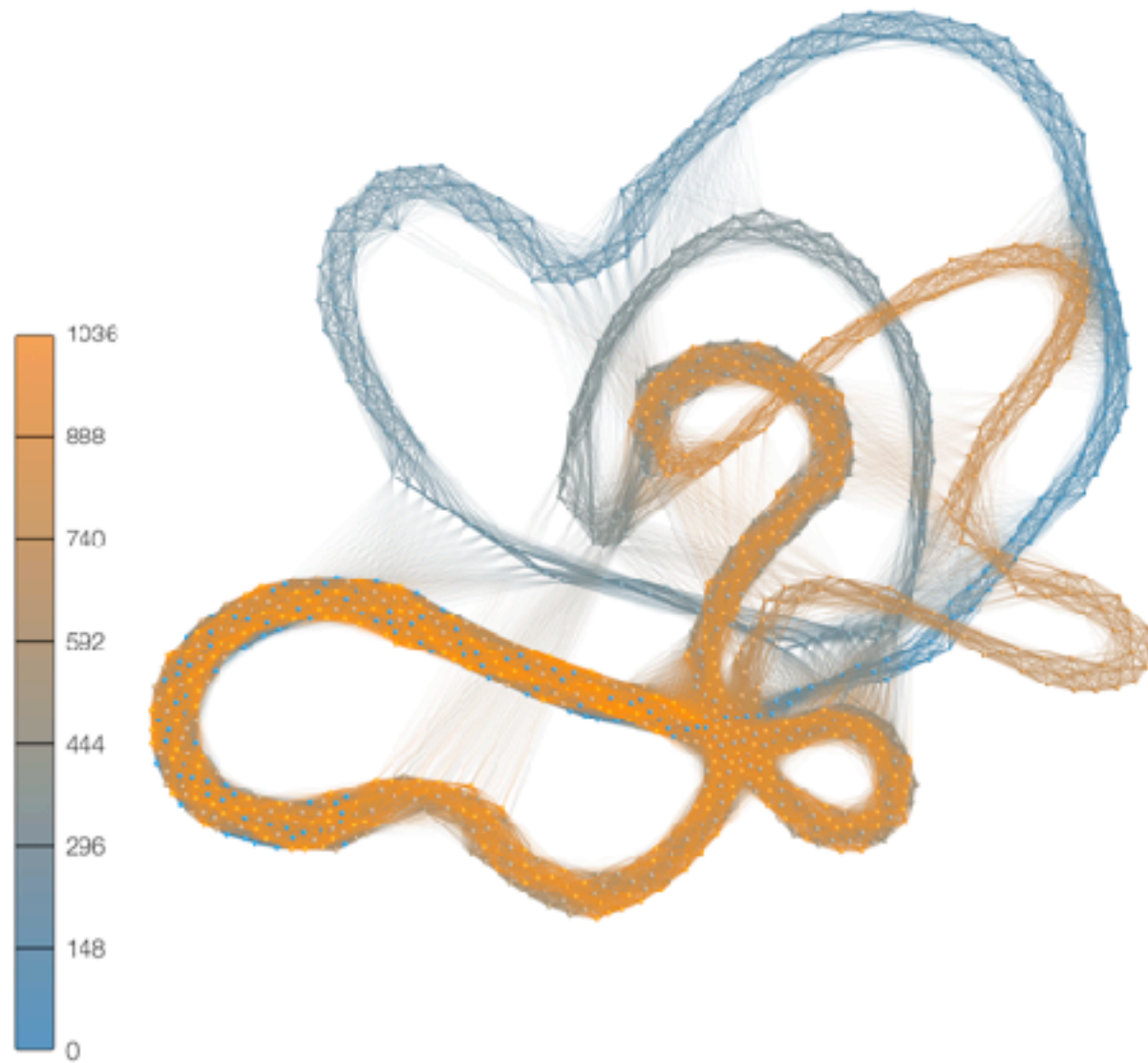


$w_1$ : "ab", "bc", and "cd"  
 $w_2$ : "bc", "cd", and "de"  
 $w_3$ : "cd", "de", and "ef"  
 $w_4$ : "de", "ef", and "fg"  
 $w_5$ : "ef", "fg", and "gh"  
 $w_6$ : "fg", "gh", and "hi"  
 $w_7$ : "gh", "hi", and "ij"

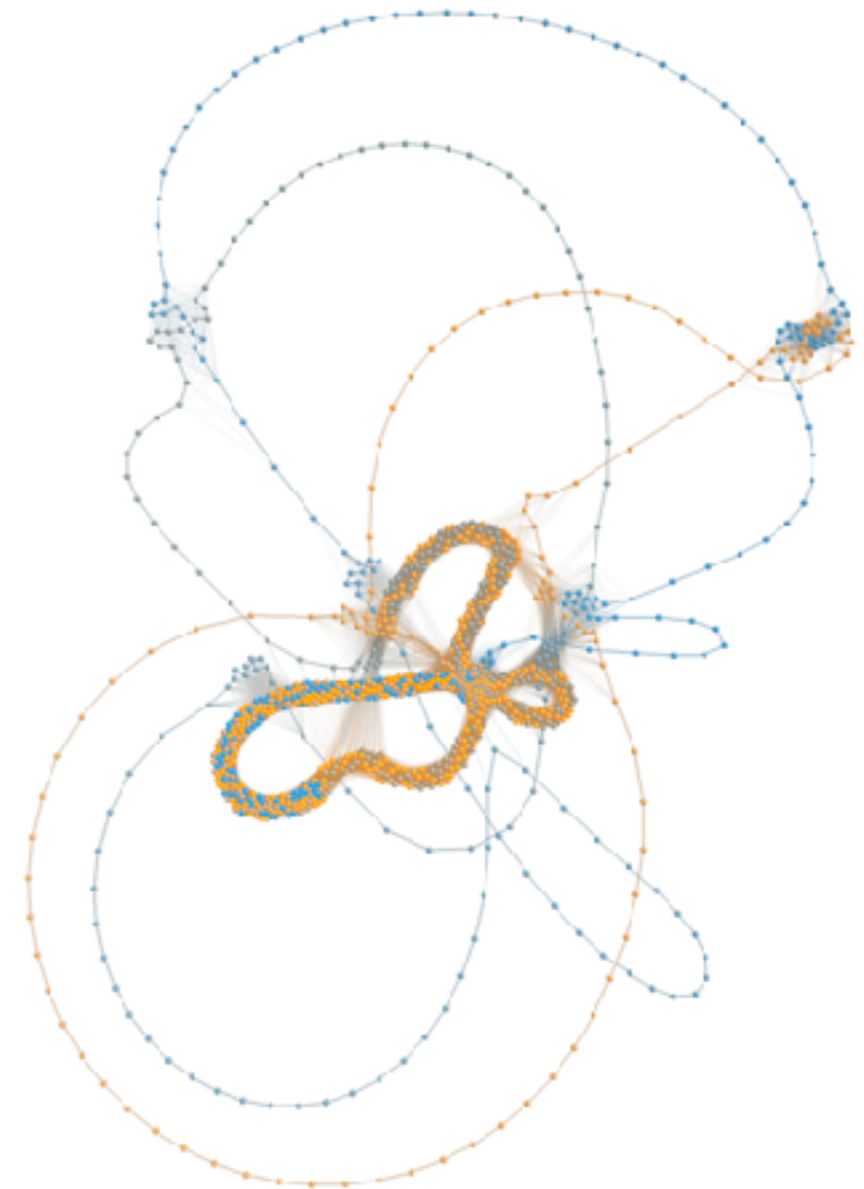


⋮

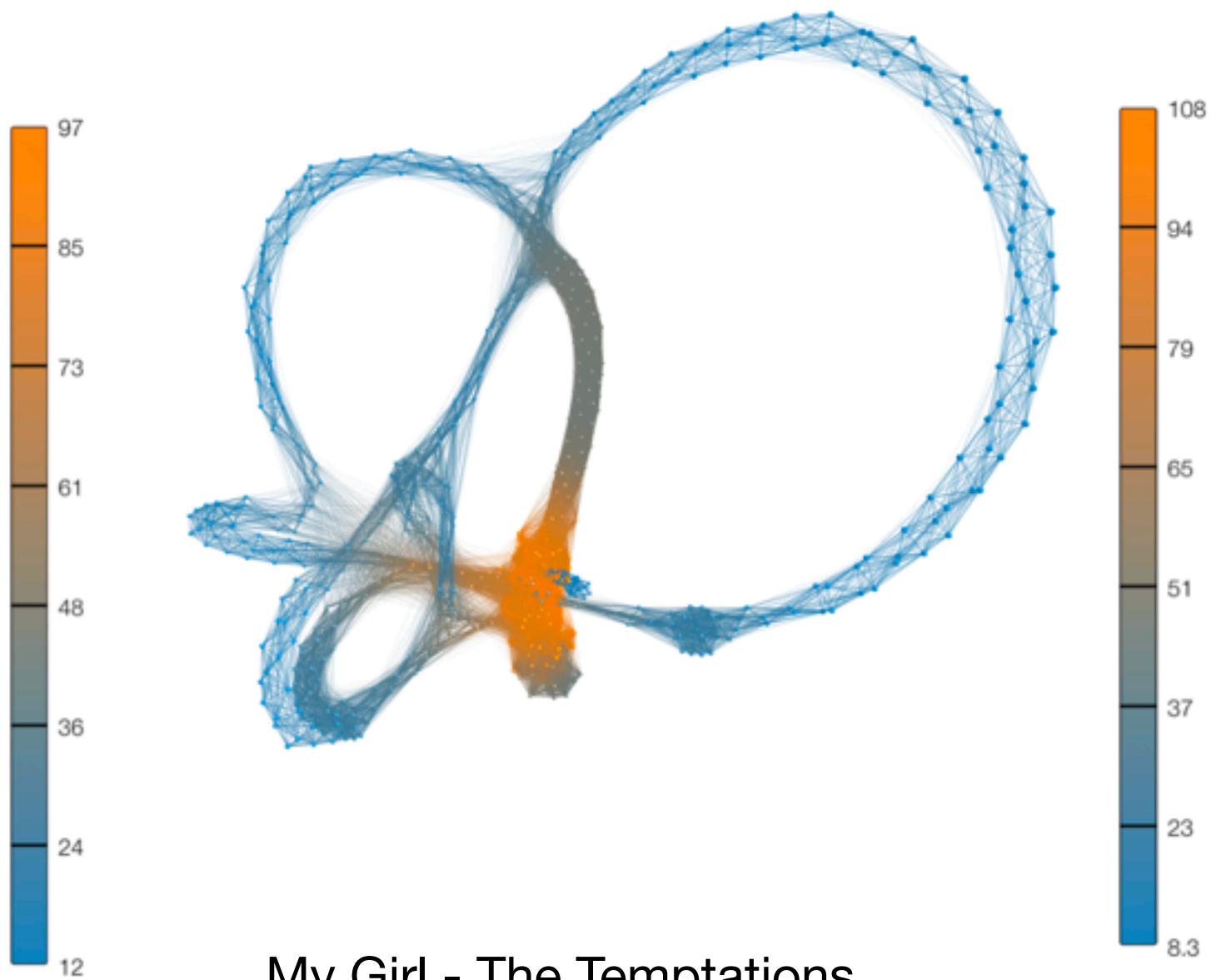
# Lyrics



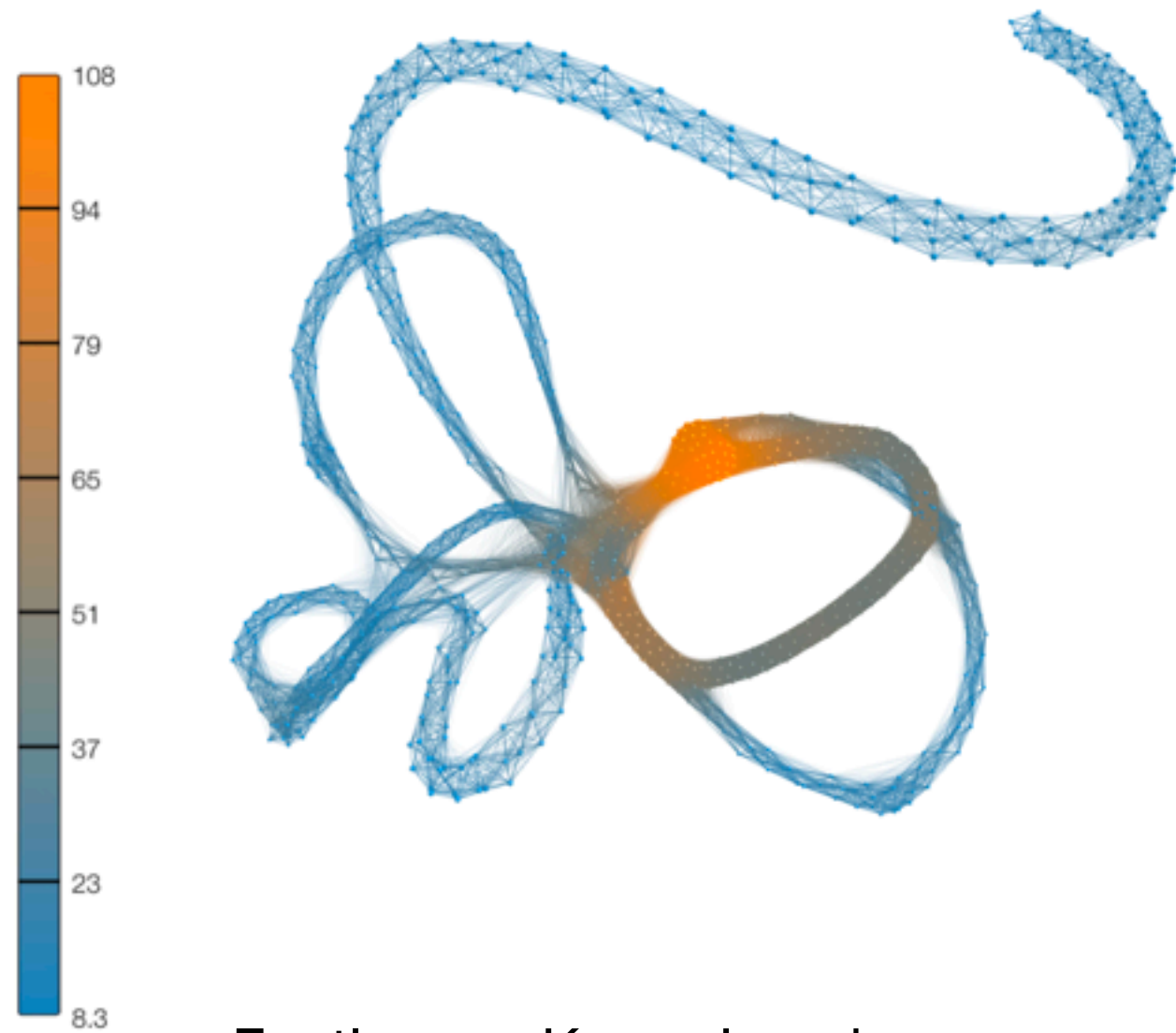
Dancing Queen - ABBA



# Lyrics



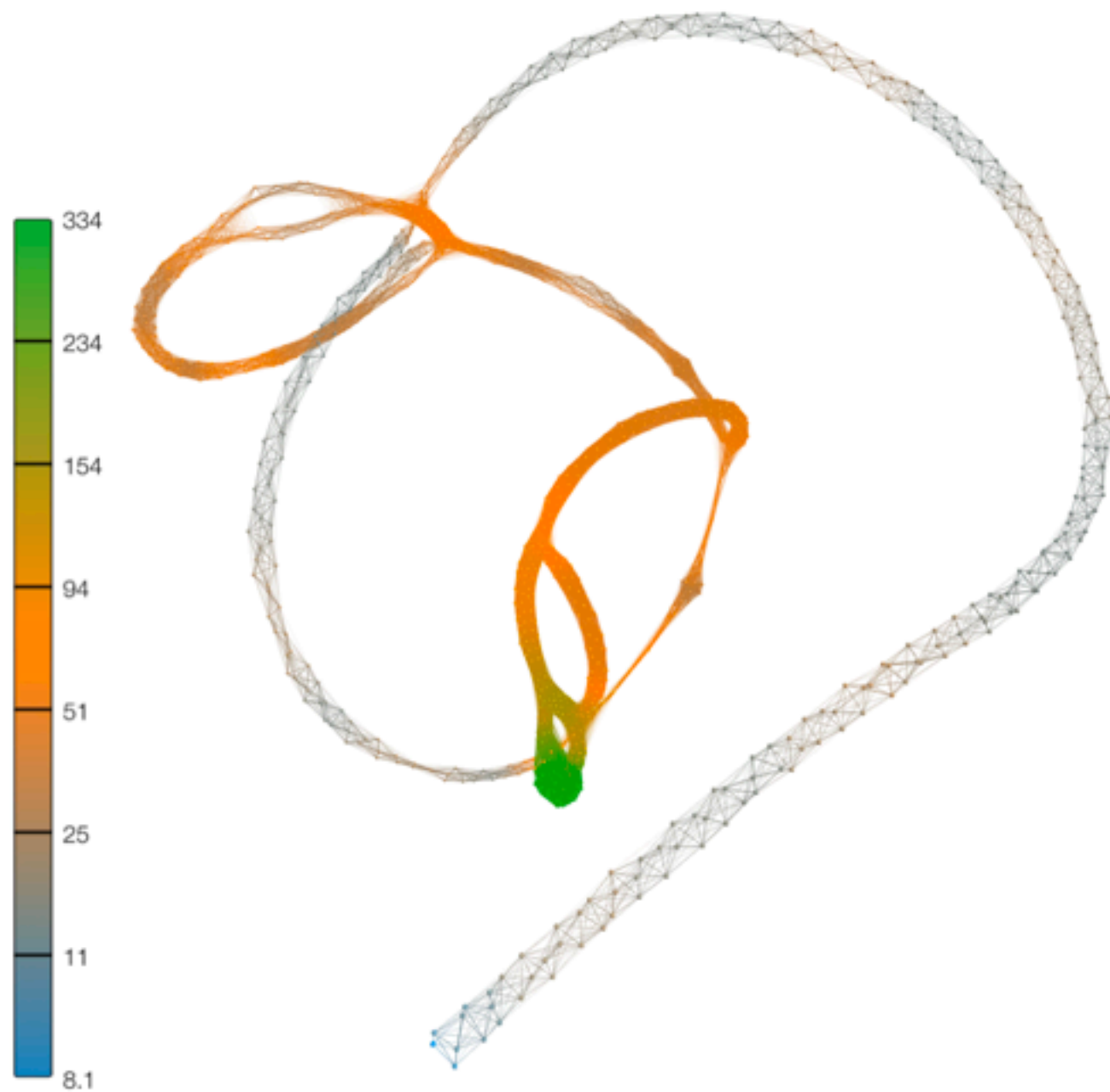
My Girl - The Temptations



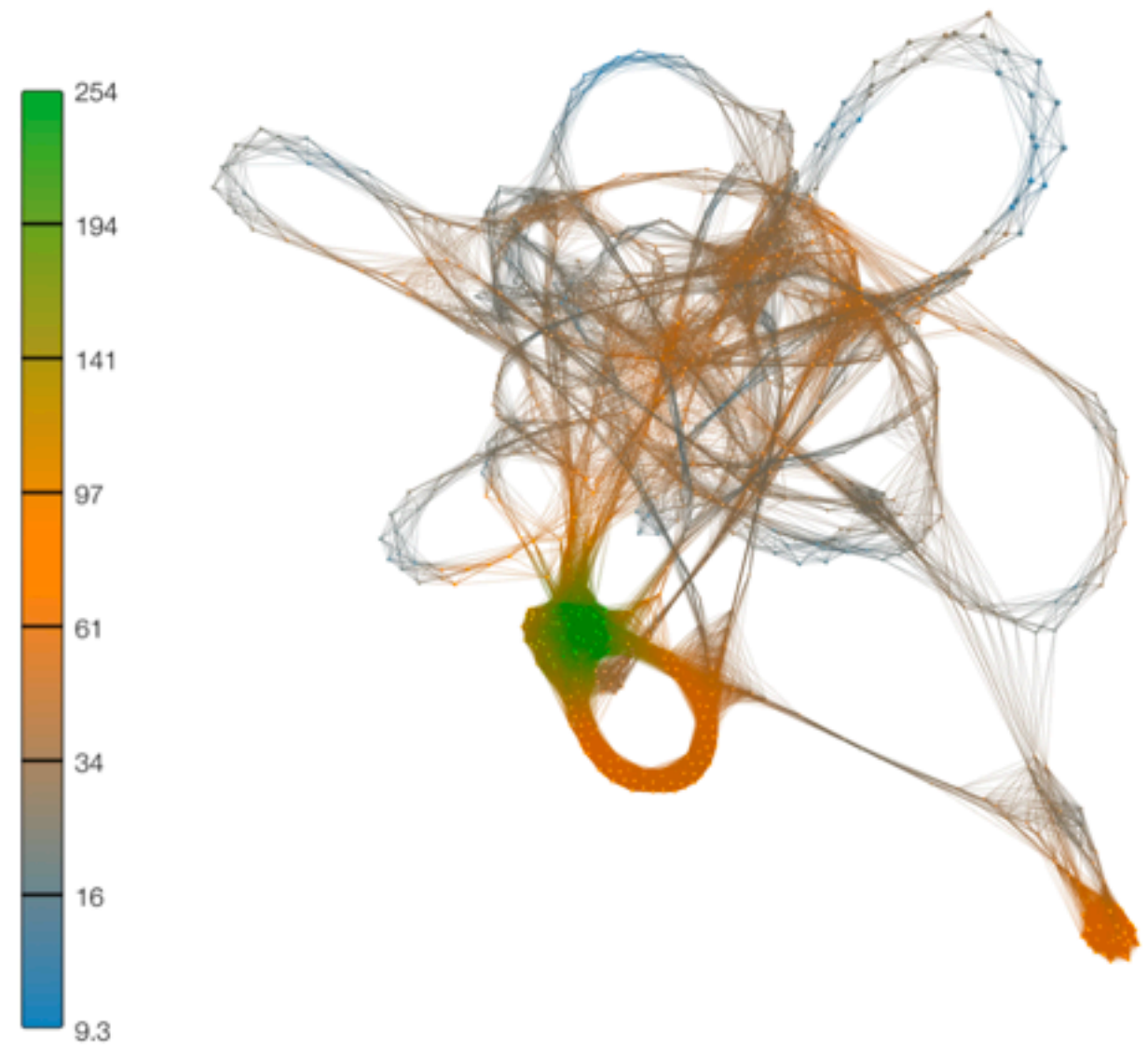
Footloose - Kenny Loggins



# Lyrics

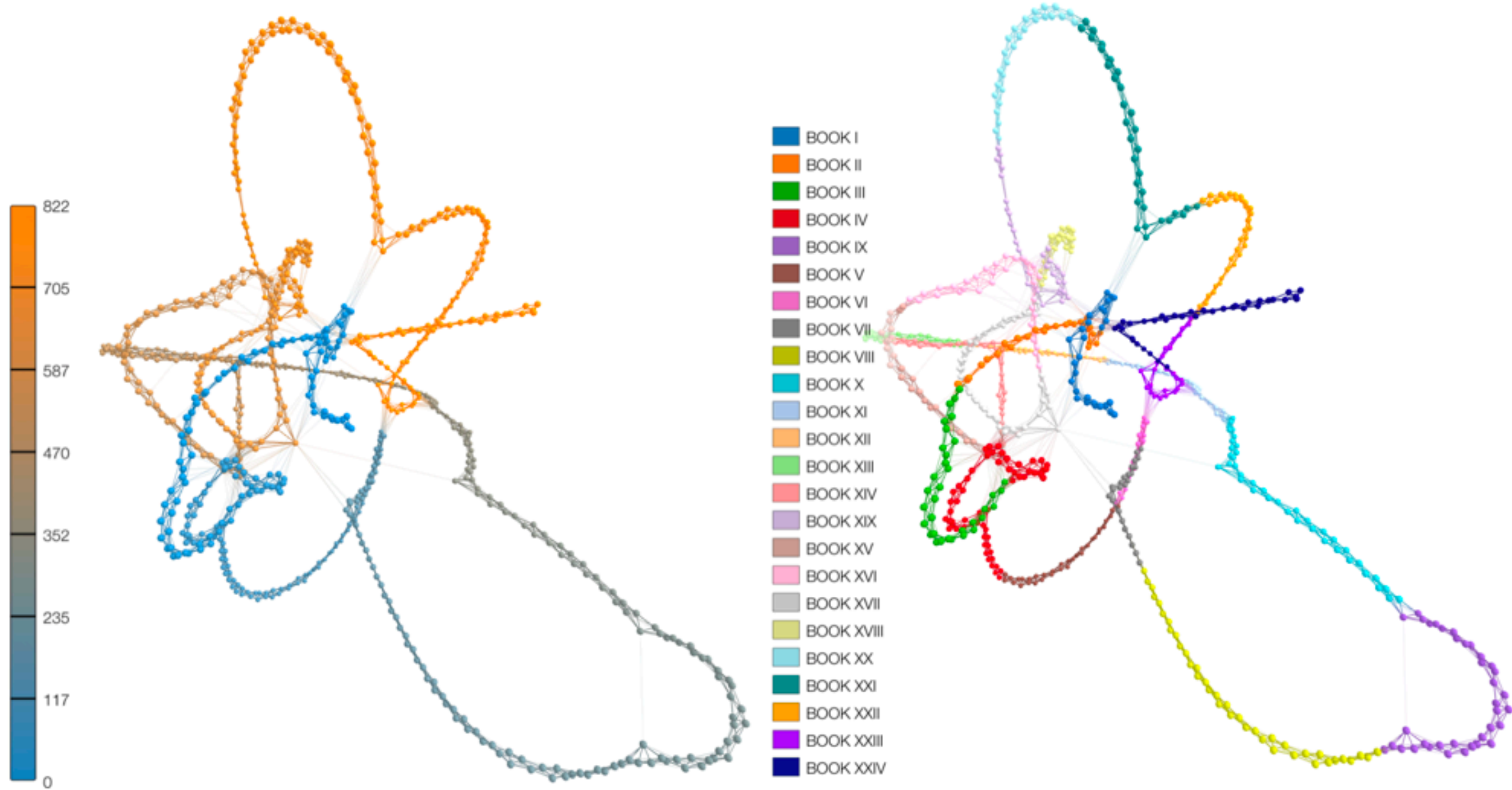


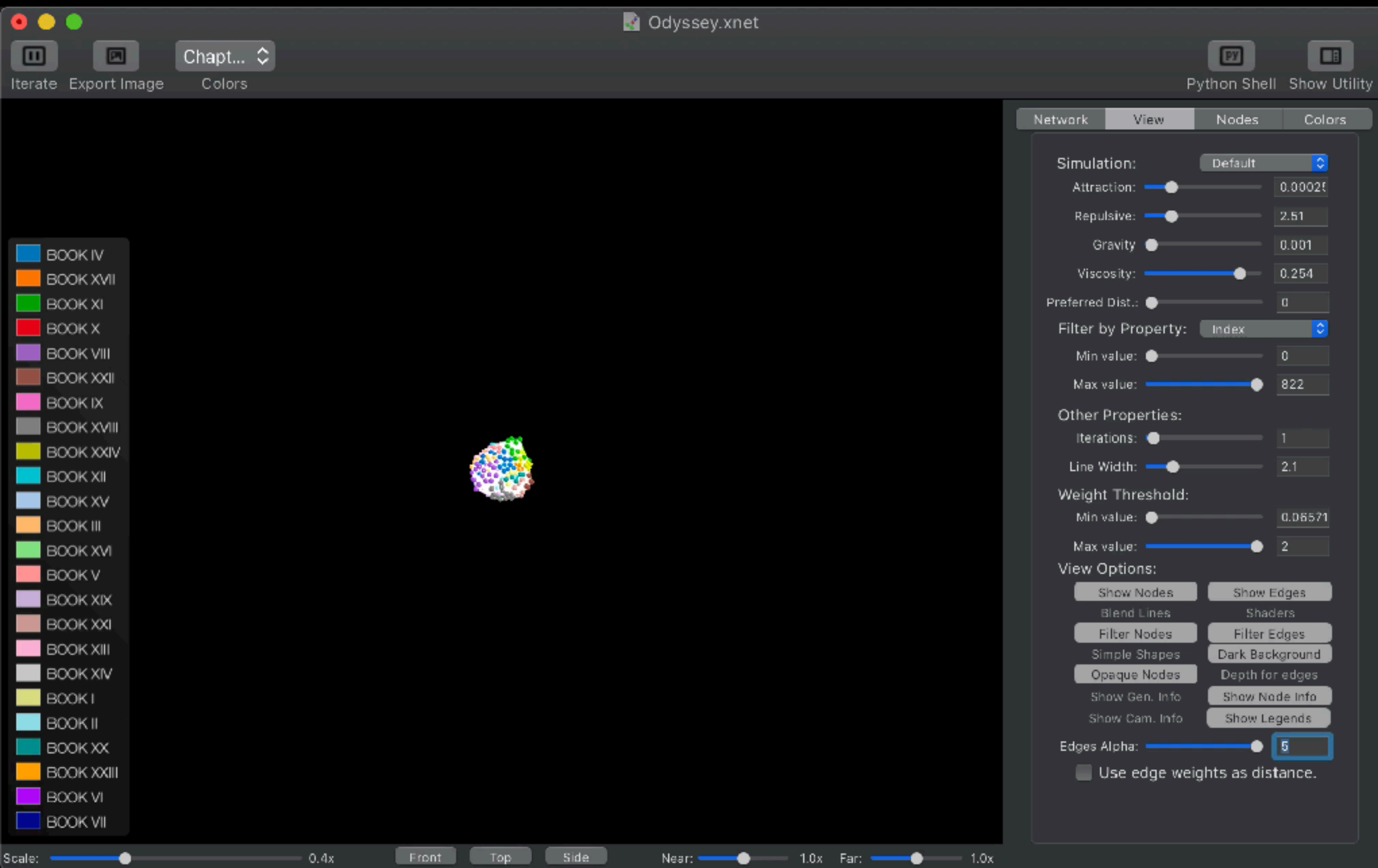
Roar - Kate Perry



Baby - Justin Bieber

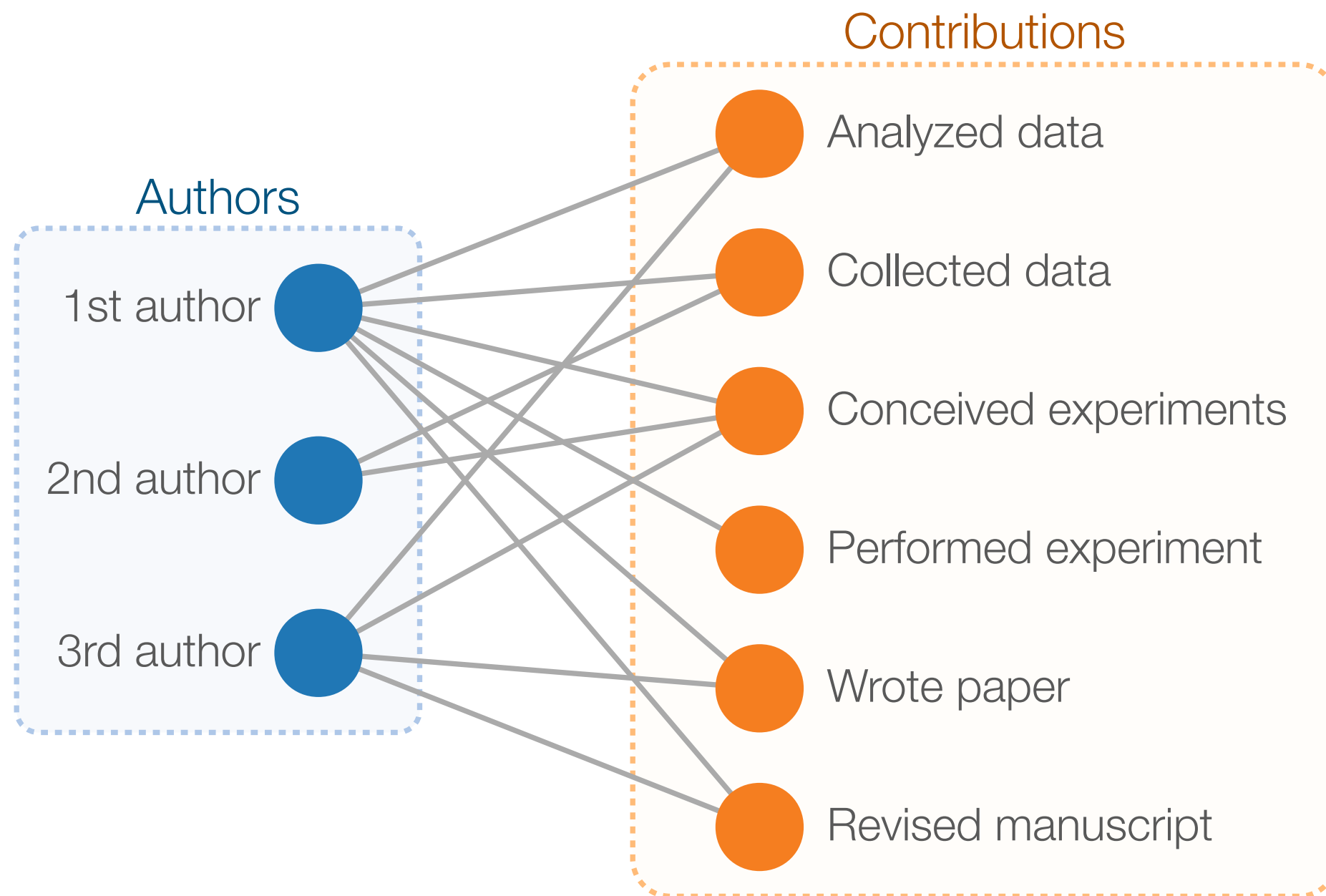
# Odyssey

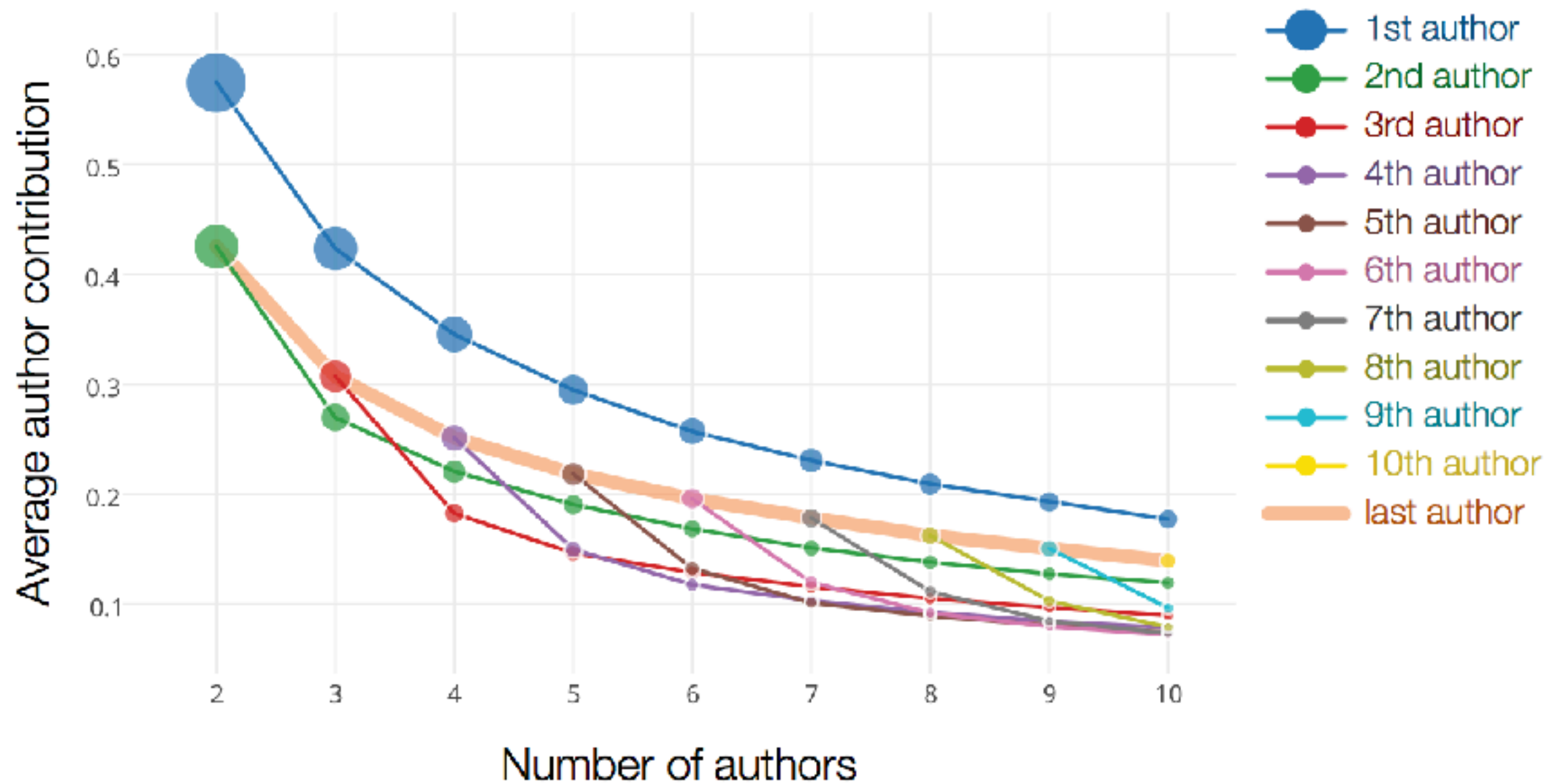
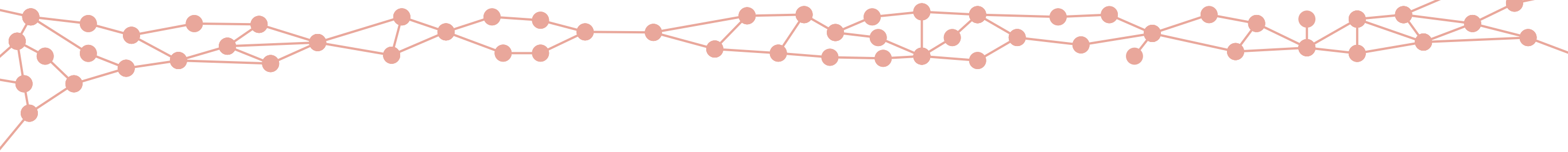
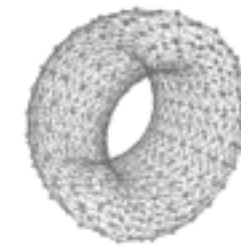






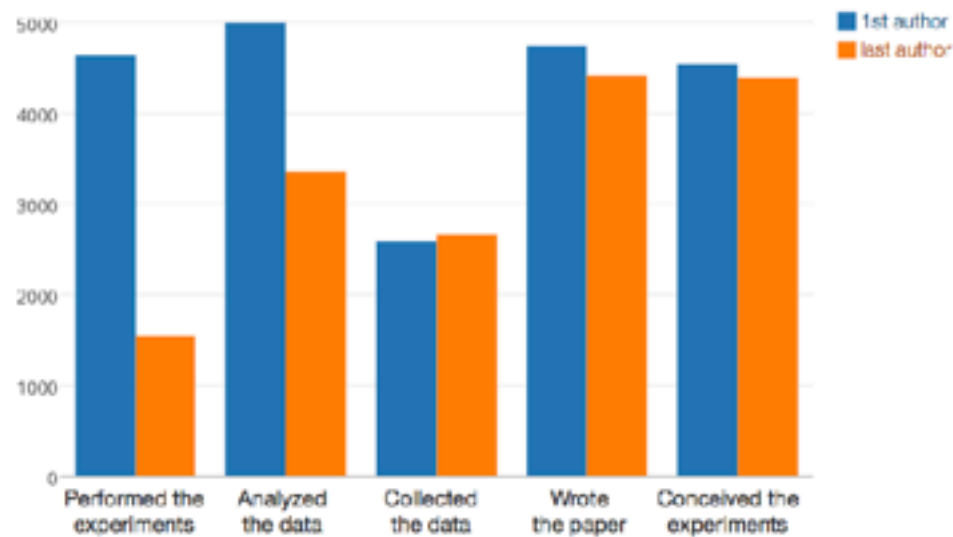
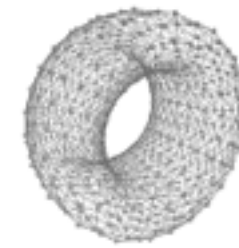
## Patterns of authors contribution in scientific manuscripts



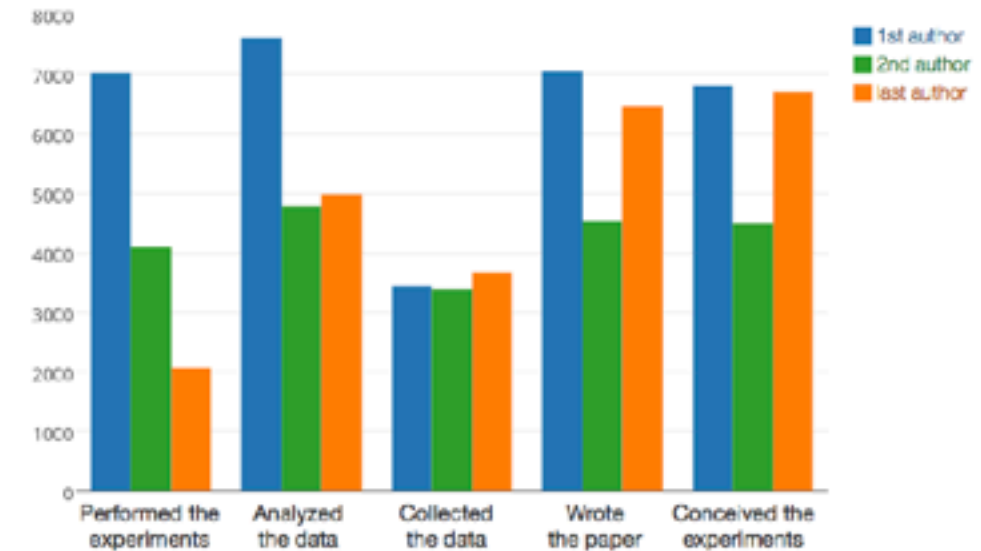


# Other applications

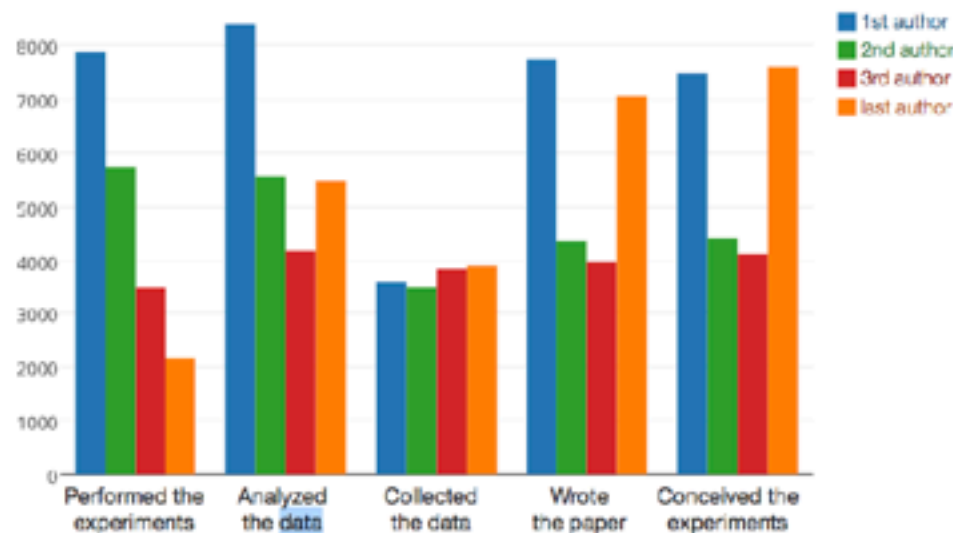
## Patterns of authors contribution in scientific manuscripts



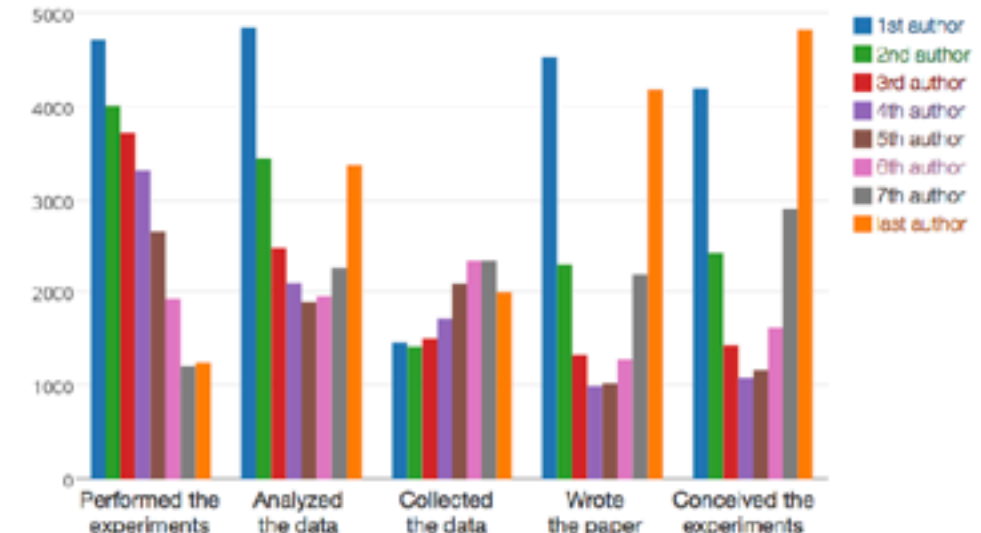
(a)



(b)



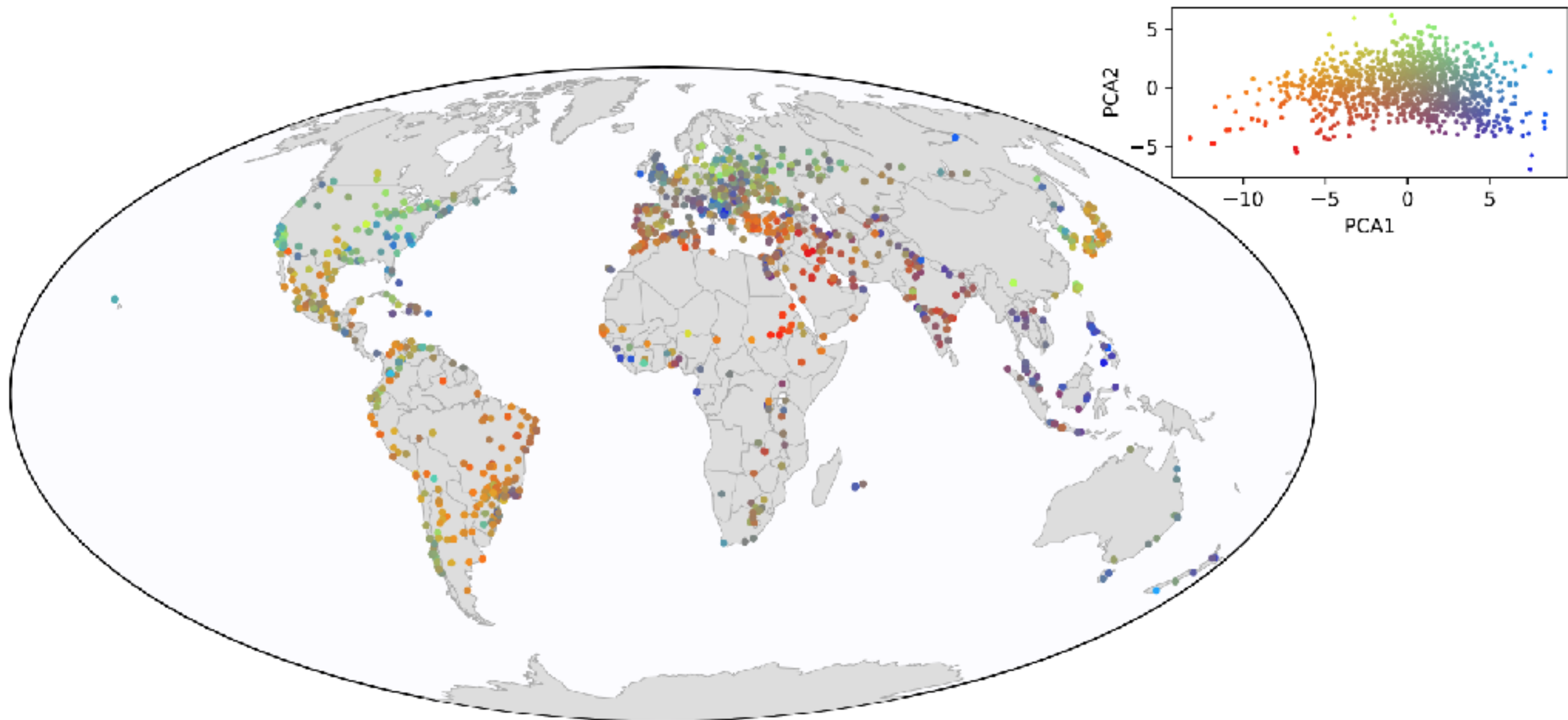
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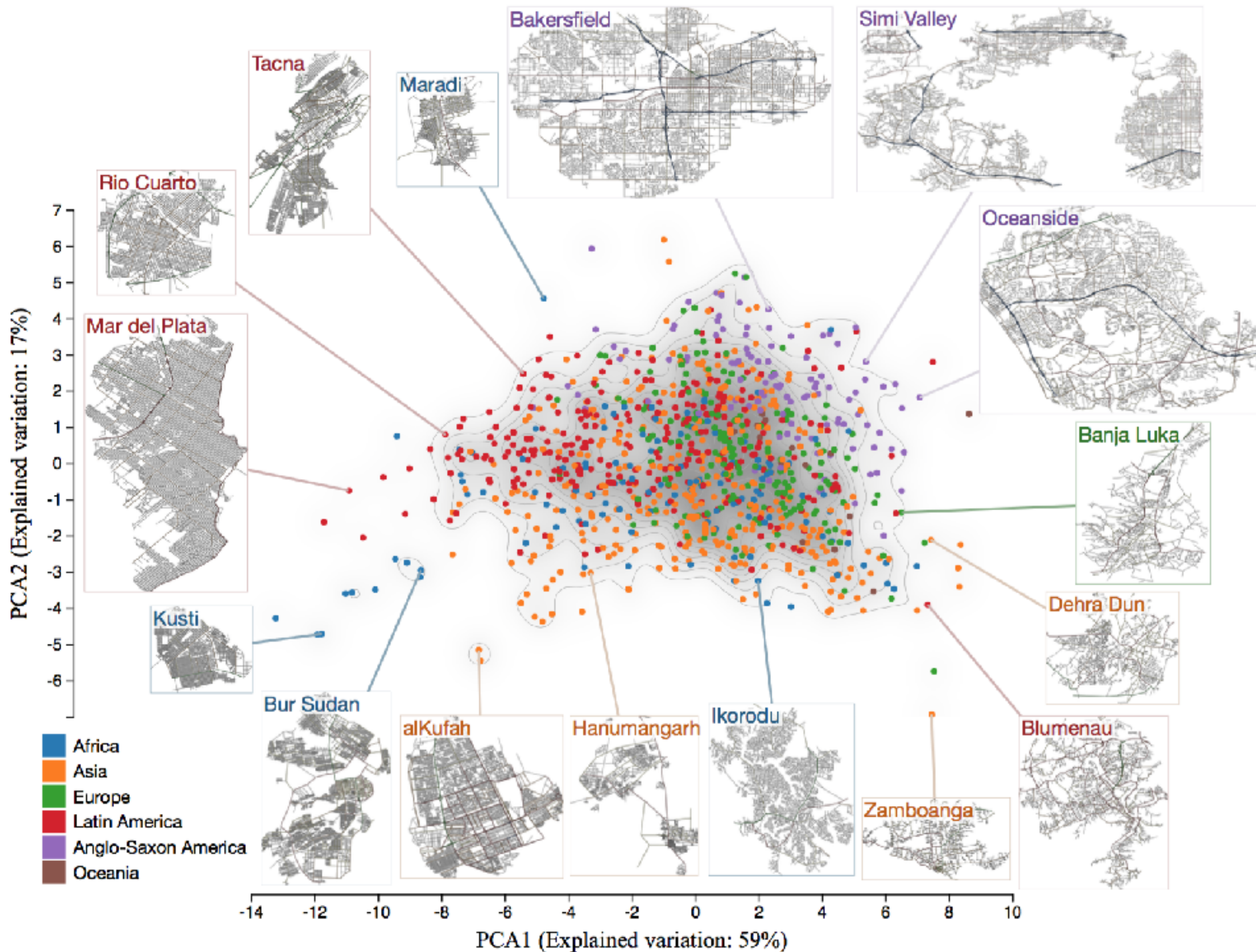
(d)



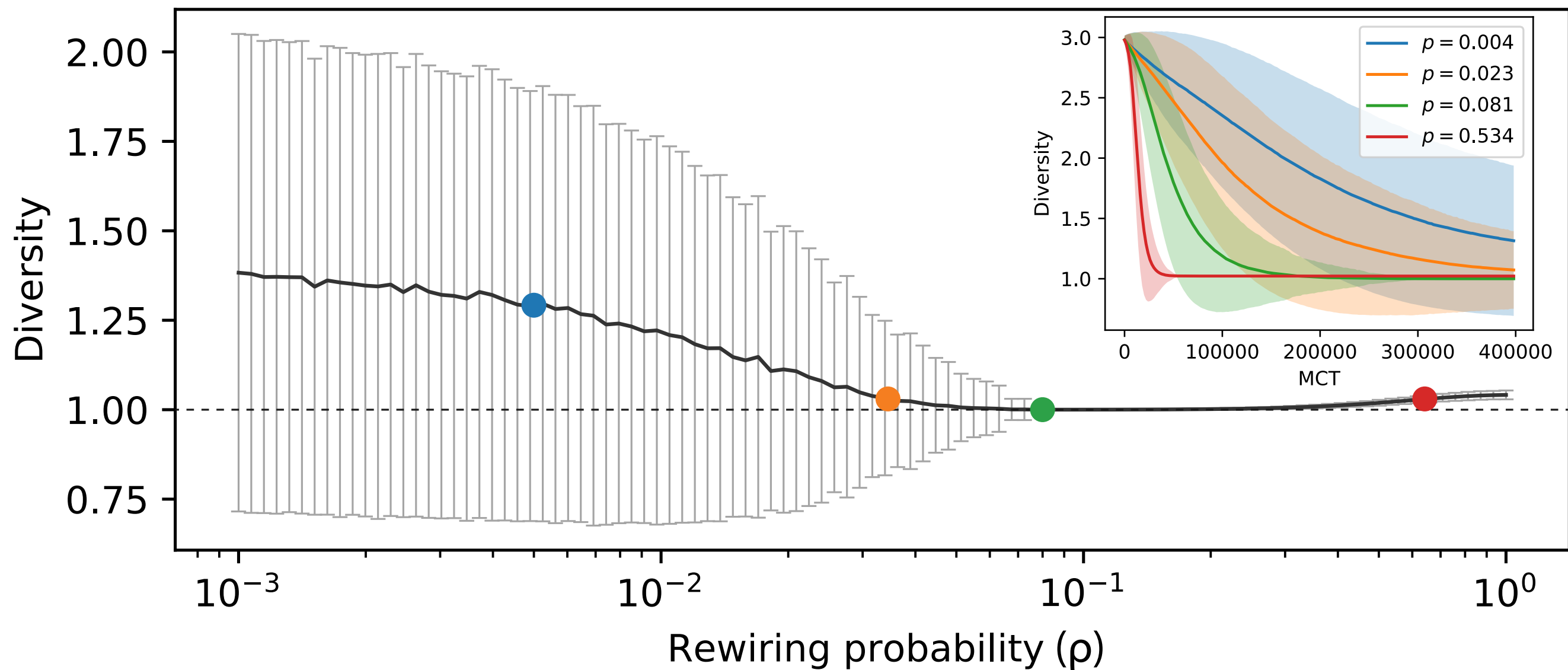
# Topological structure of world cities



Domingues, G. S., Silva, F. N., Comin, C. H., & da F Costa, L. (2018). Topological characterization of world cities. *Journal of Statistical Mechanics: Theory and Experiment*, 2018(8), 083212.

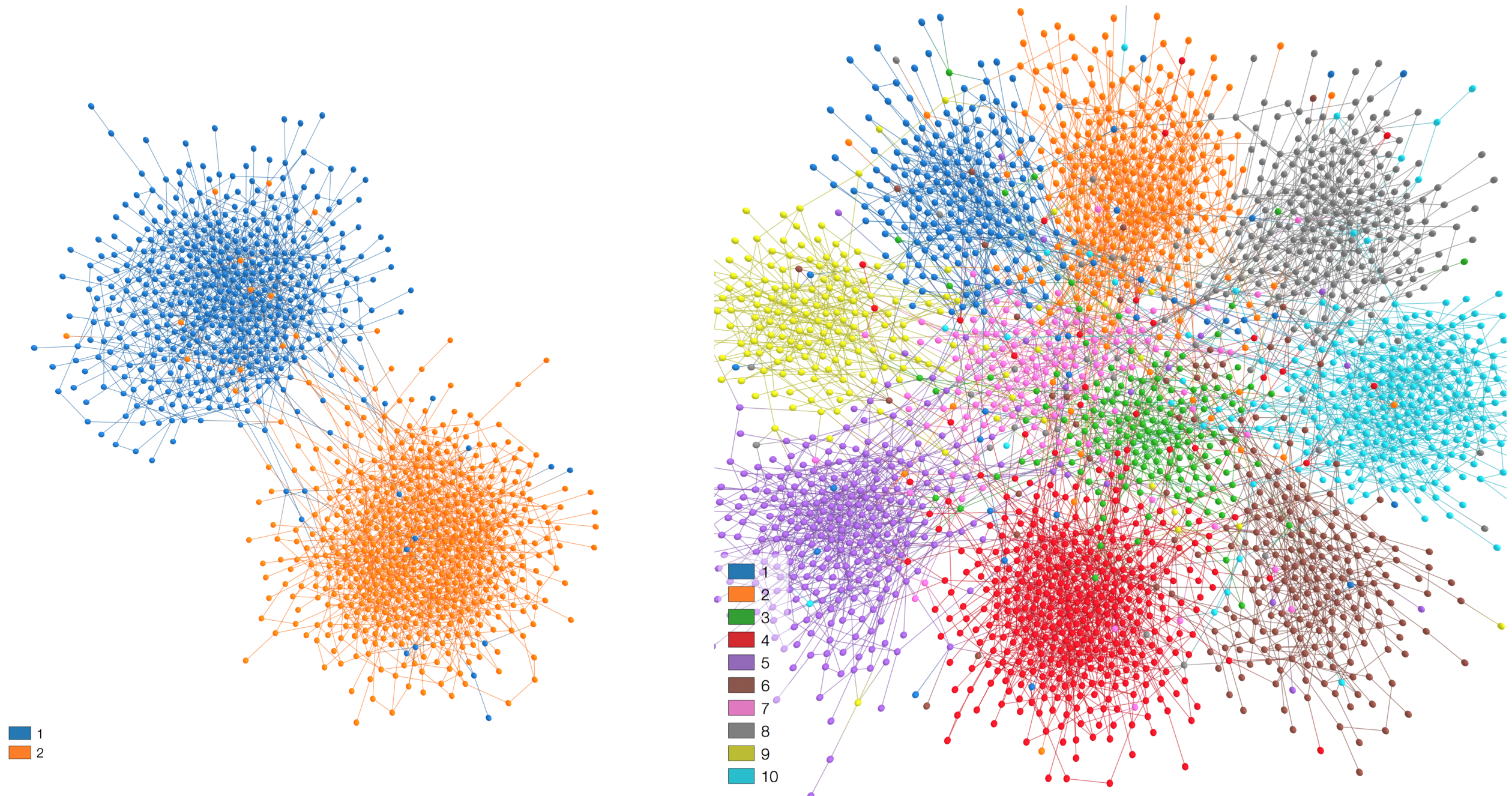


# Locality vs Diversity (Sznajd dynamics)

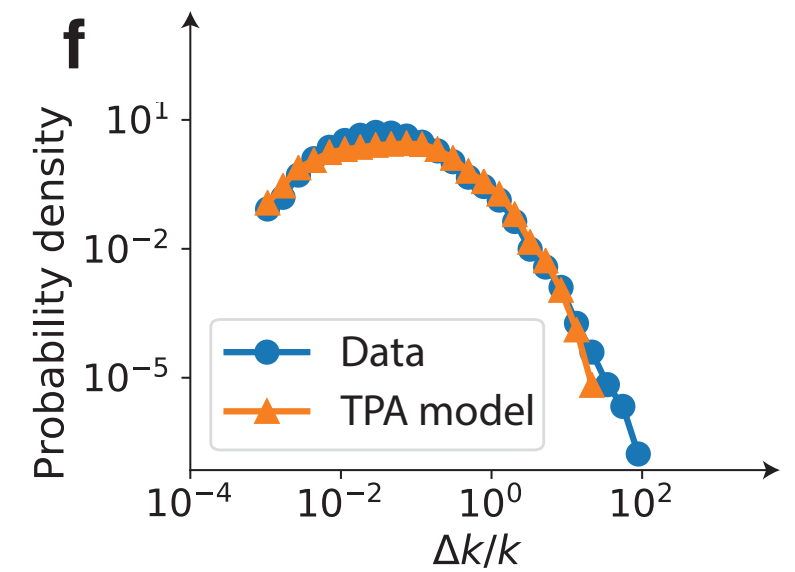
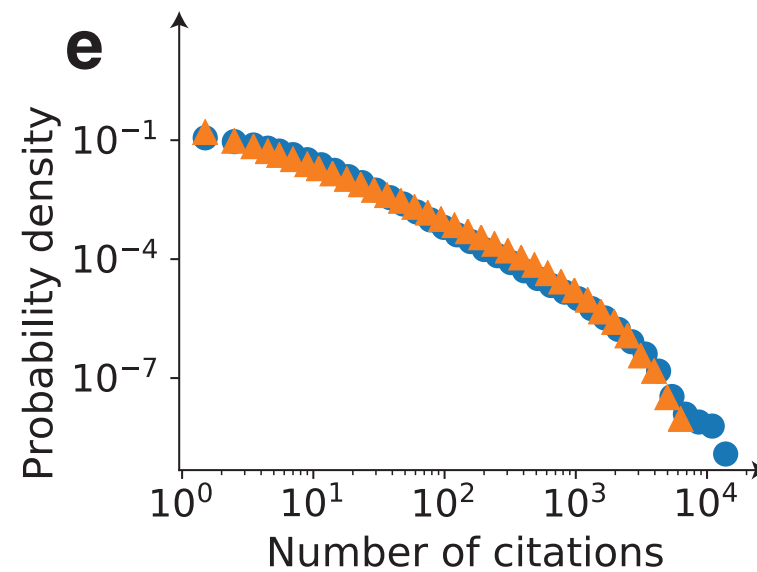
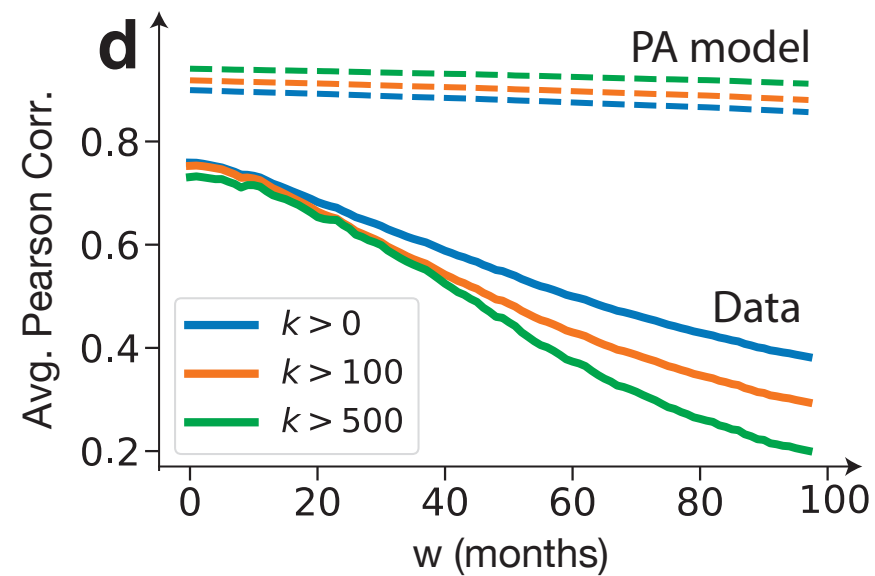
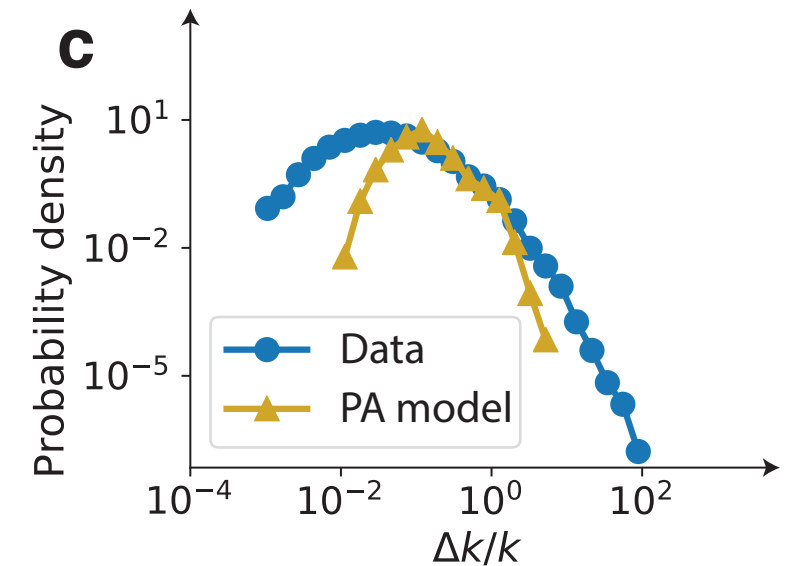
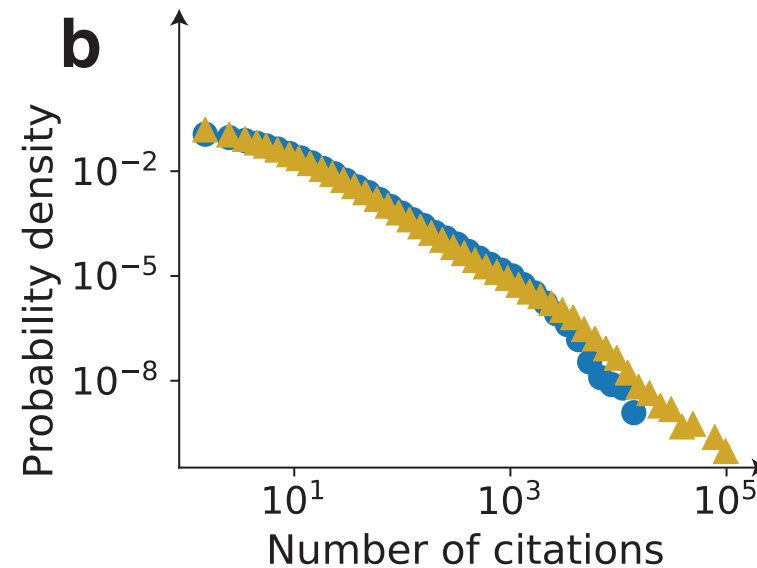
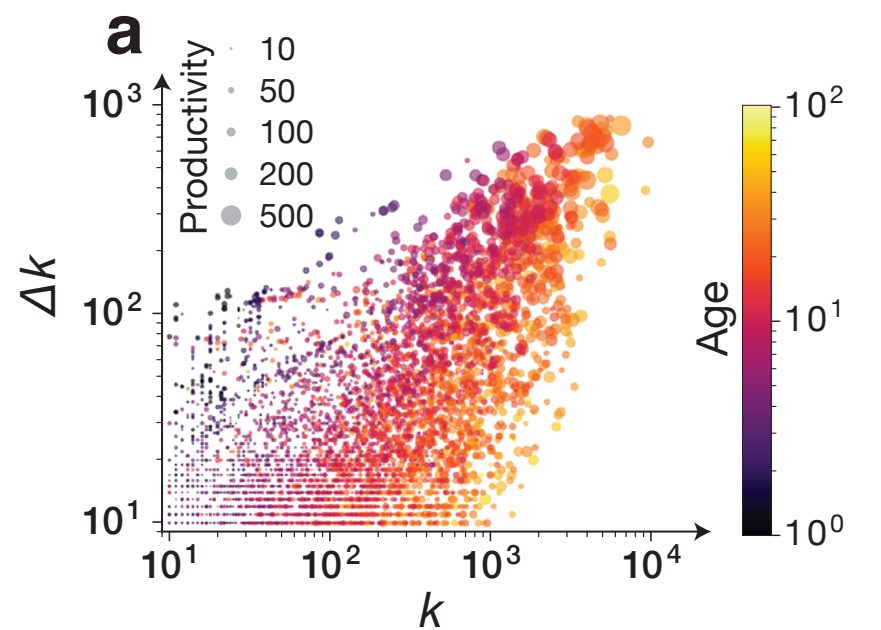




# Social Bubbles dynamics using Sznajd Model



# Recency and burstiness in authors citations







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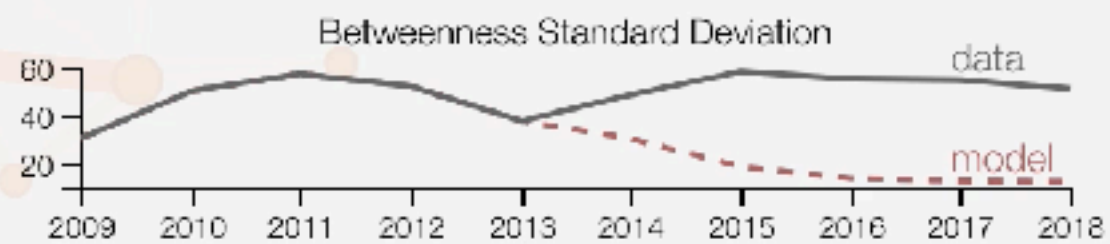
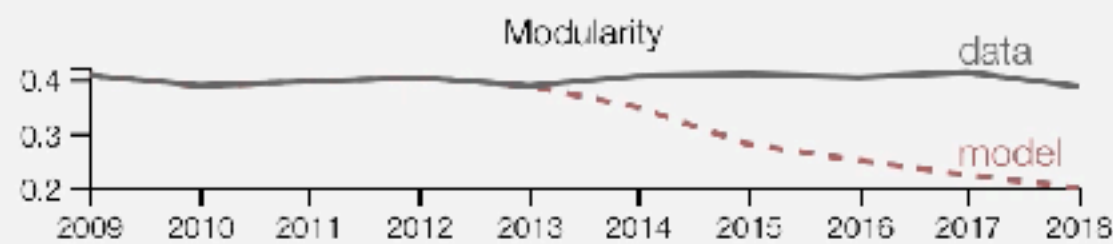
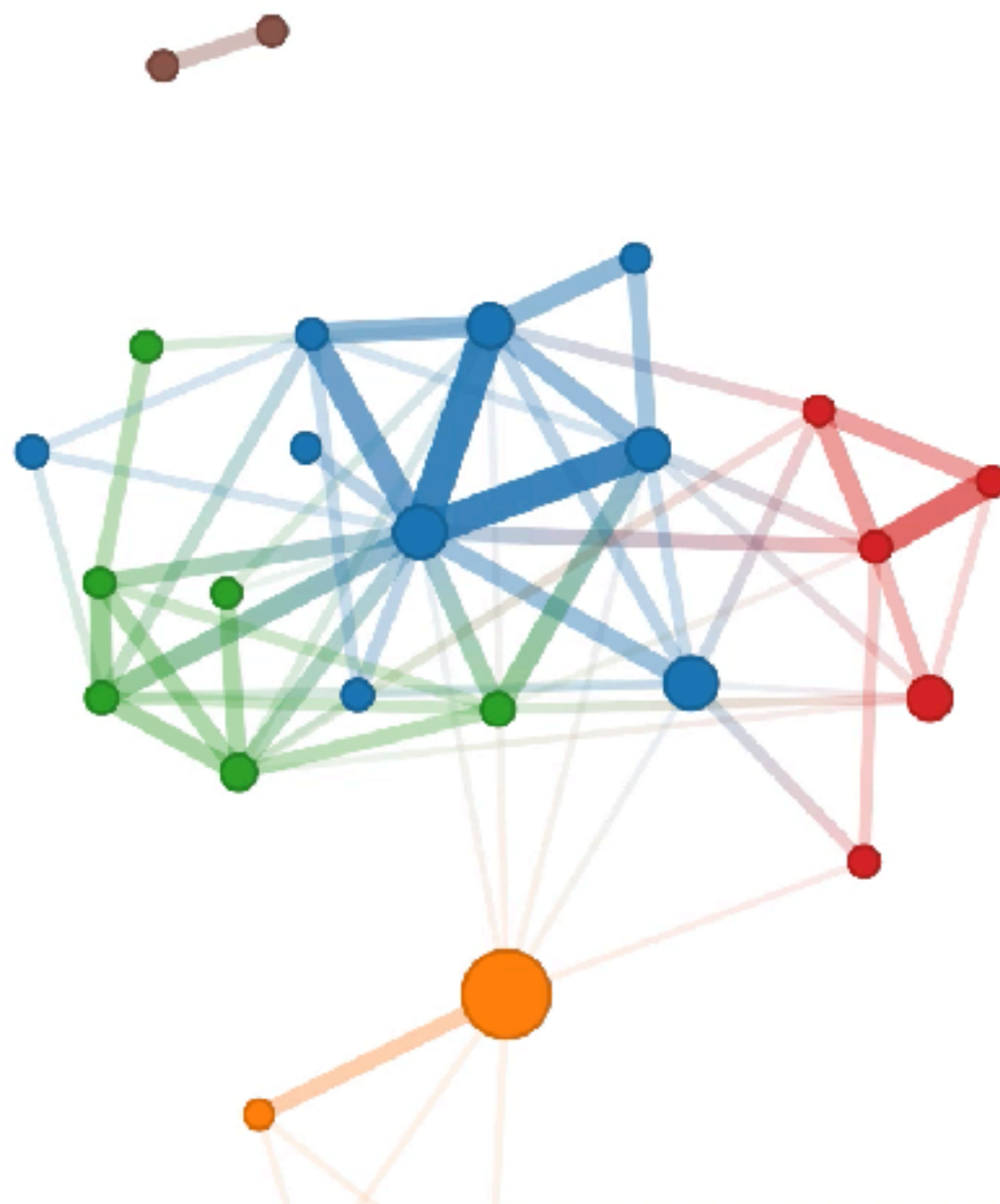
Enter an author or discipline

informatics

Top Authors







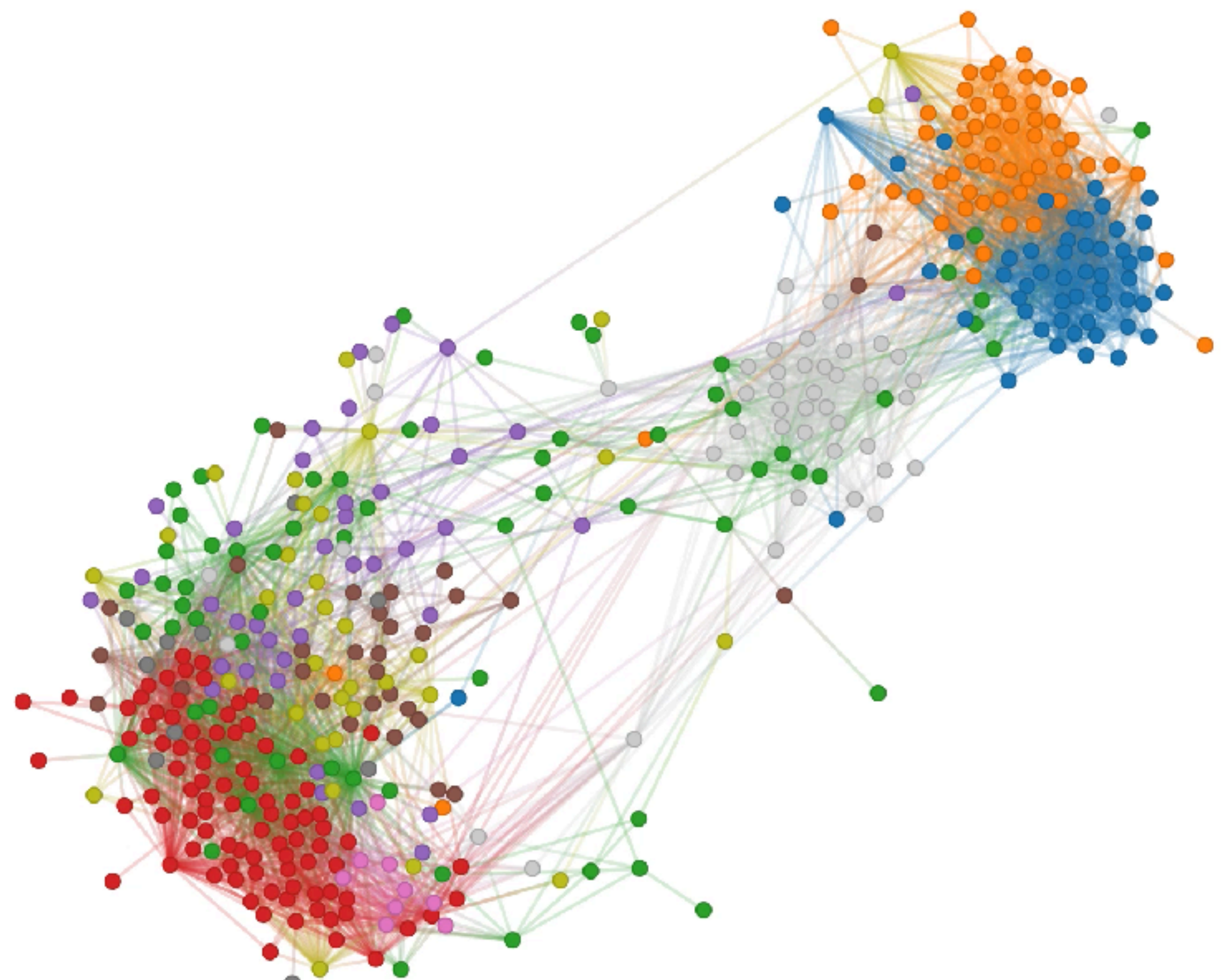
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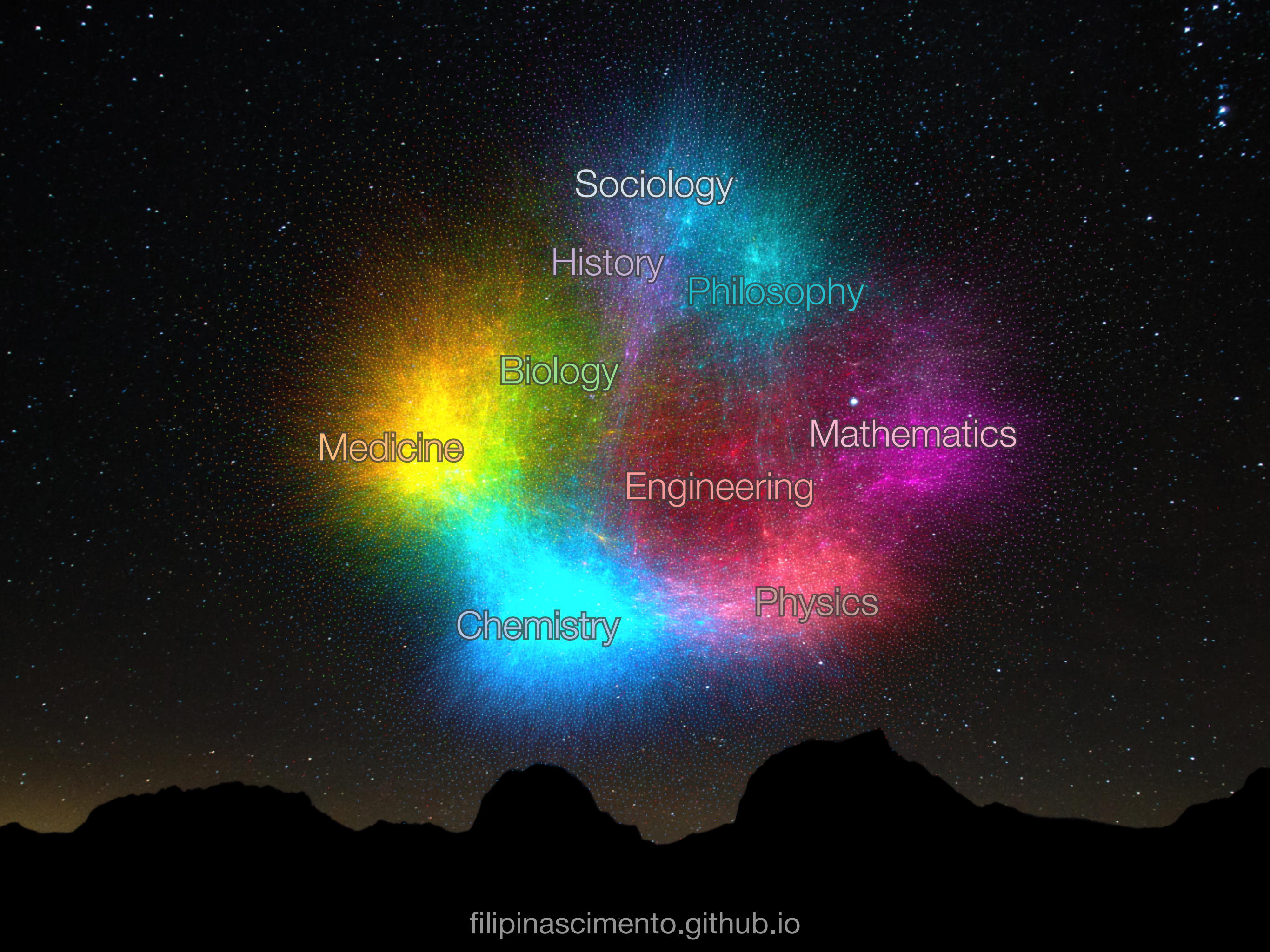
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