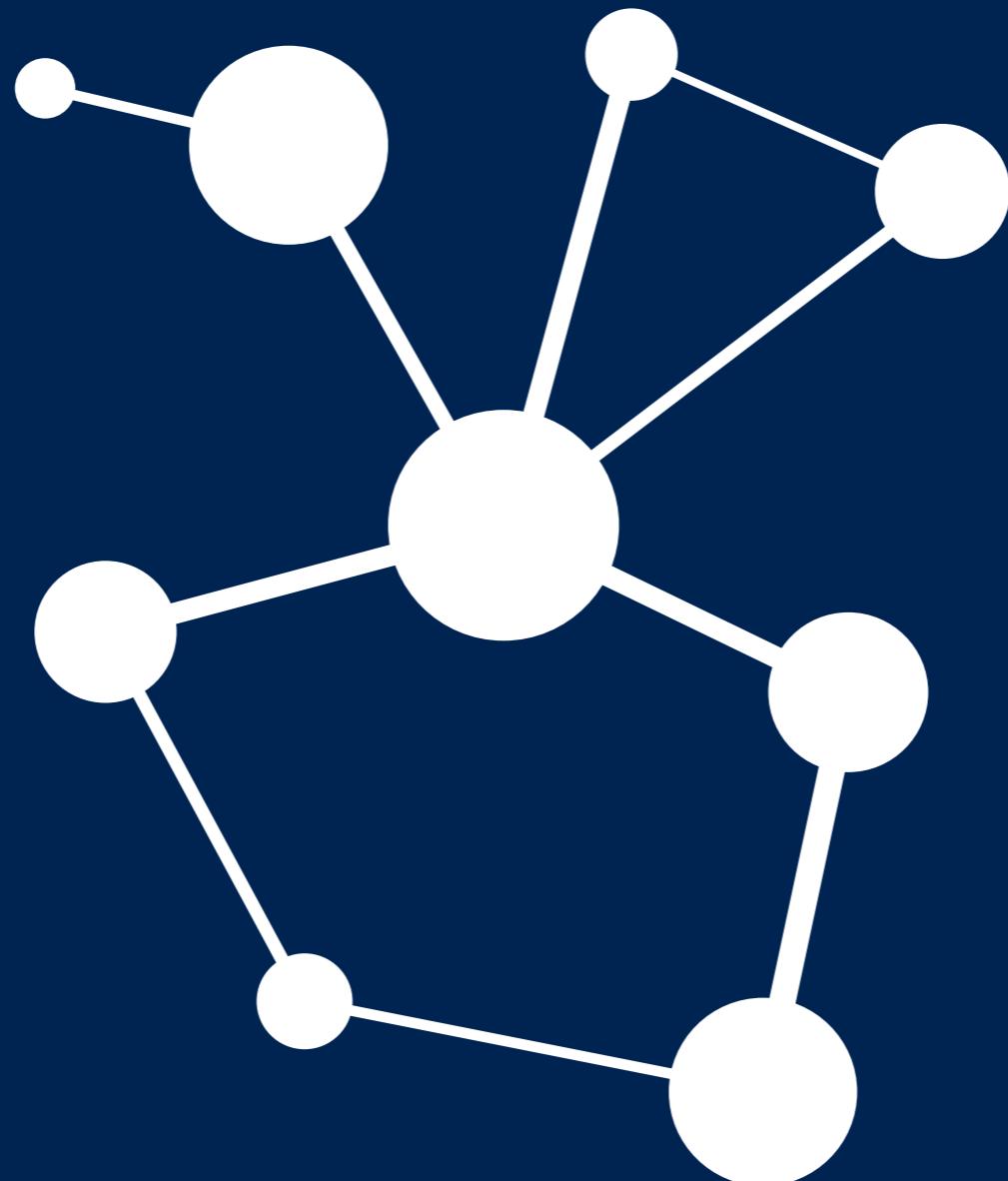
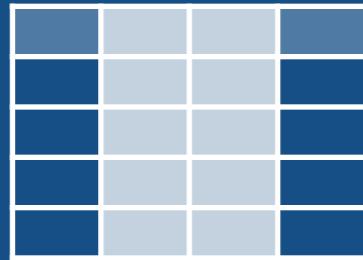
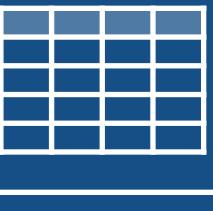


# Introdução à visualização interativa de redes complexas

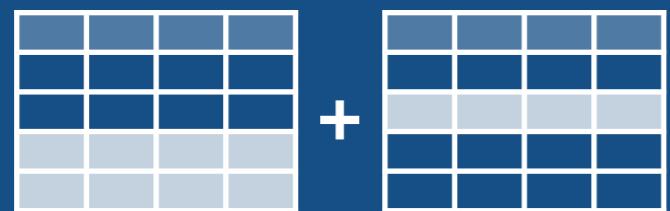


Filipi N. Silva ([filiphinascimento@gmail.com](mailto:filiphinascimento@gmail.com))  
Prof. Luciano da F. Costa

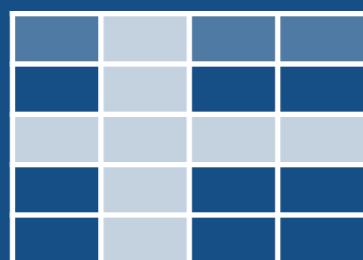
# Visualização de dados



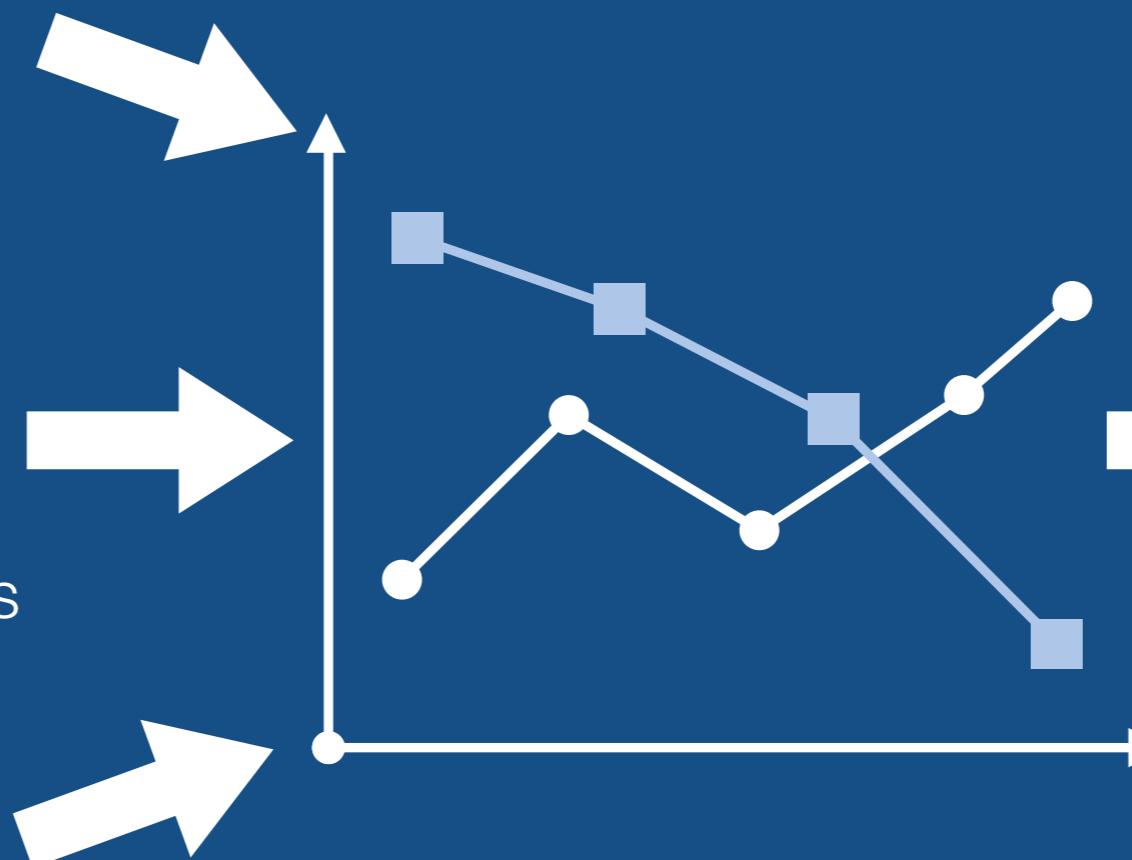
Sumarizar informação



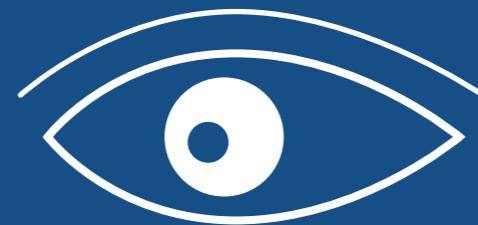
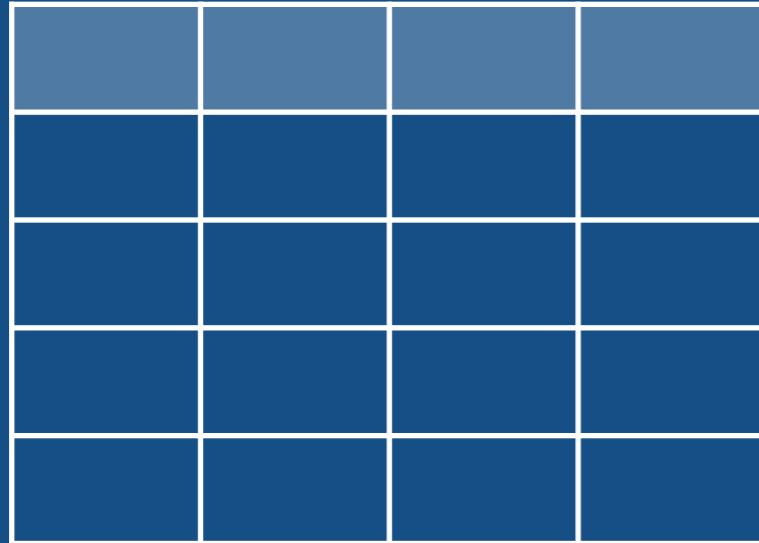
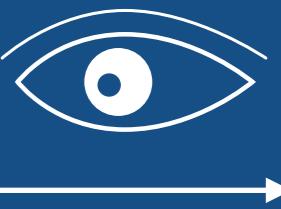
Relações entre elementos



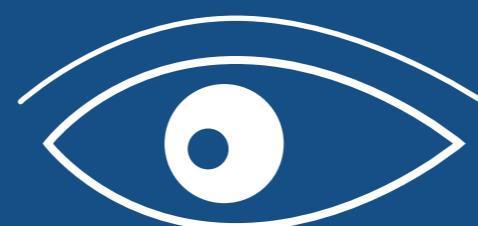
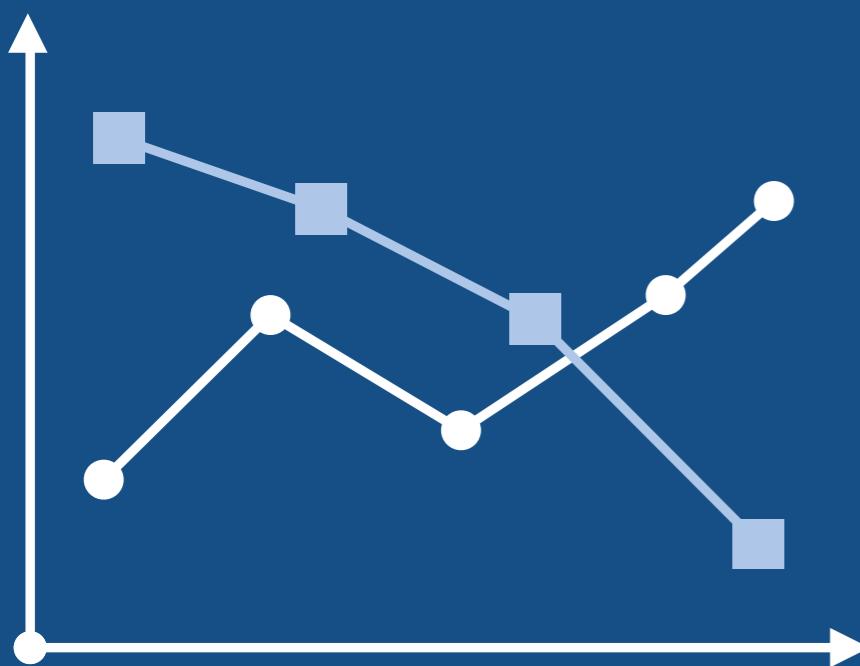
Destacar informação



# Visualização de dados



**Maior** tempo de resposta

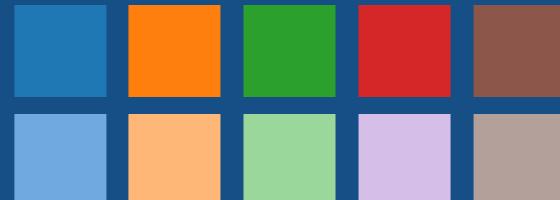


**Menor** tempo de resposta  
maior aproveitamento  
do cortex visual

# Visualização de dados



Seguir contornos e linhas



Detectar cores



Detector formas simples



Detector orientação

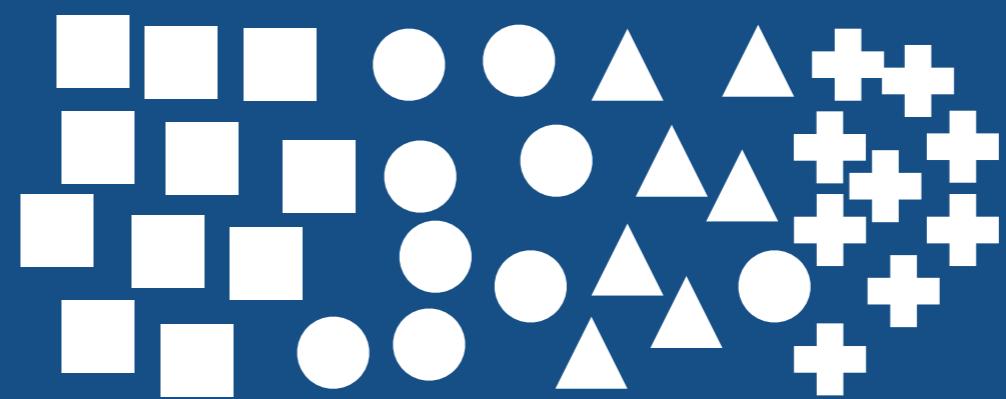


Detector tamanho

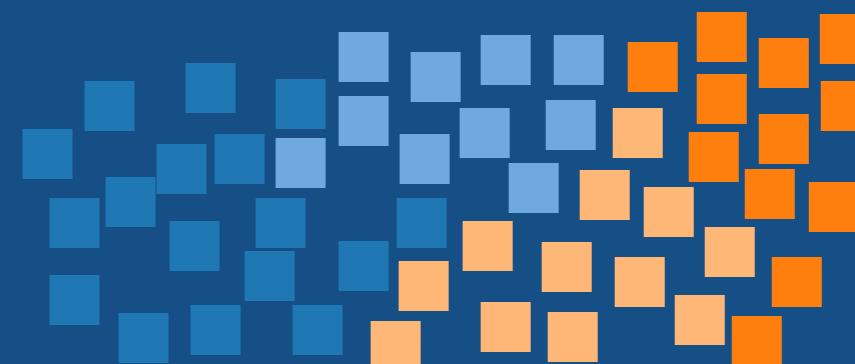
etc



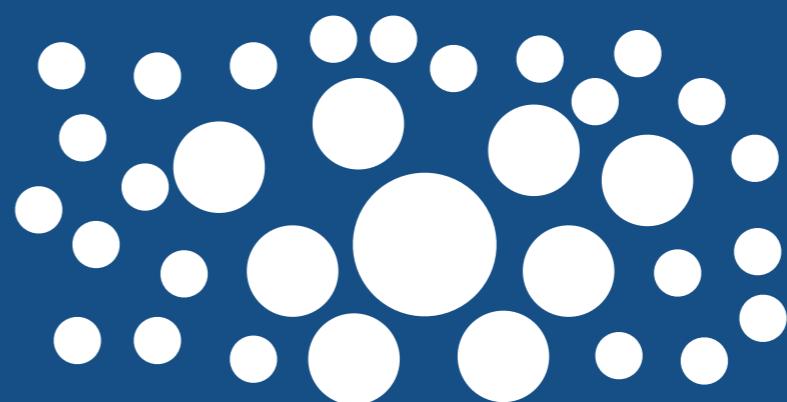
# Visualização de dados



Gradiente de formas



Gradiente de cores



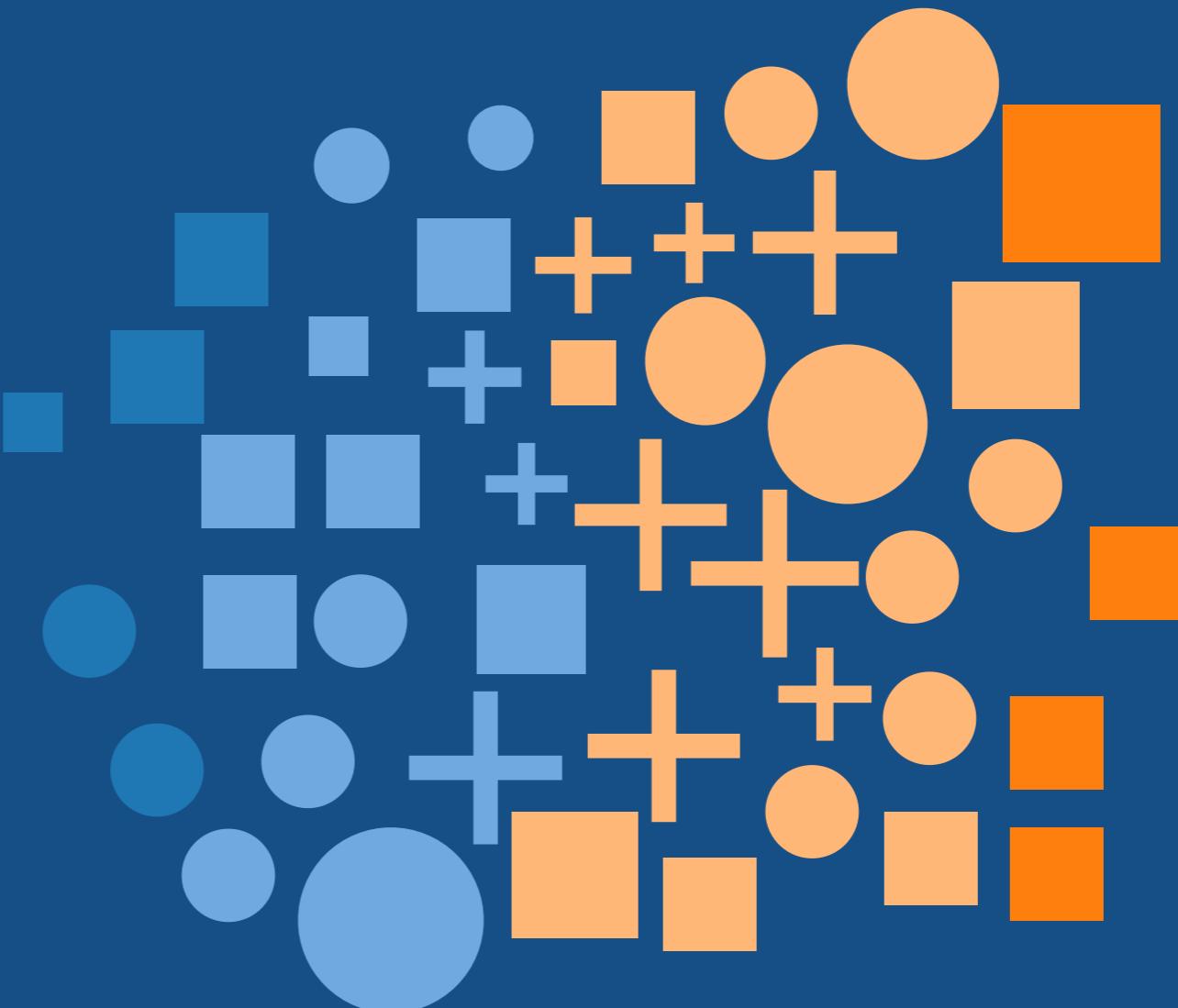
Gradiente de escala



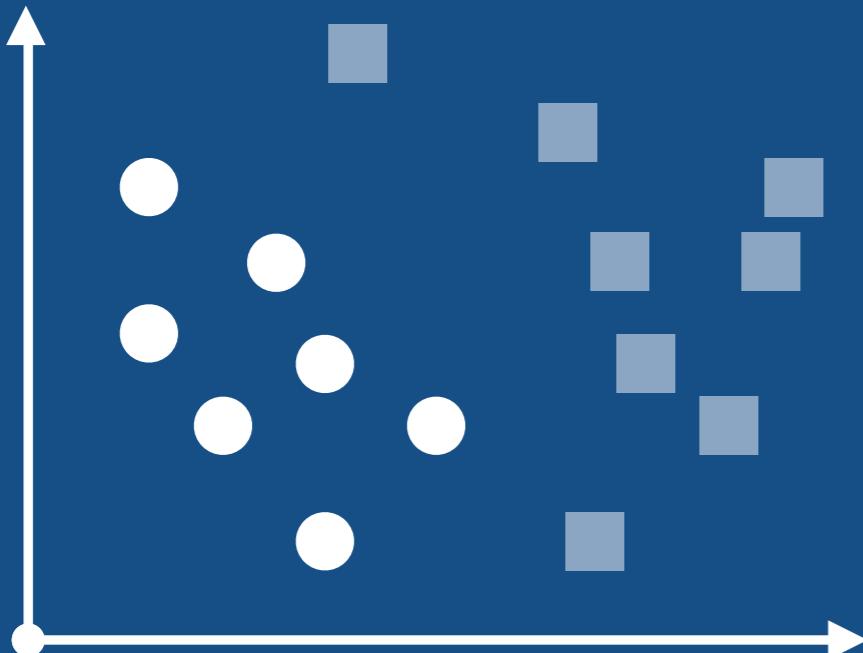
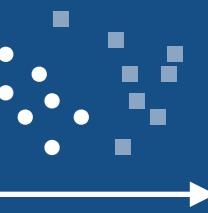
# Visualização de dados



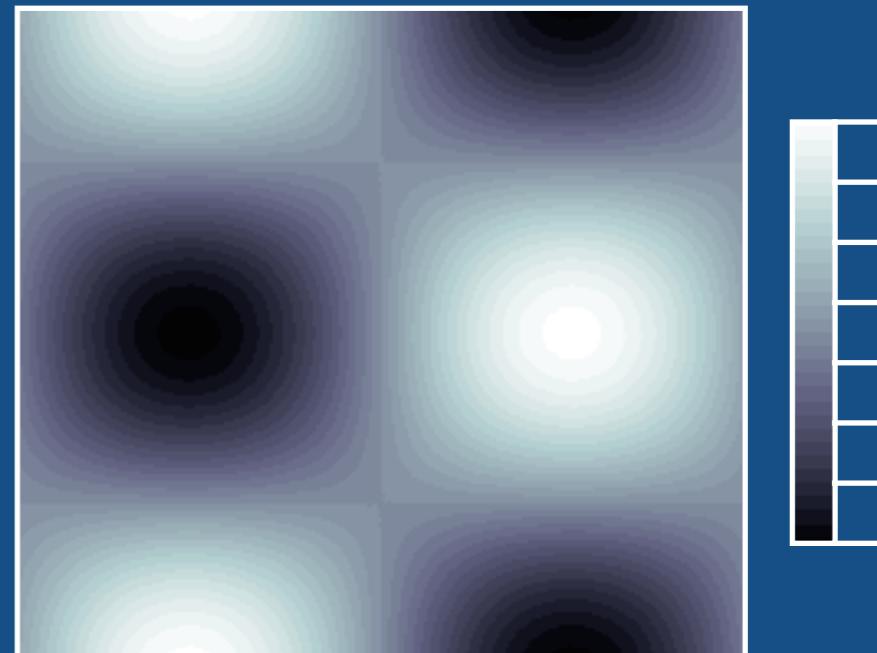
Hierarquia e confusão visual  
Tentem identificar os padrões



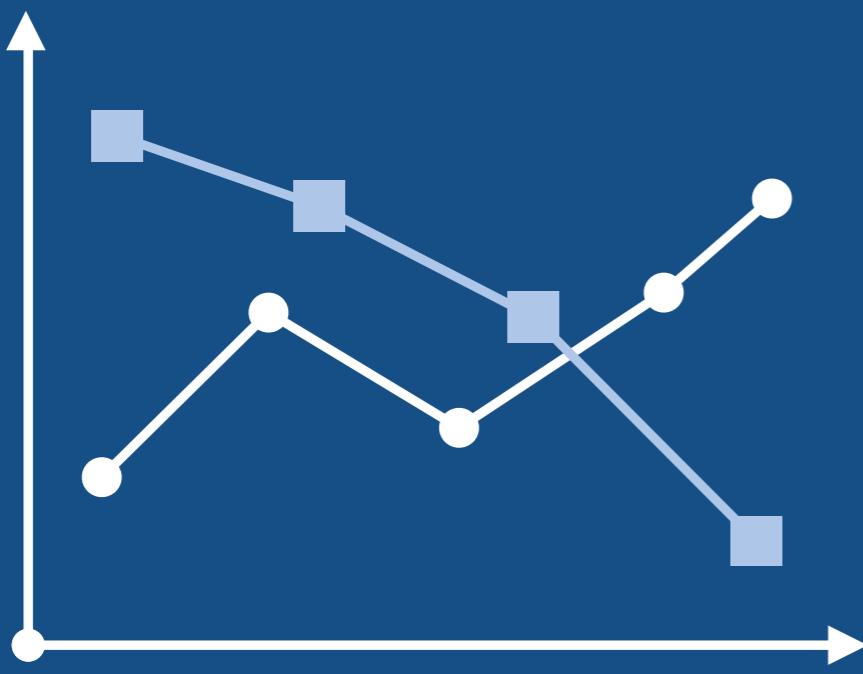
# Tipos de visualização de dados



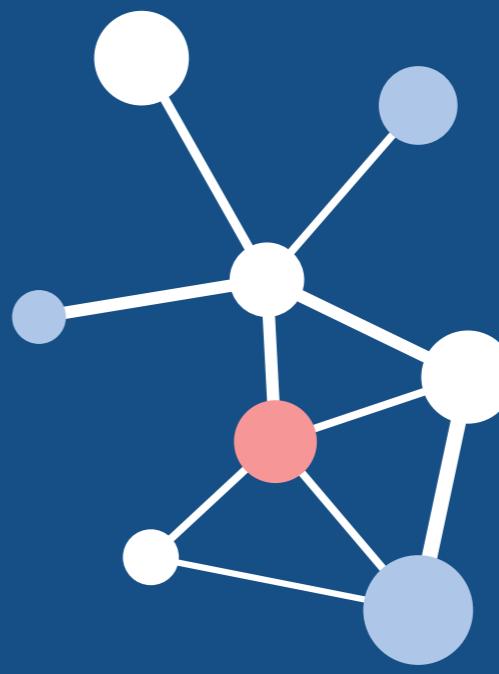
Scatter plots



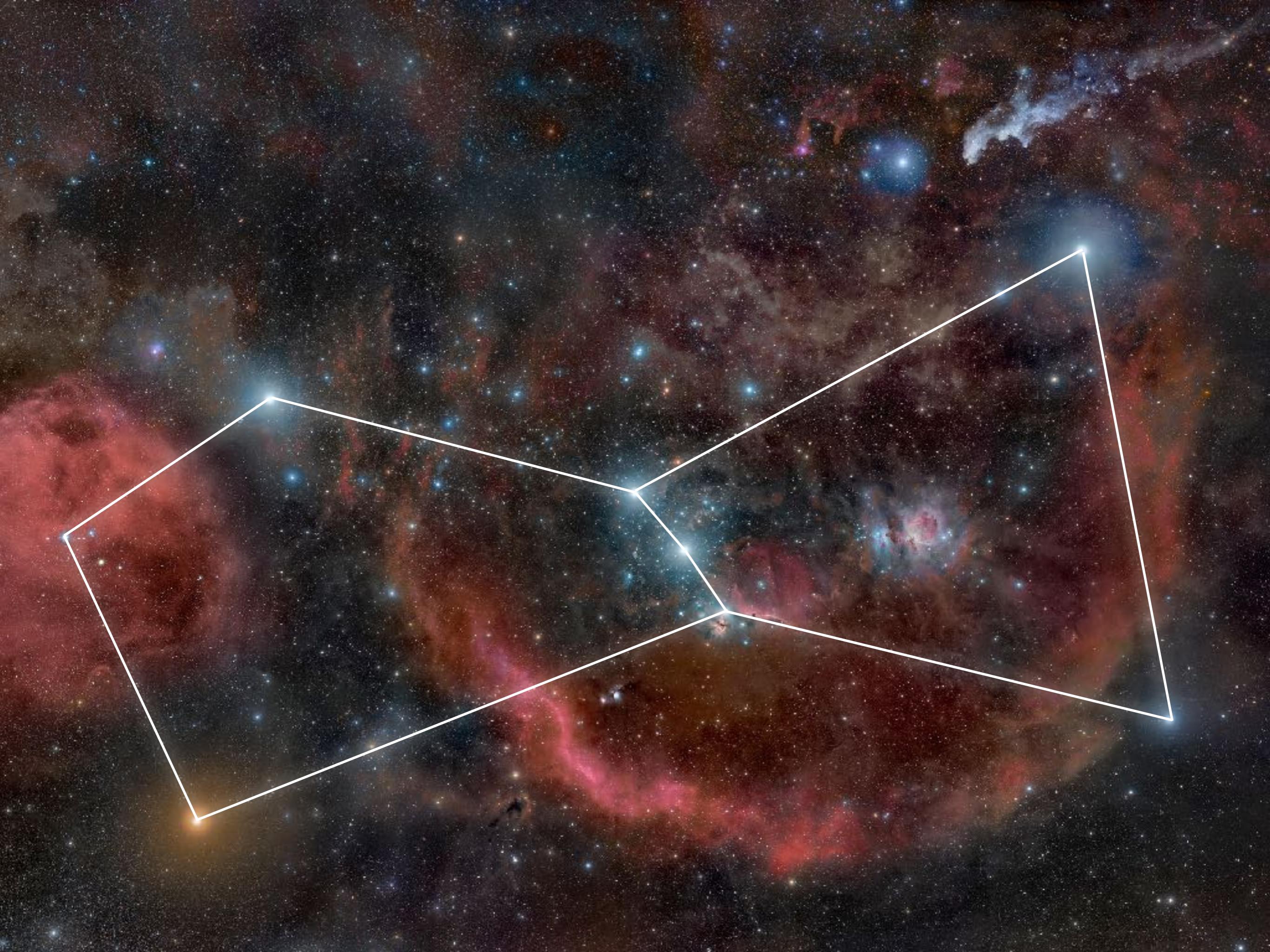
Mapas de superfície

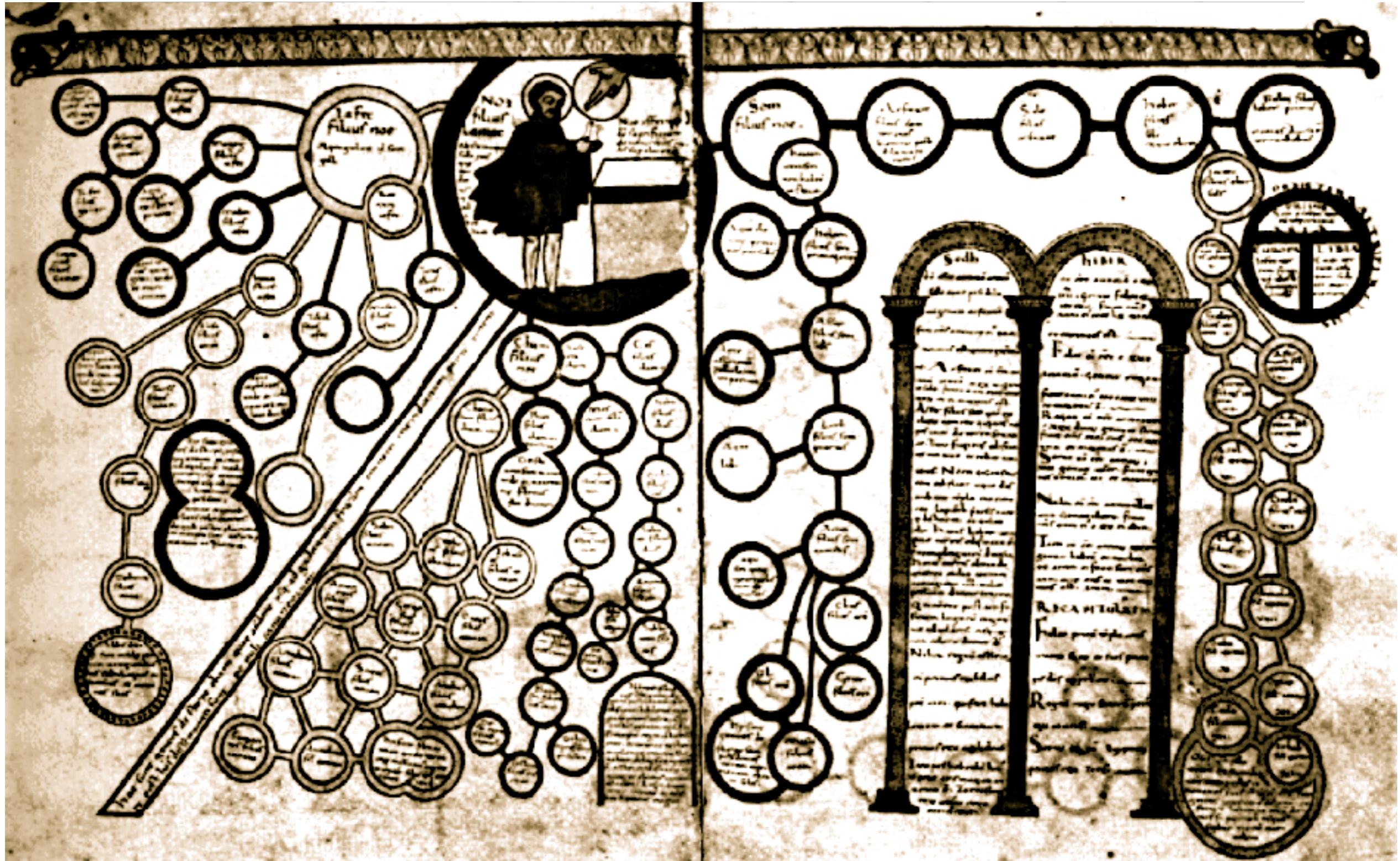


Séries temporais e  
eixos paralelos



Grafos

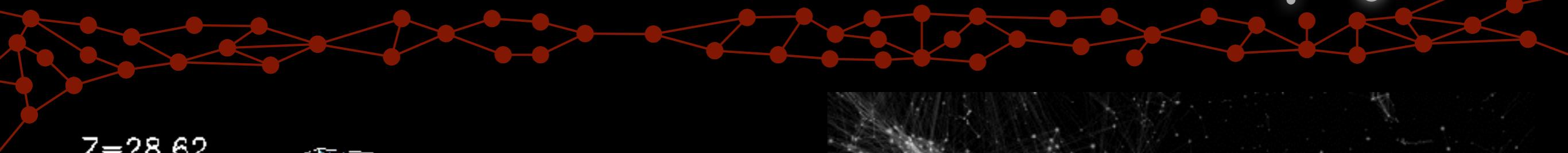




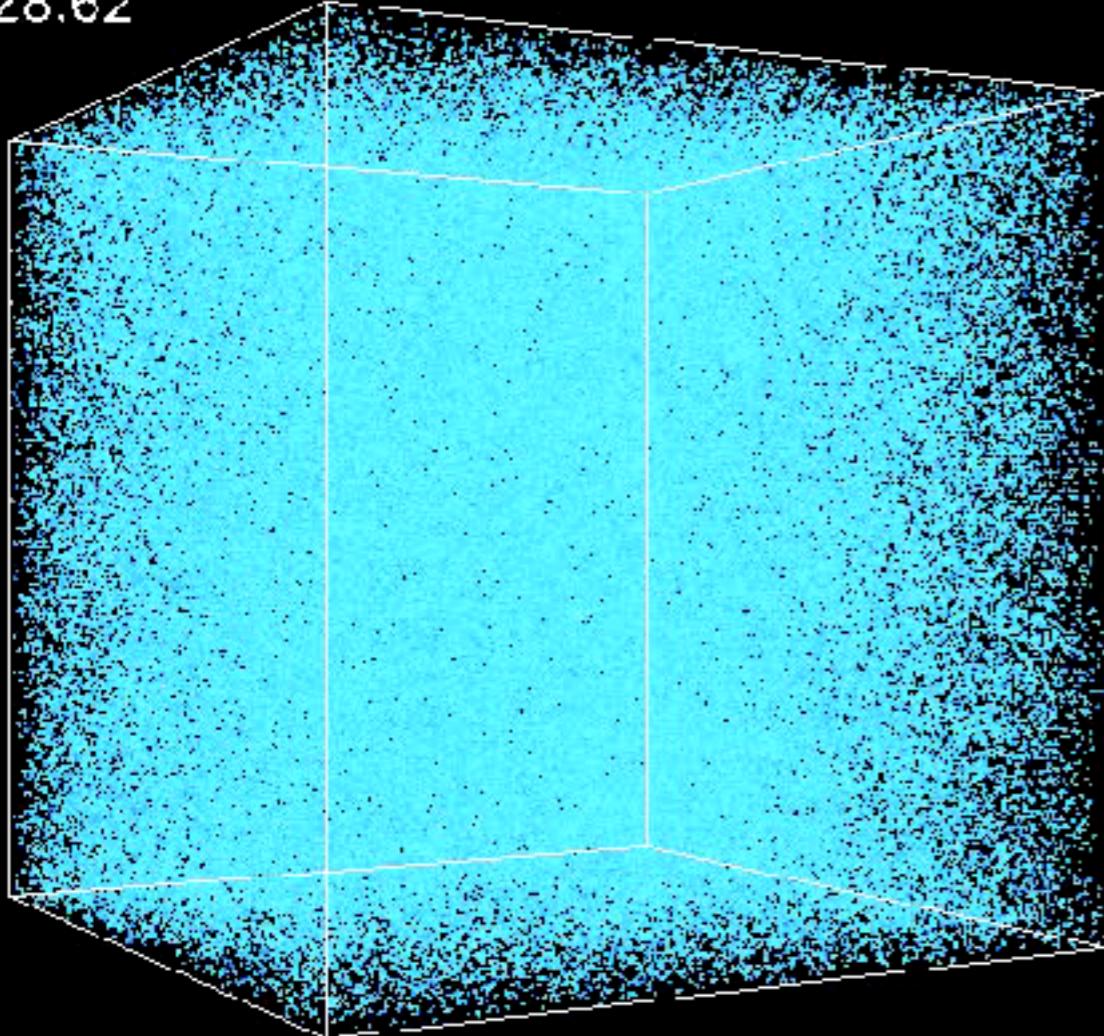
Descendentes de Noé X<sup>o</sup> séc. XI (domínio público)

Kabbalah - séc. XVI (domínio público)

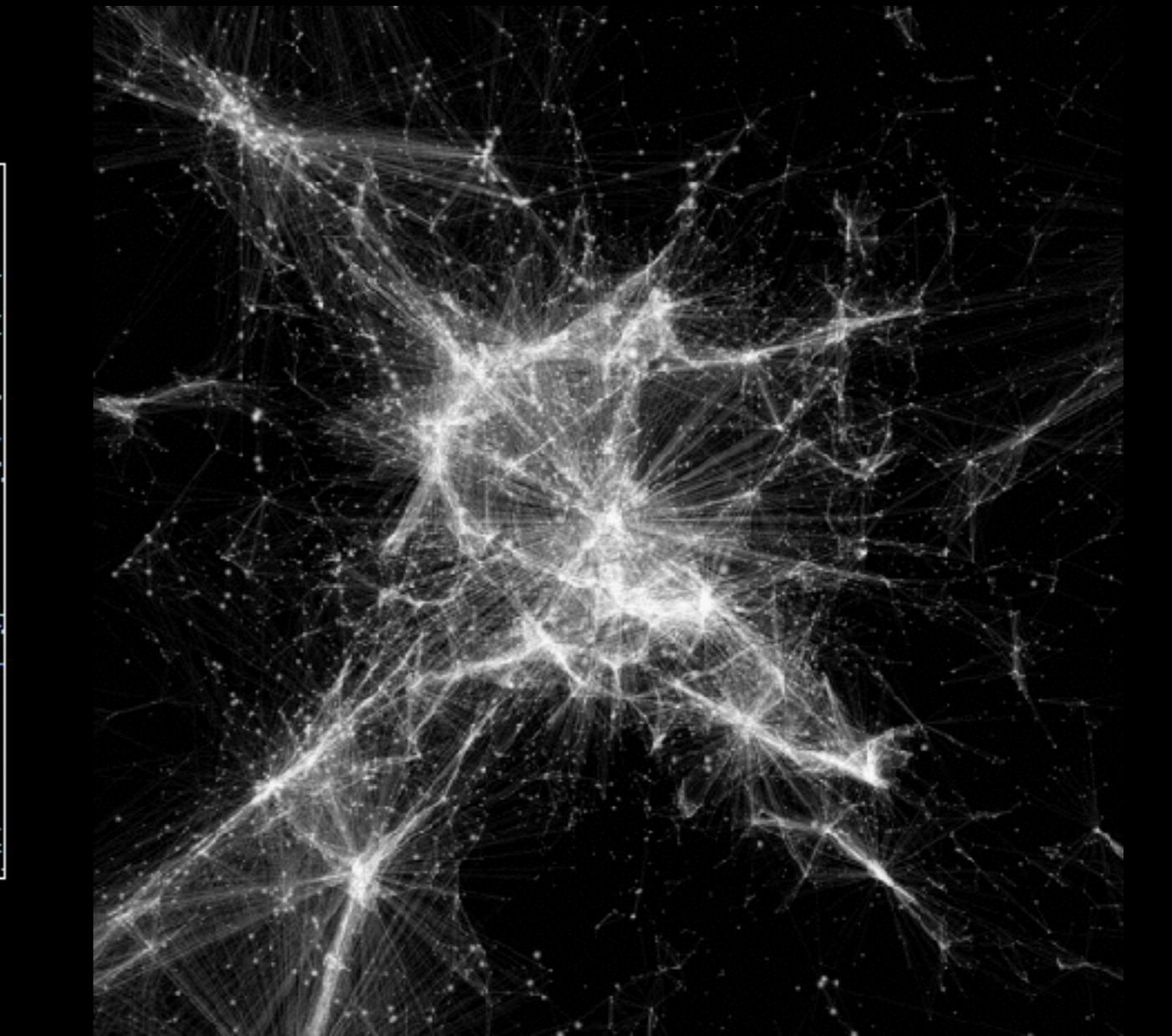
# Exemplos de redes complexas



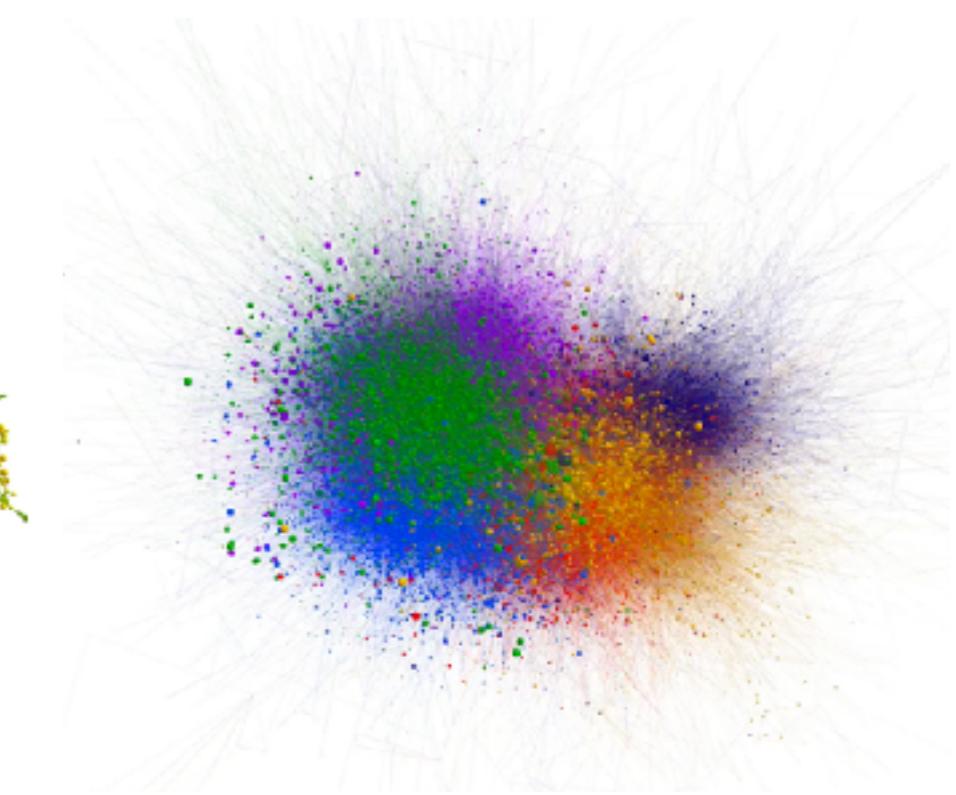
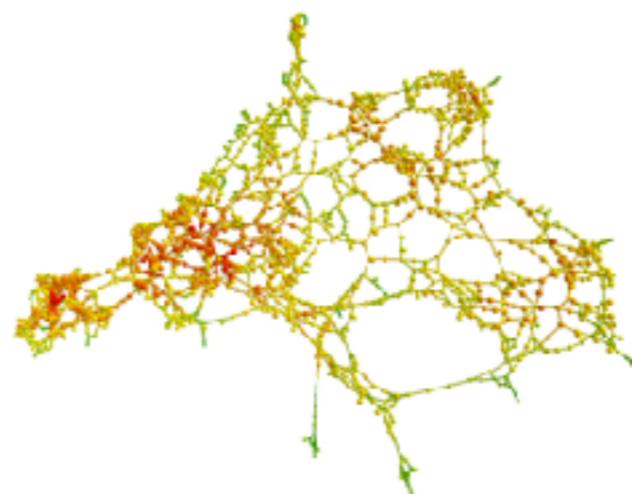
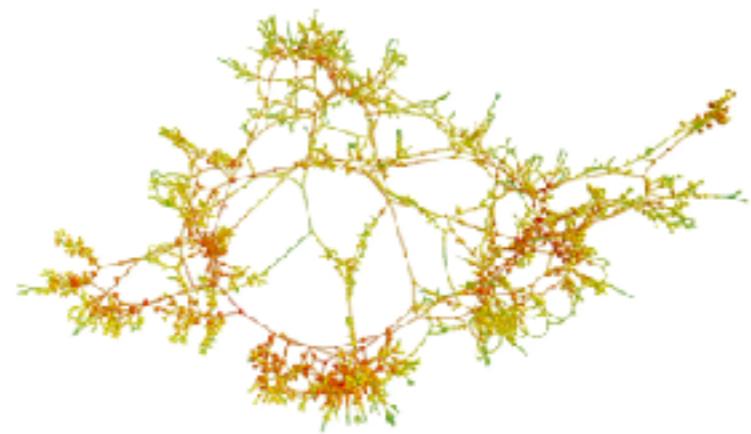
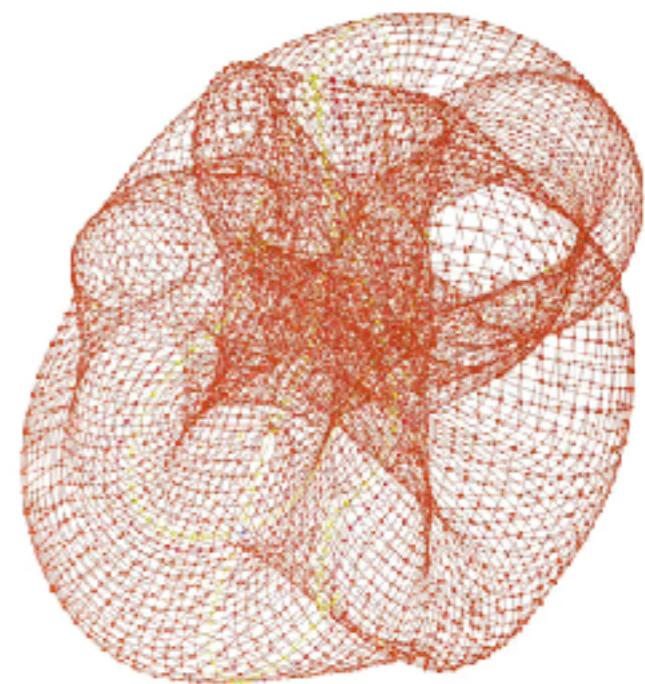
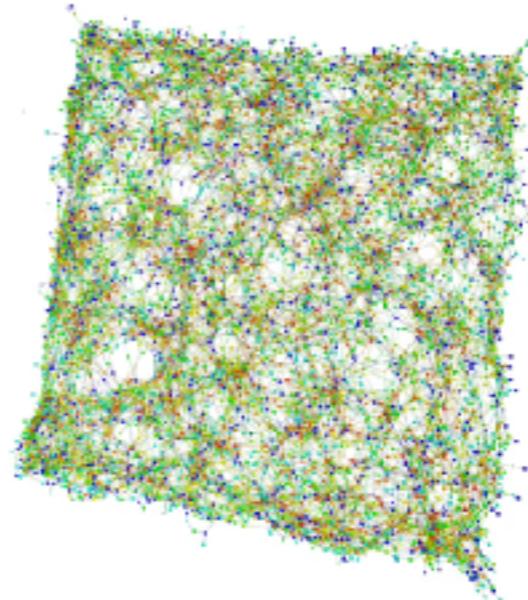
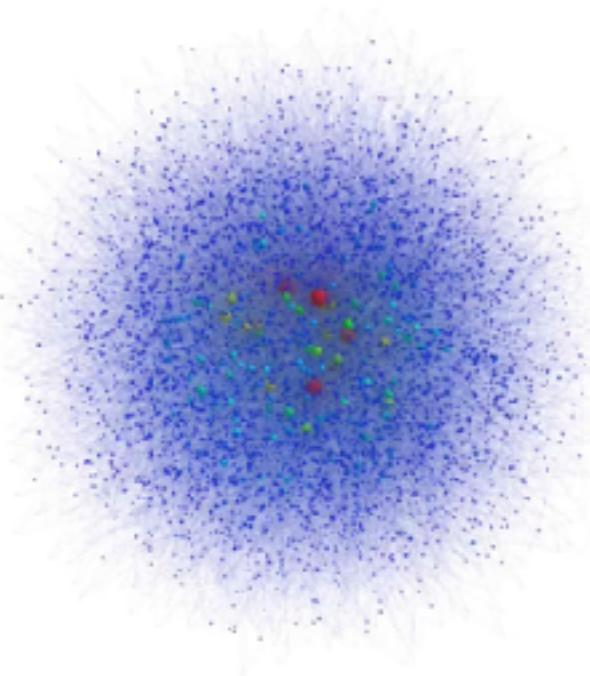
$Z=28.62$



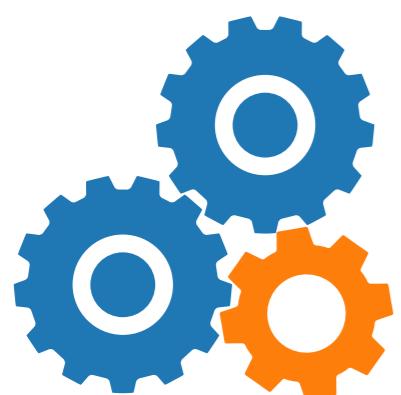
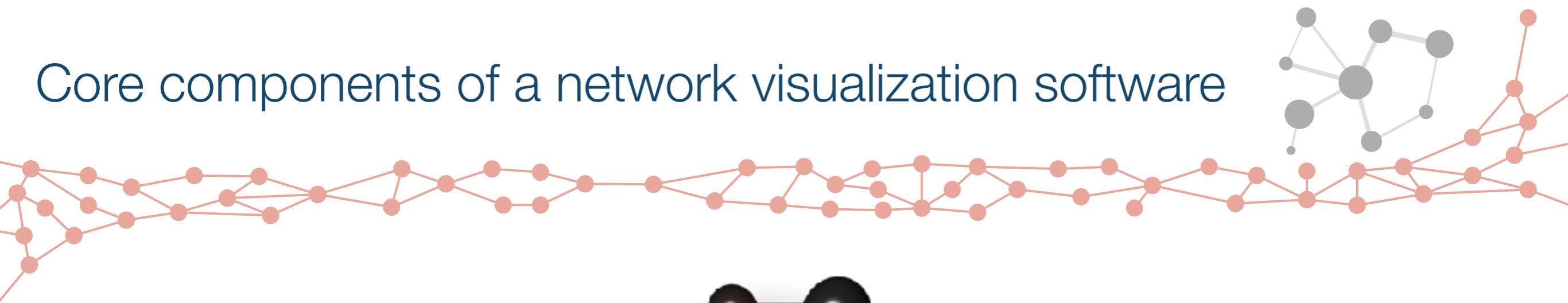
Simulação gerada por:  
National Center for Supercomputer Applications  
Andrey Kravtsov  
(The University of Chicago)  
e Anatoly Klypin  
(New Mexico State University).



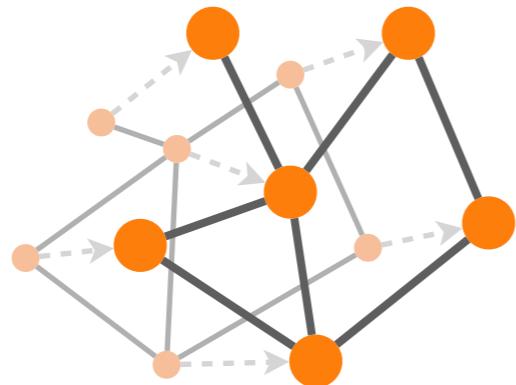
Coutinho, B. C., Hong, S., Albrecht, K., Dey, A., Barabási, A. L.,  
Torrey, P., ... & Hernquist, L. (2016). The Network Behind the  
Cosmic Web. *arXiv preprint arXiv:1604.03236*.



# Core components of a network visualization software



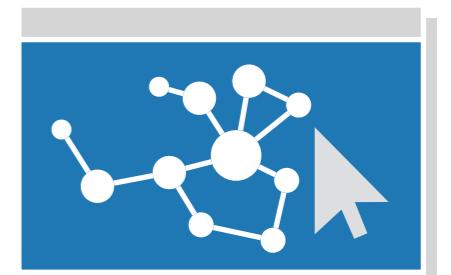
Graph Library



Layout

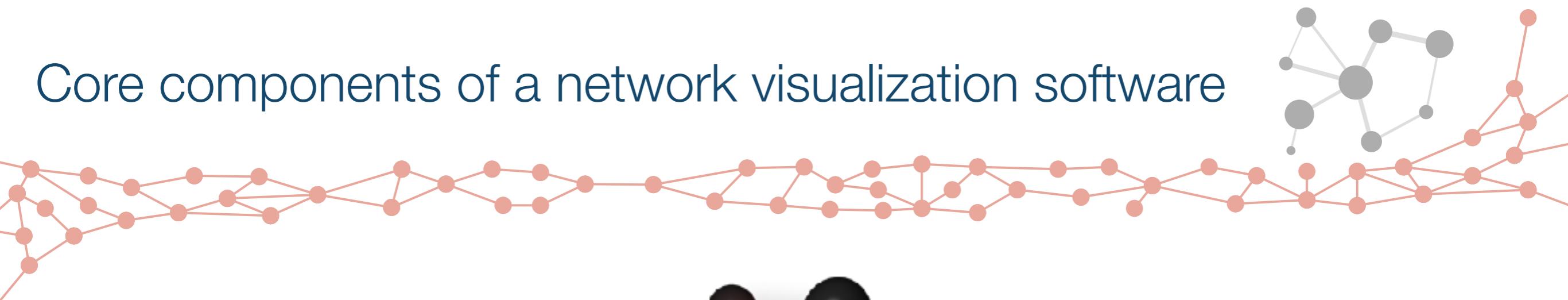


Rendering

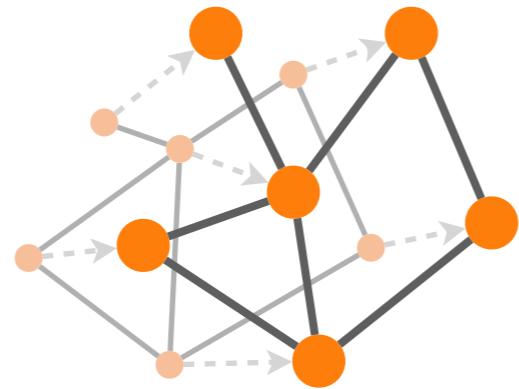


Interface

# Core components of a network visualization software



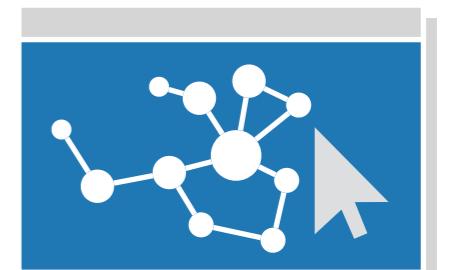
Graph Library



Layout

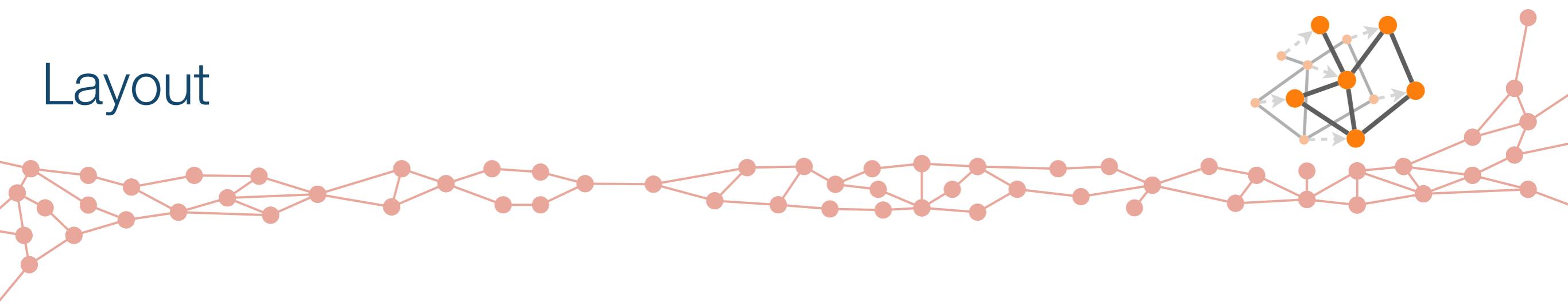


Rendering

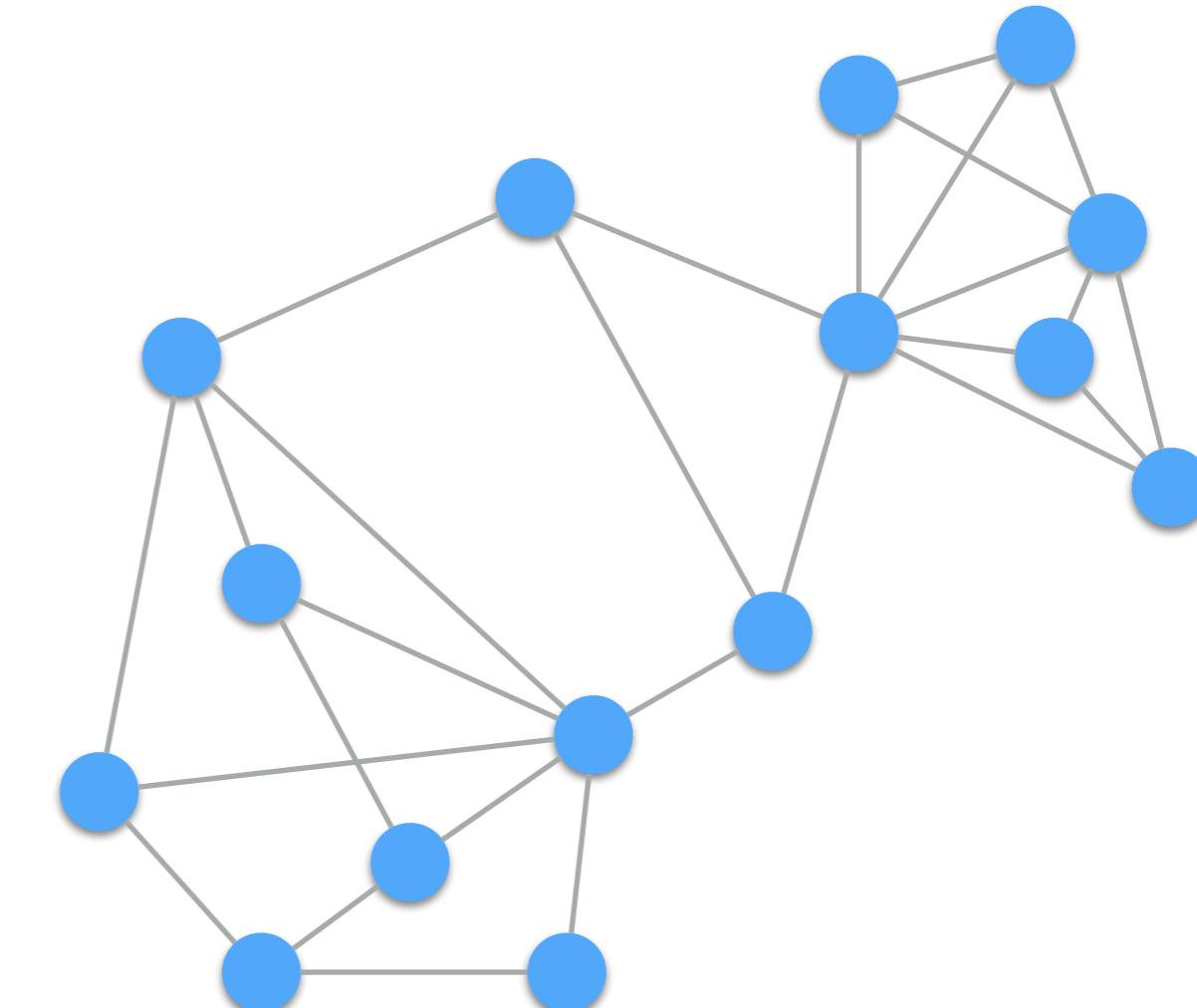


Interface

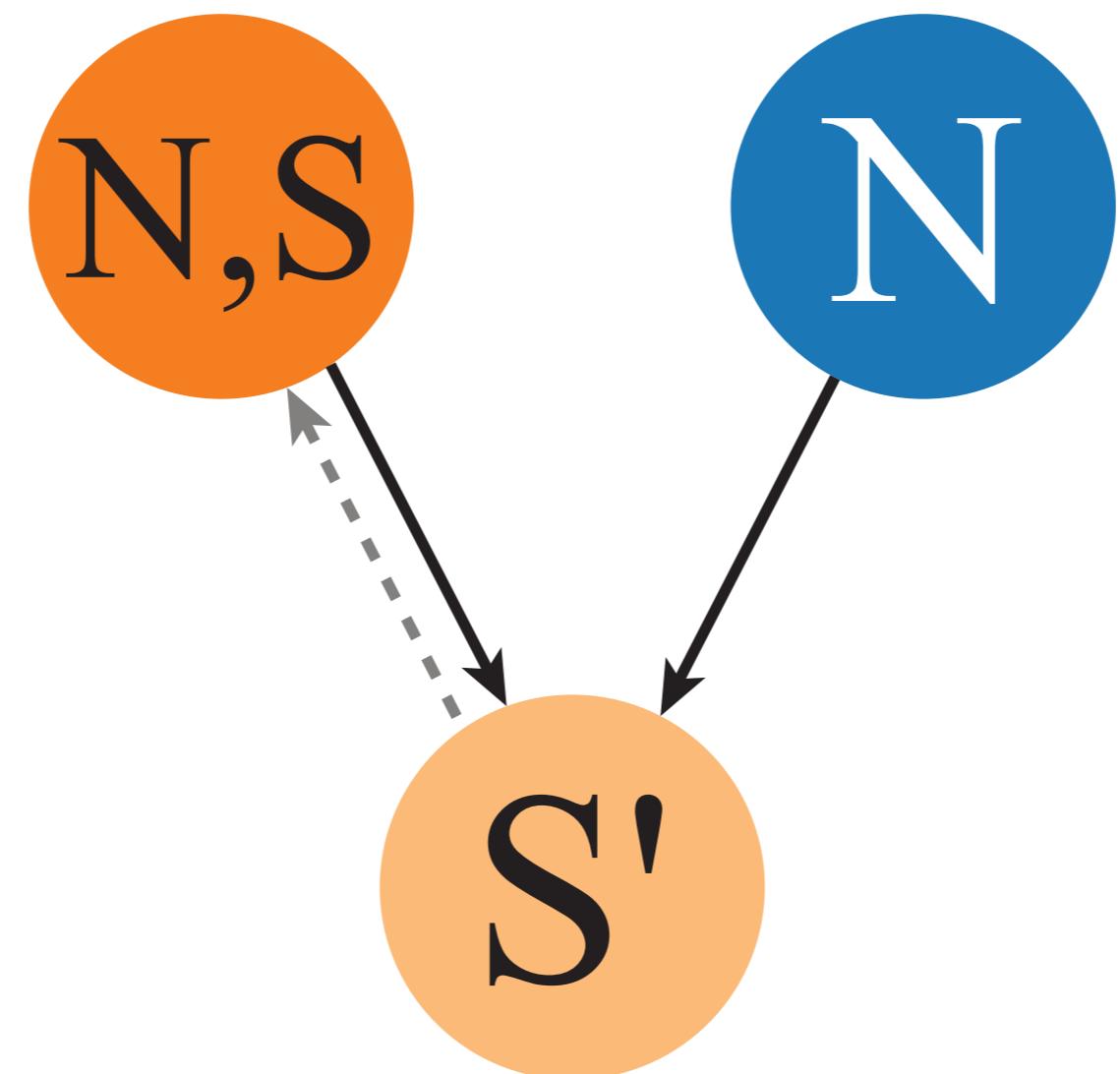
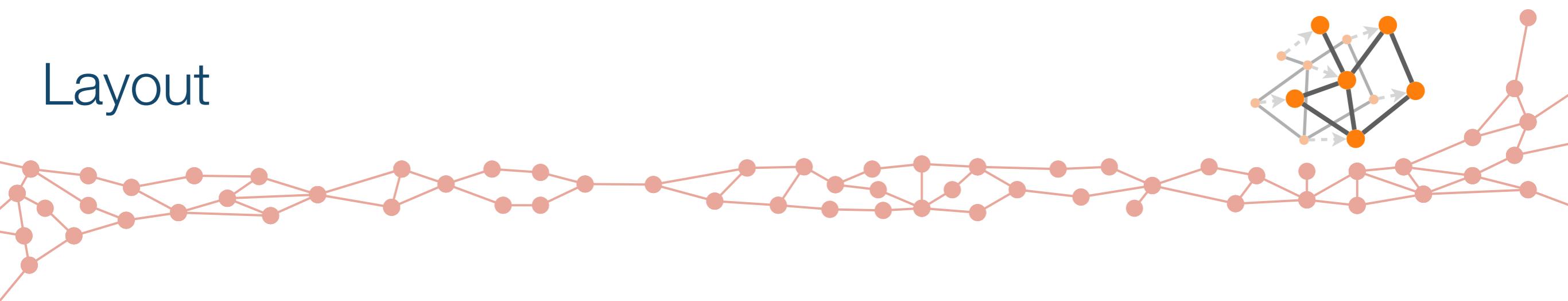
# Layout

 $\mathcal{N}$ 

		0			1			1					
0	0	1	1	1	1	1	1	1	1	1	1	1	1
1	0	1	0	1	1	0	1	1	0	1	0	1	1
1	1	0	1	1	0	1	1	0	1	1	0	1	1
1	1	1	0	1	1	0	1	1	0	1	1	0	1
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

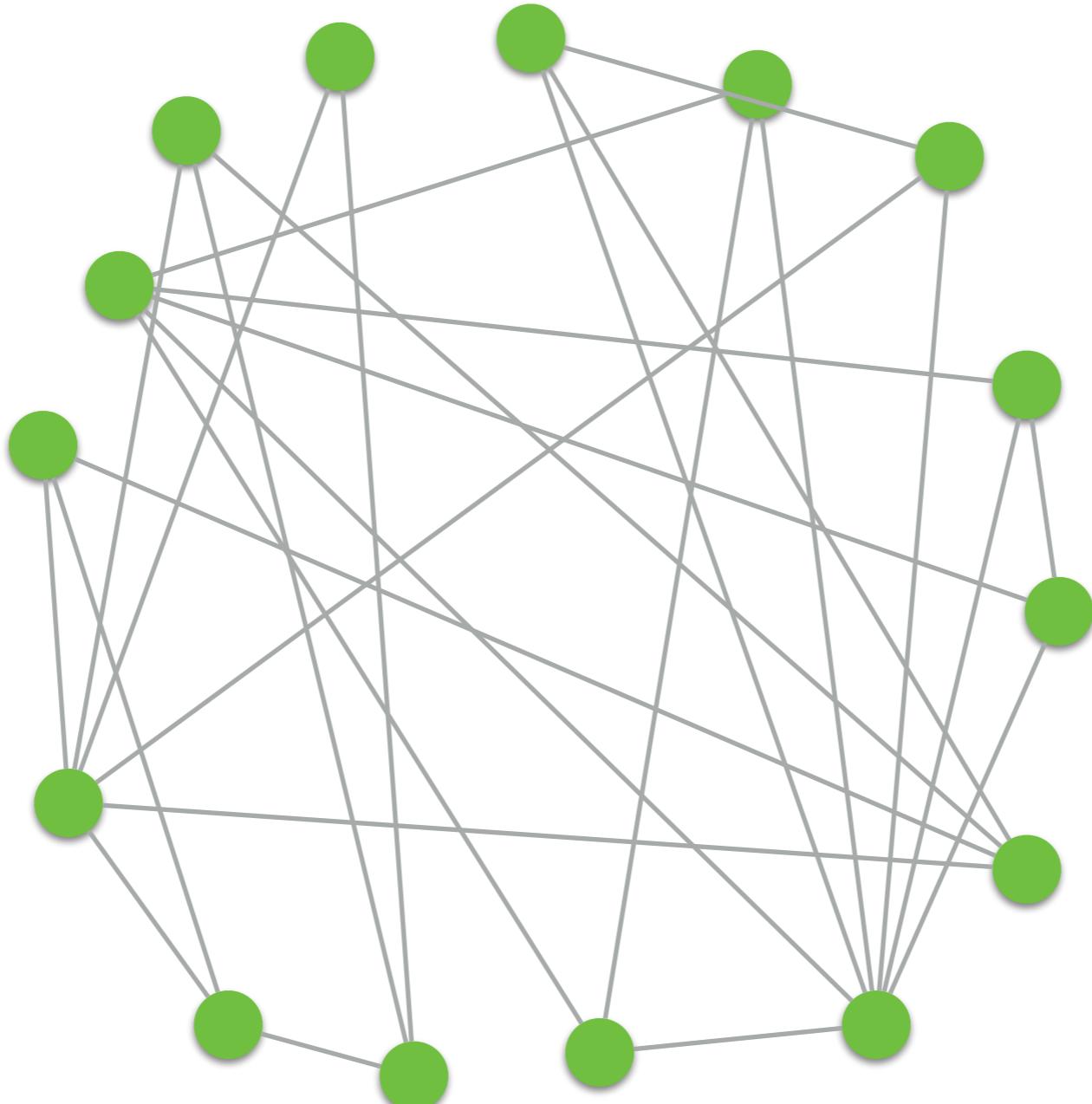
 $S'$ 

# Layout



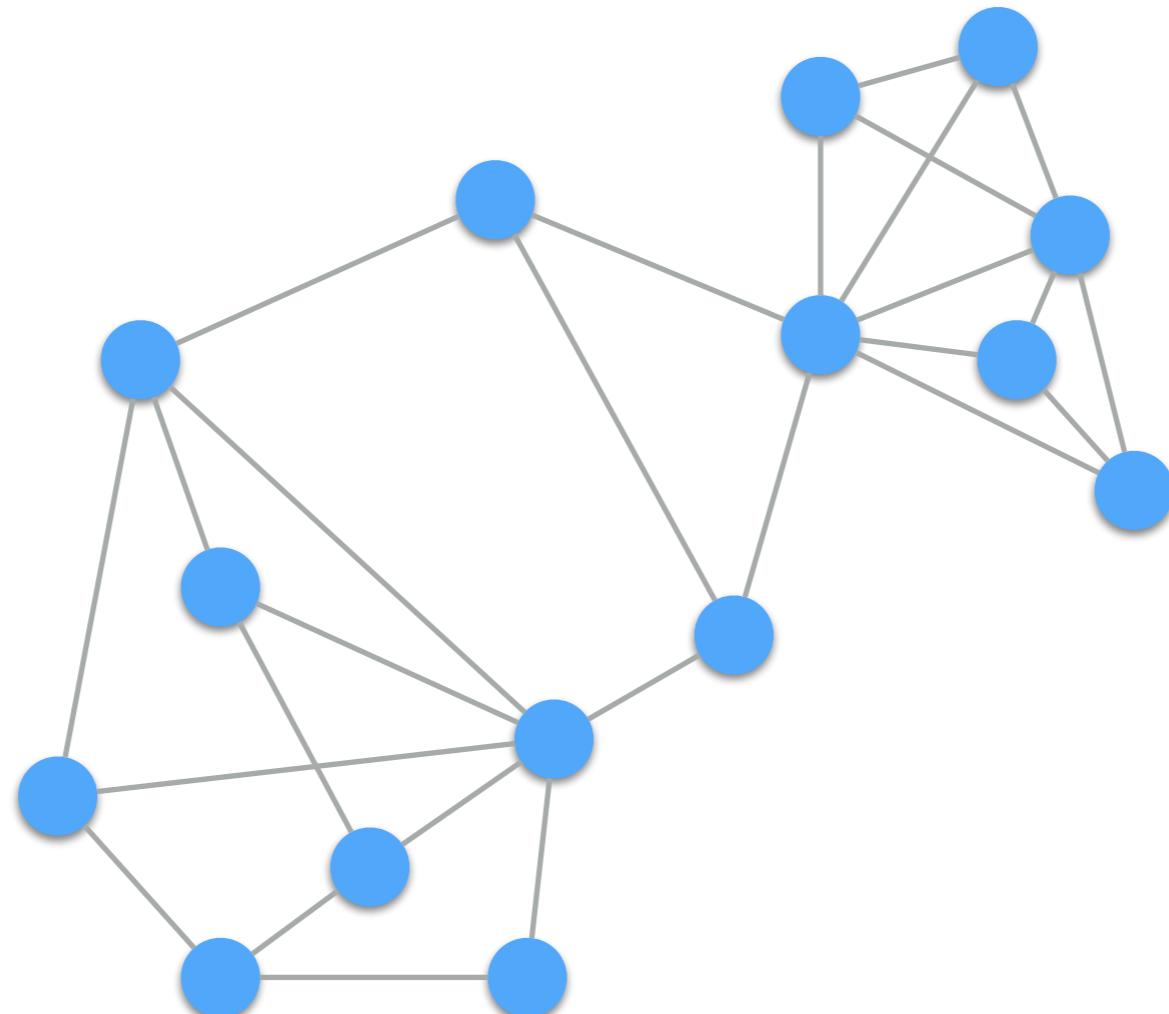


# Visualização de redes complexas



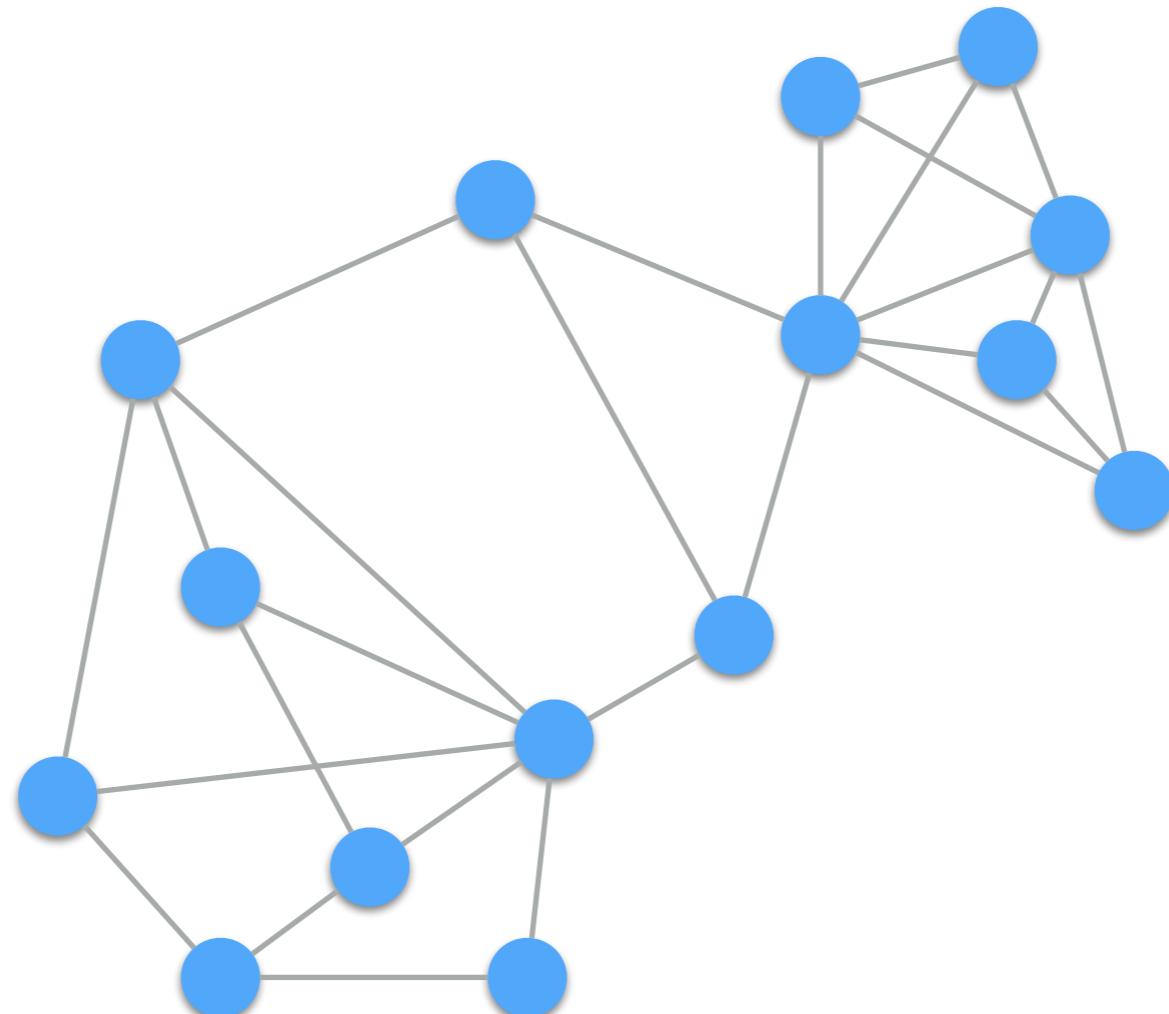


# Visualização de redes complexas



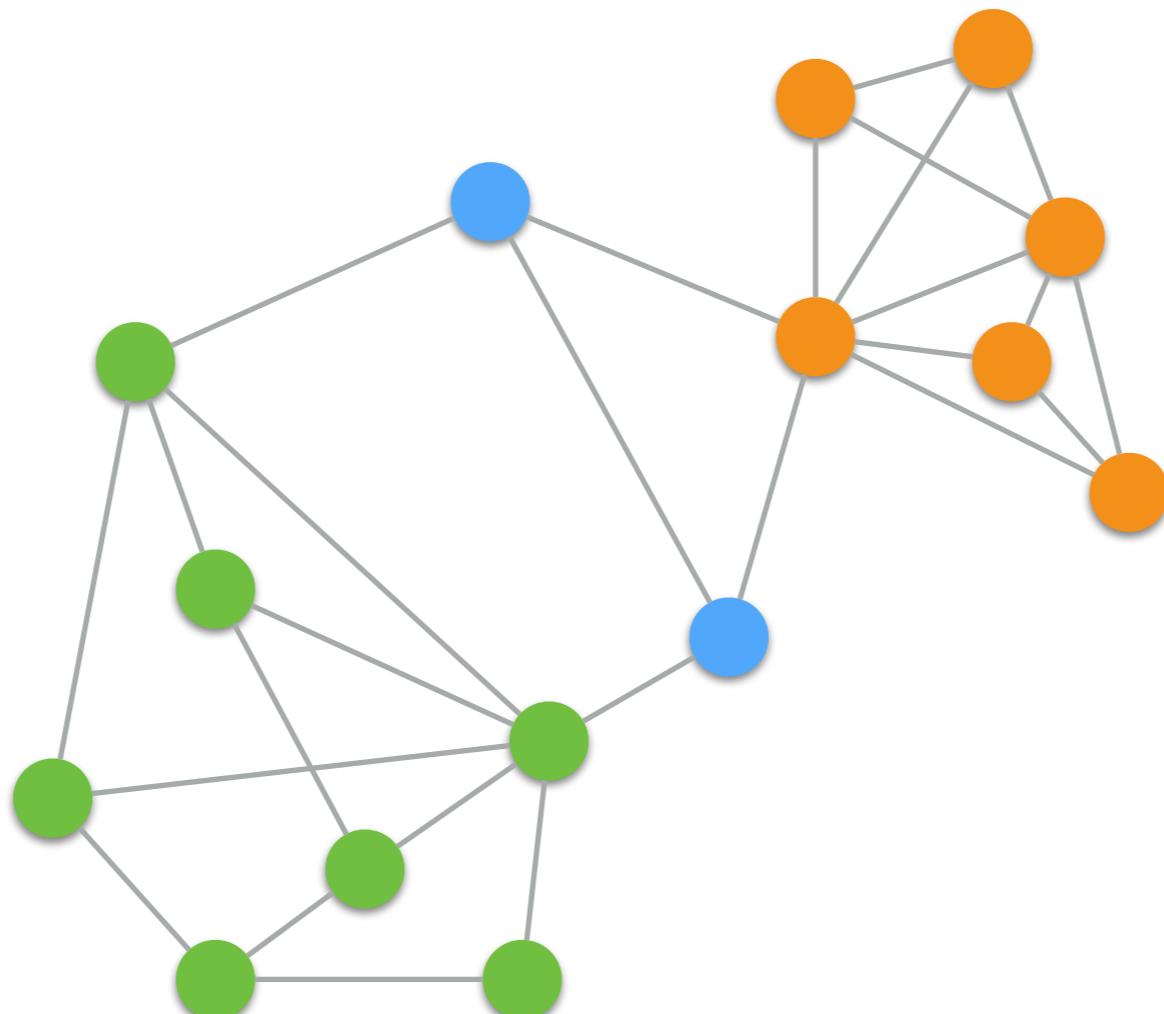


# Visualização de redes complexas



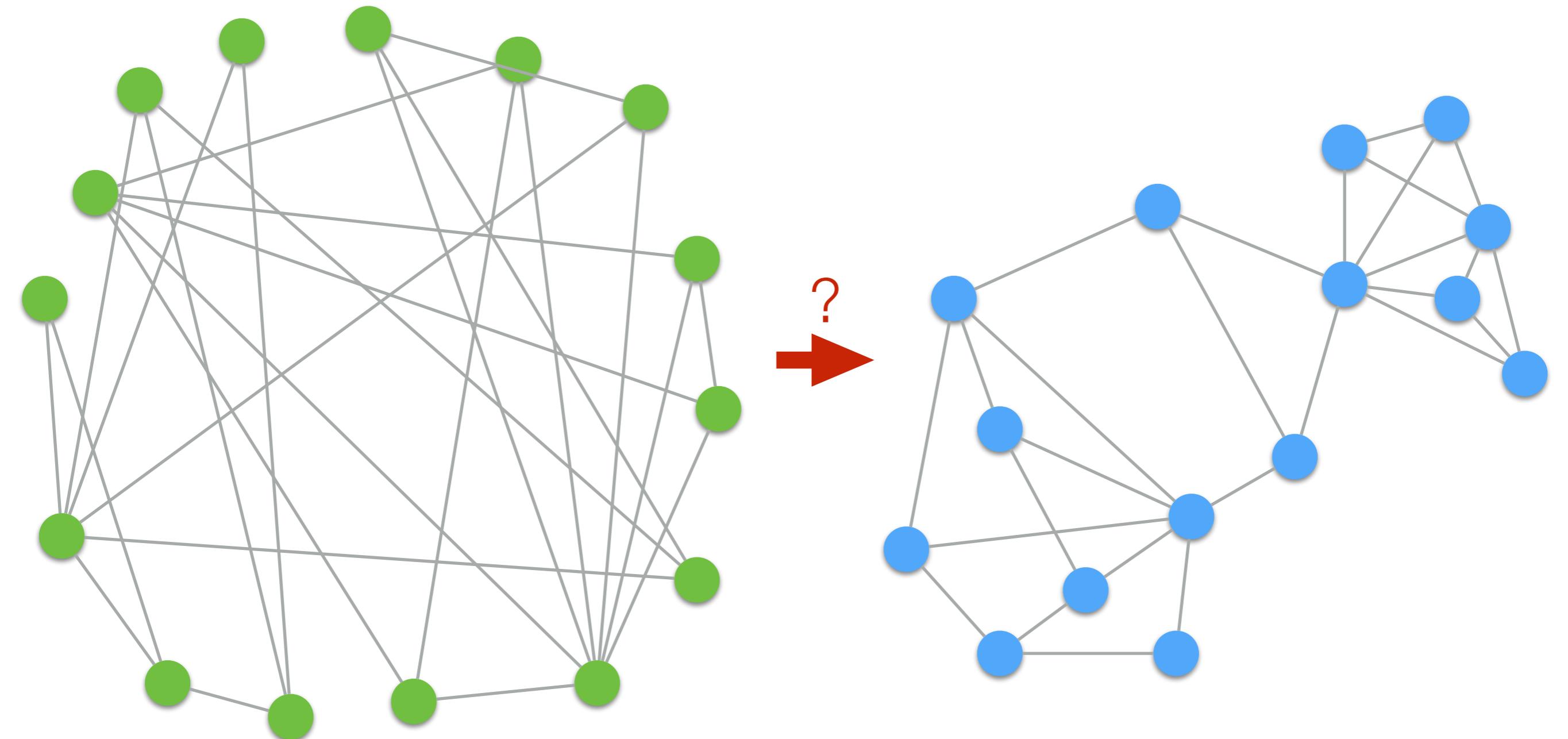


# Visualização de redes complexas



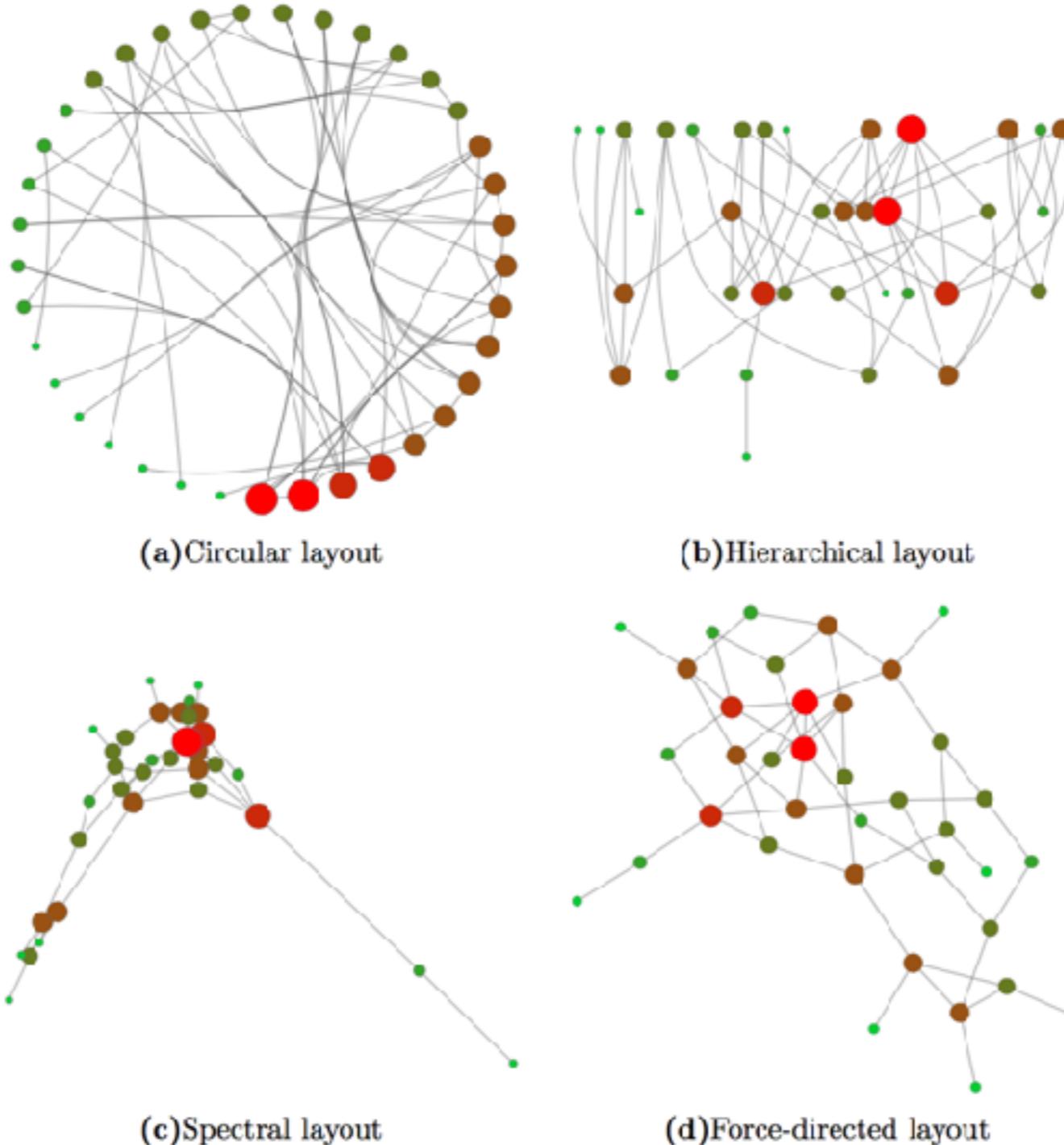


# Visualização de redes complexas





# Visualização de redes complexas



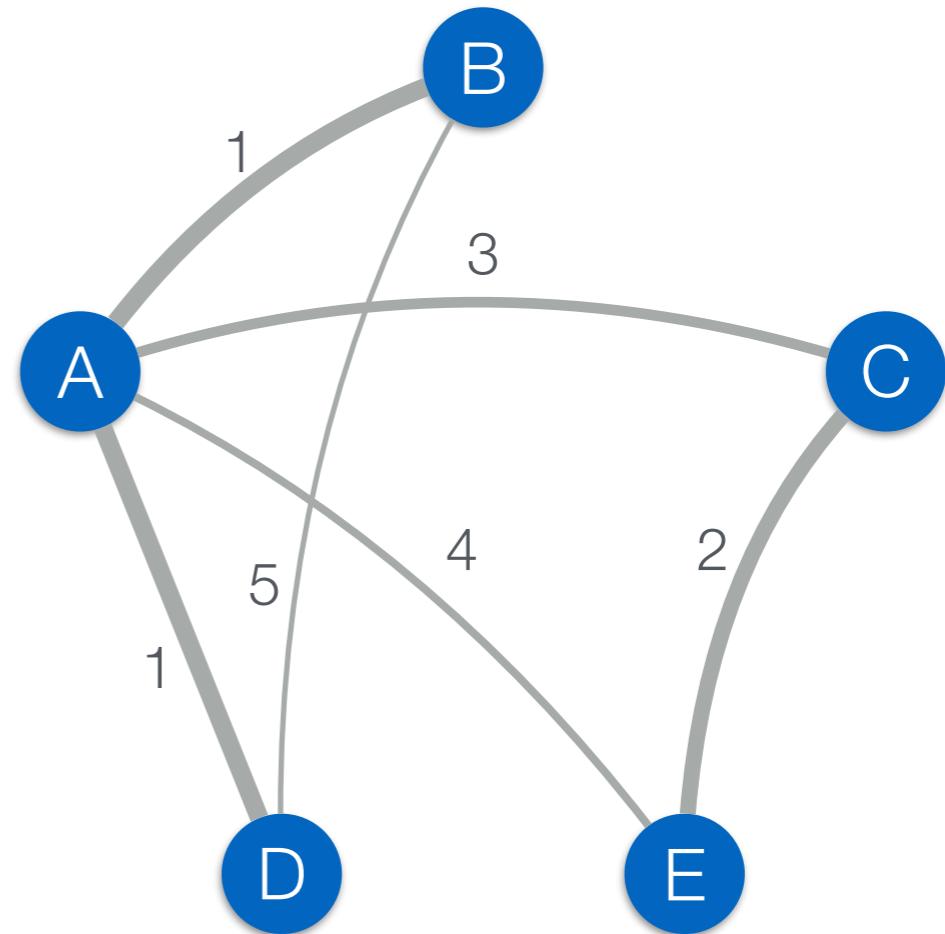
Complex systems: features, similarity and connectivity  
C. H. Comin, T. K. DM. Peron, F. N. Silva, D. R. Amancio, F. A. Rodrigues, L. da F. Costa  
<https://arxiv.org/abs/1606.05400>



# Visualização de redes complexas

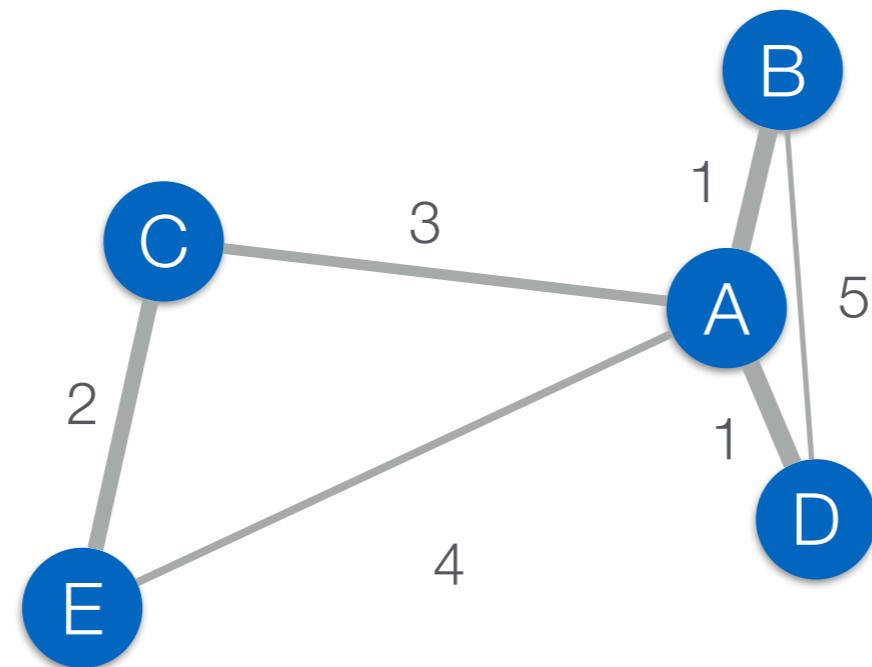
Matriz de distâncias

	A	B	C	D	E
A	0	1	3	1	4
B	1	0	5		
C	3		0	2	
D	1	5		0	
E	4	2		0	

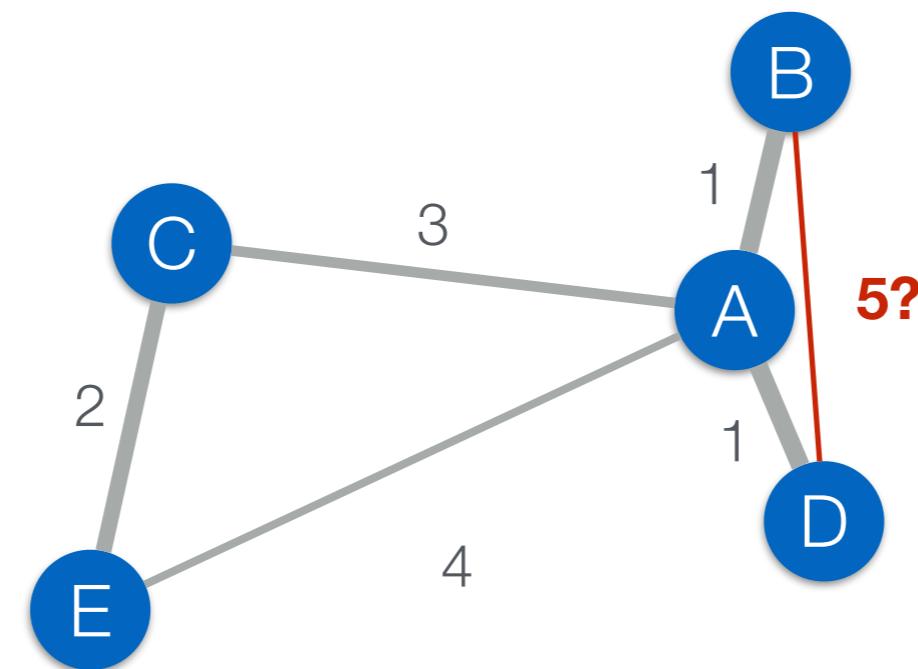




# Método direcionado por forças



# Método direcionado por forças

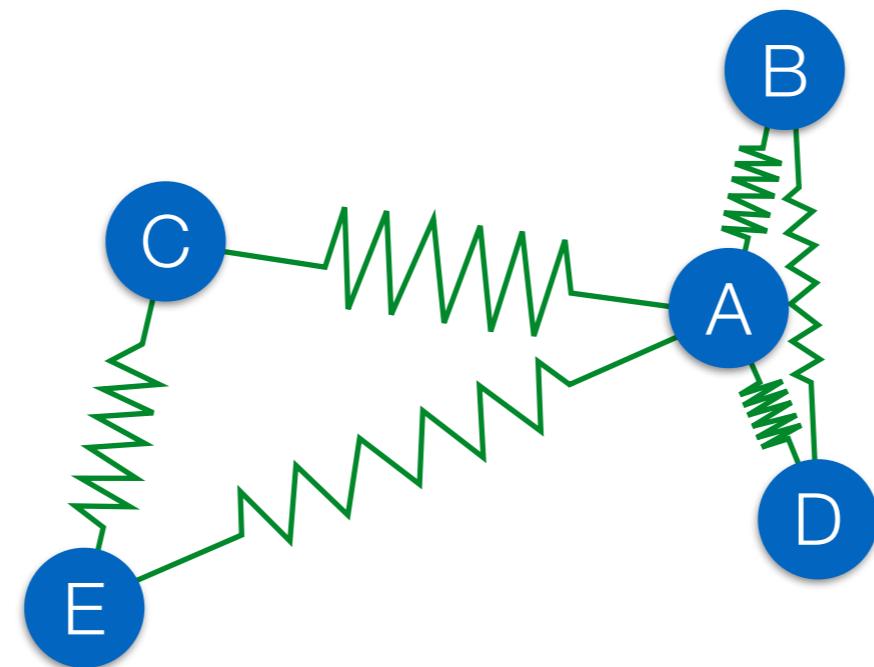


Conseguem imaginar um método físico para resolver o problema?



# Método direcionado por forças

Forças do tipo massa-mola

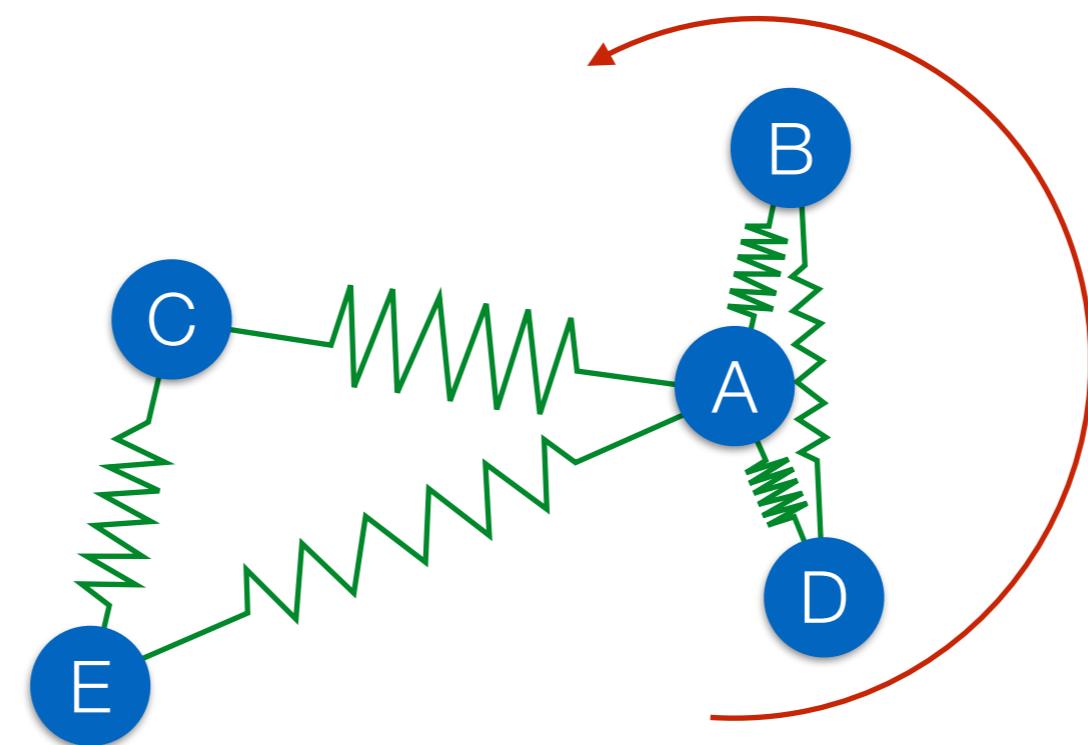


Problemas?



# Método direcionado por forças

Forças do tipo massa-mola

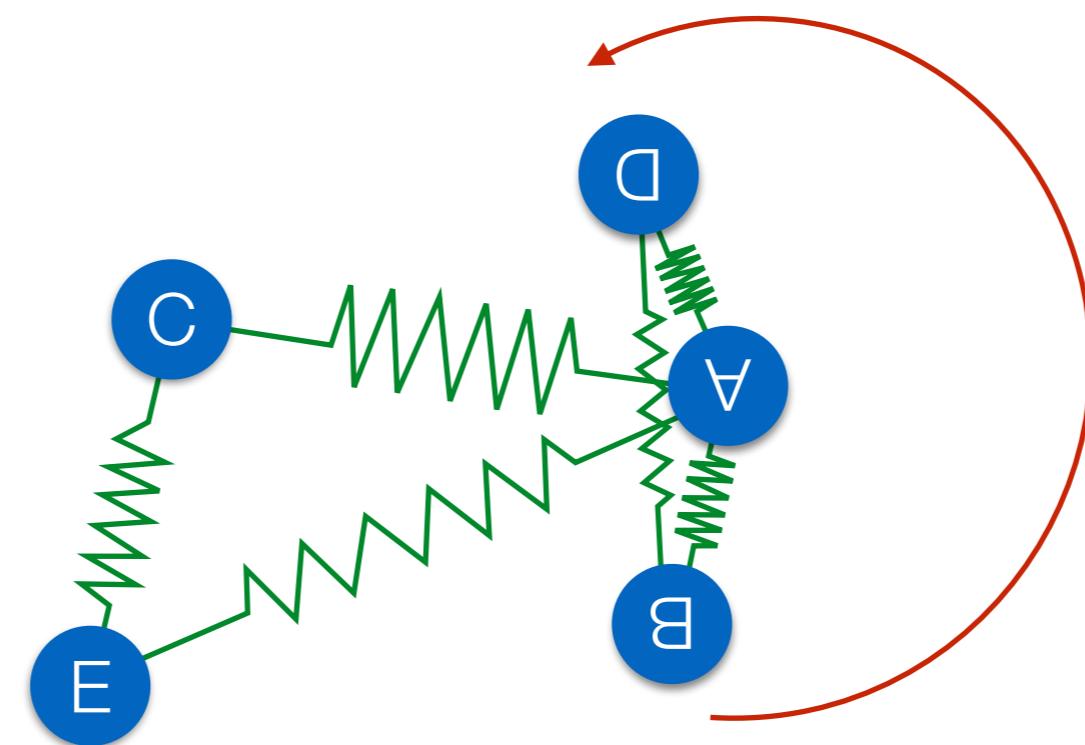


Problemas?



# Método direcionado por forças

Forças do tipo massa-mola

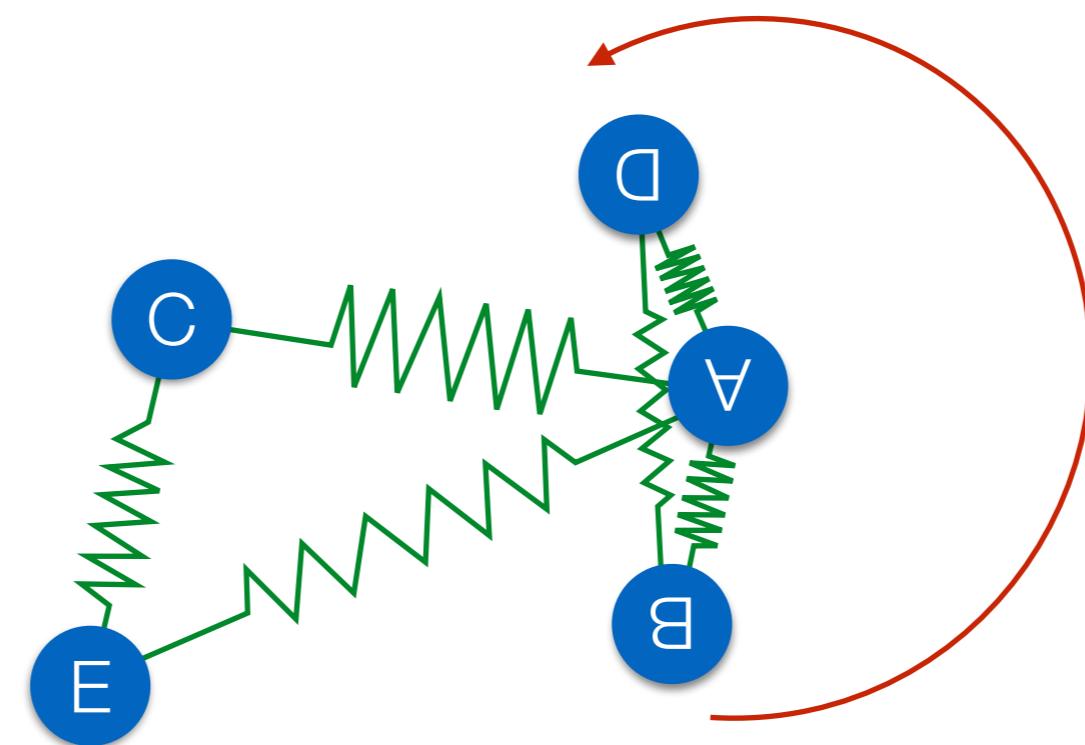


Alternativas?



# Método direcionado por forças

Forças do tipo massa-mola

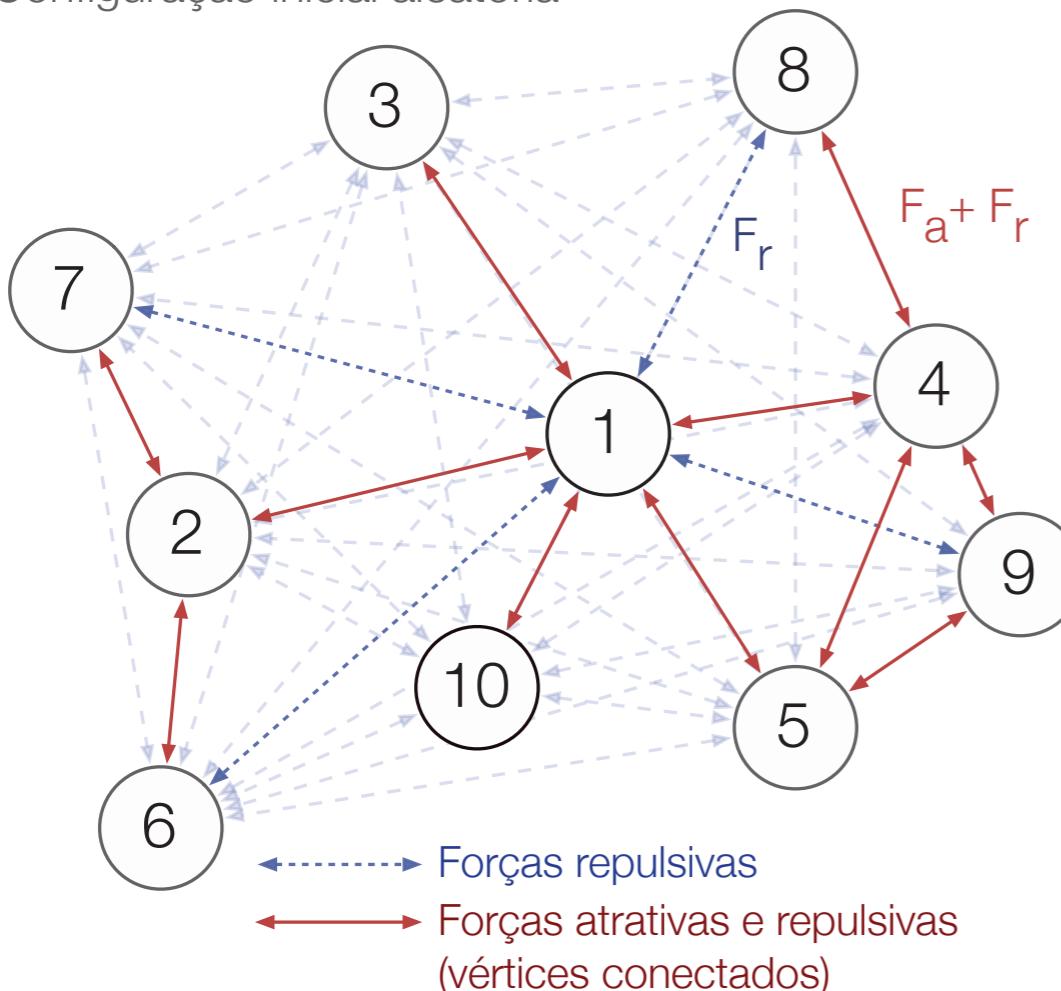


Alternativas?



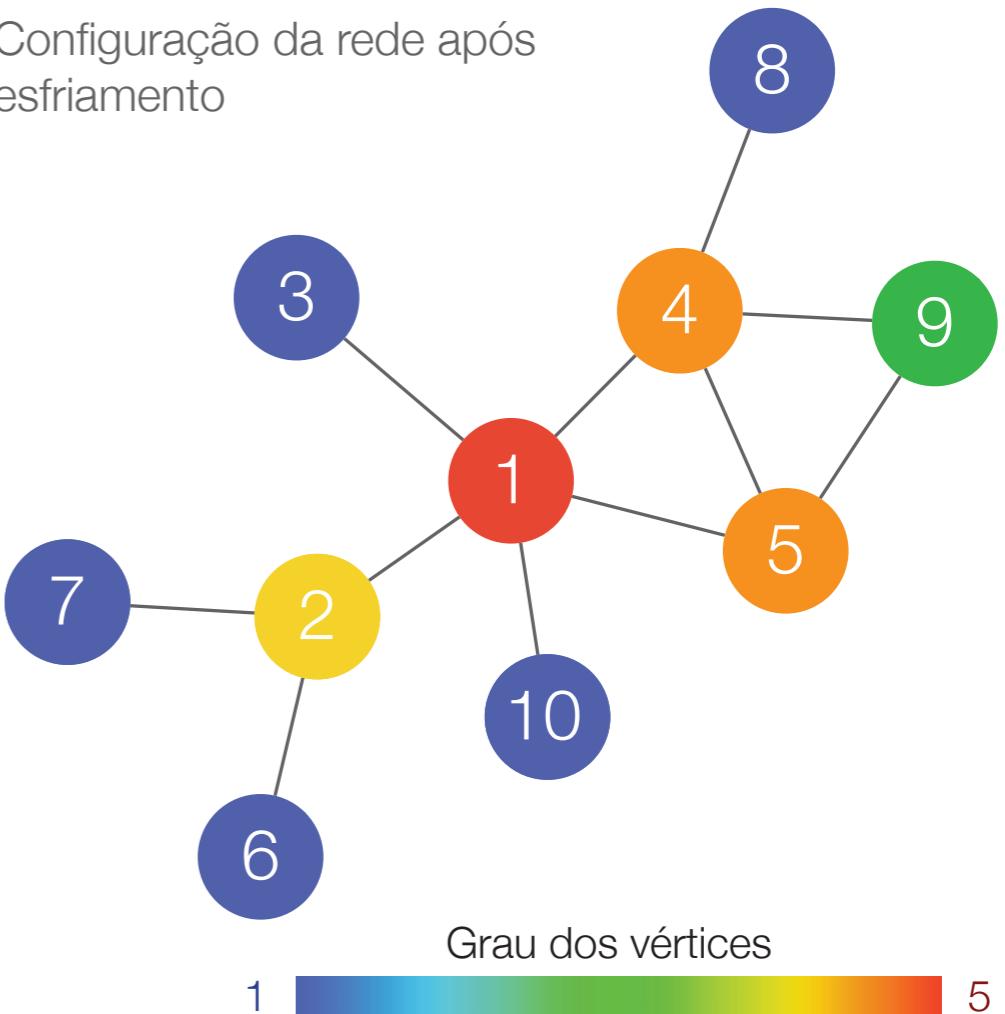
# Método direcionado por forças

Configuração inicial aleatória



Simulação de dinâmica molecular

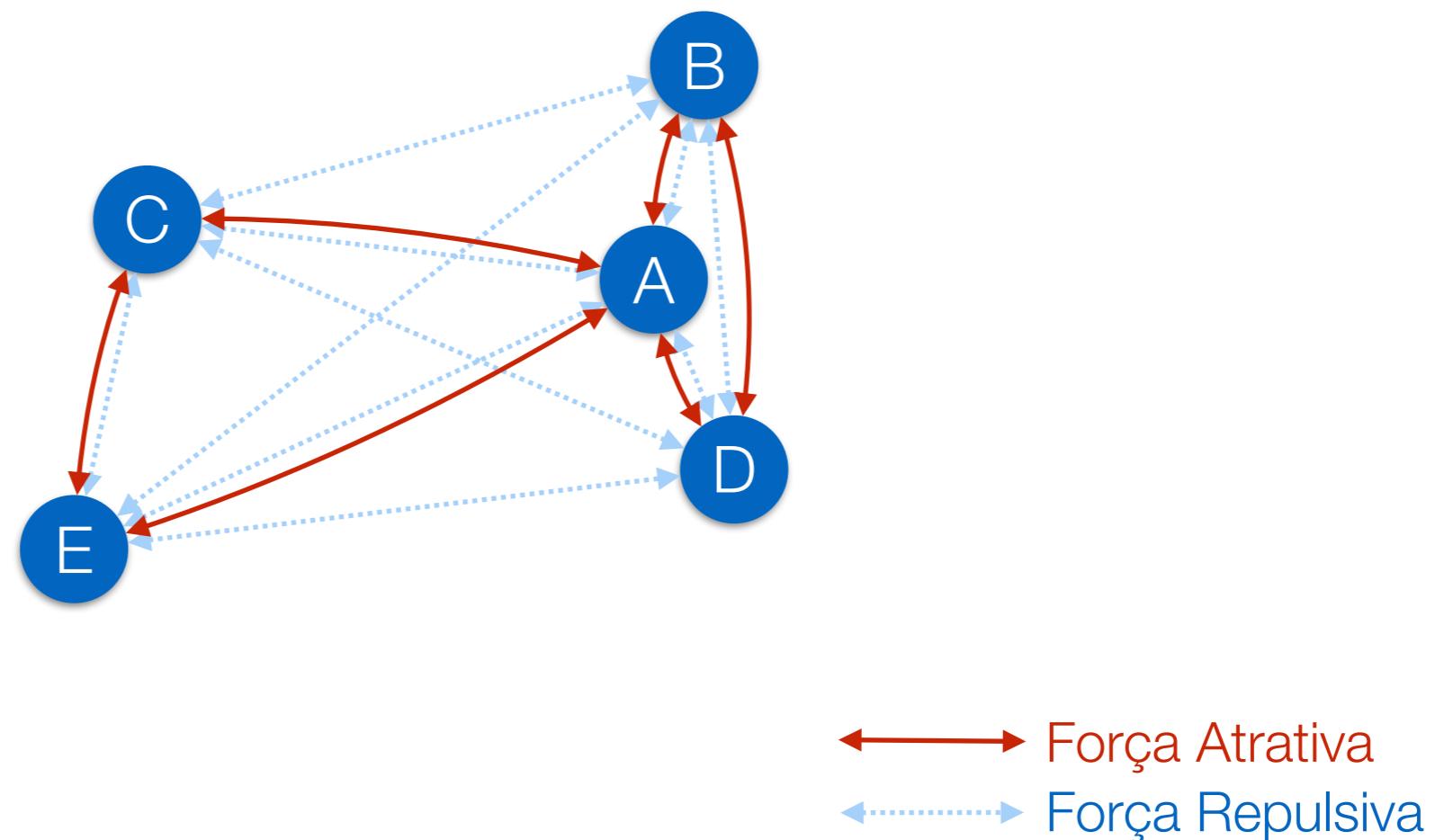
Configuração da rede após esfriamento



# Método direcionado por forças



Forças do tipo elétrica + massa-mola





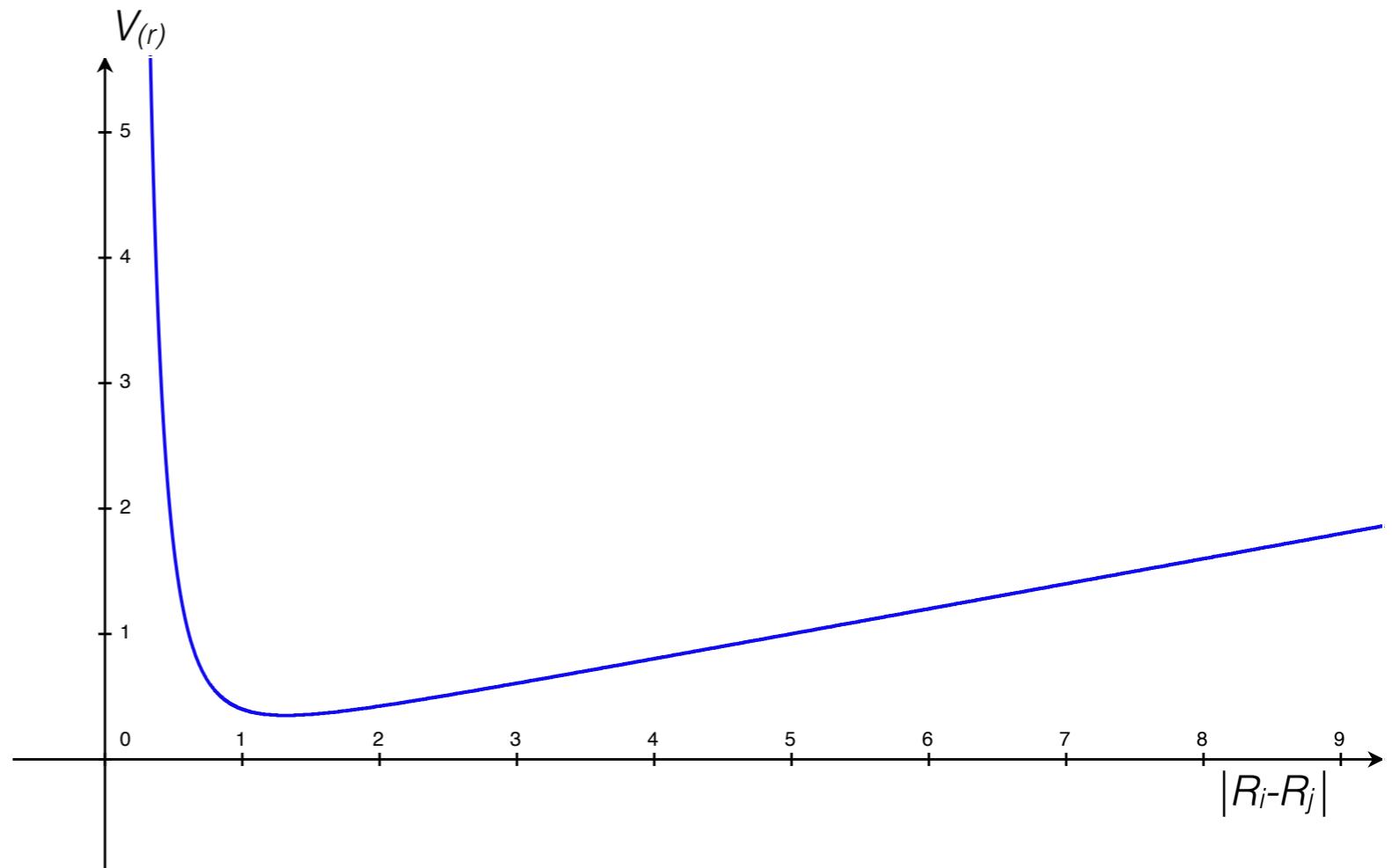
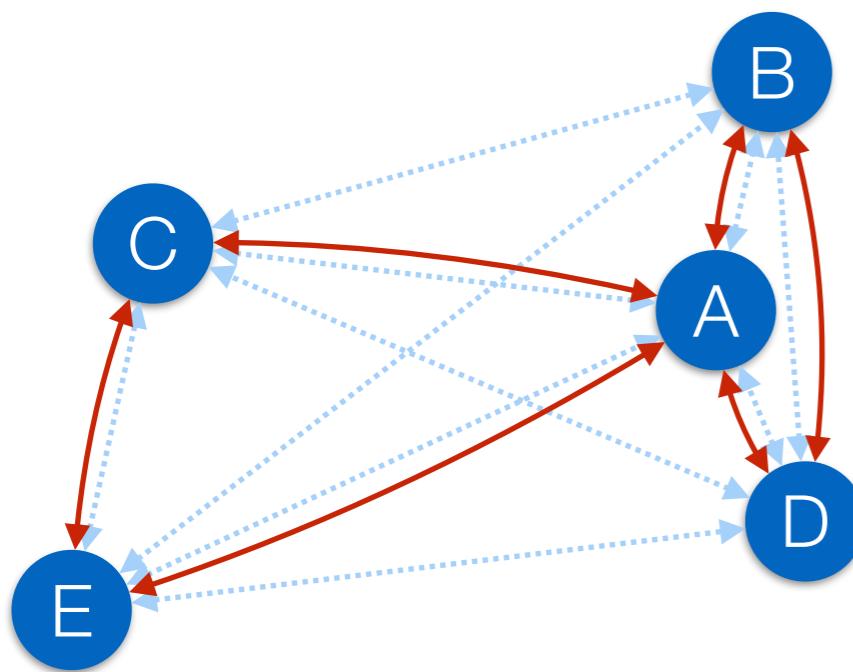
# Técnicas de simulação molecular

Força Atrativa

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

Força Repulsiva

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



Viscosidade

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



# Técnicas de simulação molecular

## Método numérico - Verlet

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

$$\frac{\Delta^2 \vec{R}(t)}{\Delta t^2} = \frac{\frac{\vec{R}(t+\Delta t) - \vec{R}(t)}{\Delta t} - \frac{\vec{R}(t) - \vec{R}(t-\Delta t)}{\Delta t}}{\Delta t} = \frac{\vec{R}(t + \Delta t) - 2\vec{R}(t) + \vec{R}(t - \Delta t)}{\Delta t^2} = \vec{F}_{\text{total}}(\vec{R}(t))$$

$$\vec{R}(t + \Delta t) = 2\vec{R}(t) - \vec{R}(t - \Delta t) + \vec{F}_{\text{total}}(\vec{R}(t))\Delta t^2$$



# Técnicas de simulação molecular

## Erro - método de verlet

$$\vec{R}(t + \Delta t) = \vec{R}(t) + \vec{v}(t)\Delta t + \frac{\vec{a}(t)\Delta t^2}{2} + \frac{\vec{b}(t)\Delta t^3}{6} + \mathcal{O}(\Delta t^4)$$

+

$$\vec{R}(t - \Delta t) = \vec{R}(t) - \vec{v}(t)\Delta t + \frac{\vec{a}(t)\Delta t^2}{2} - \frac{\vec{b}(t)\Delta t^3}{6} + \mathcal{O}(\Delta t^4)$$

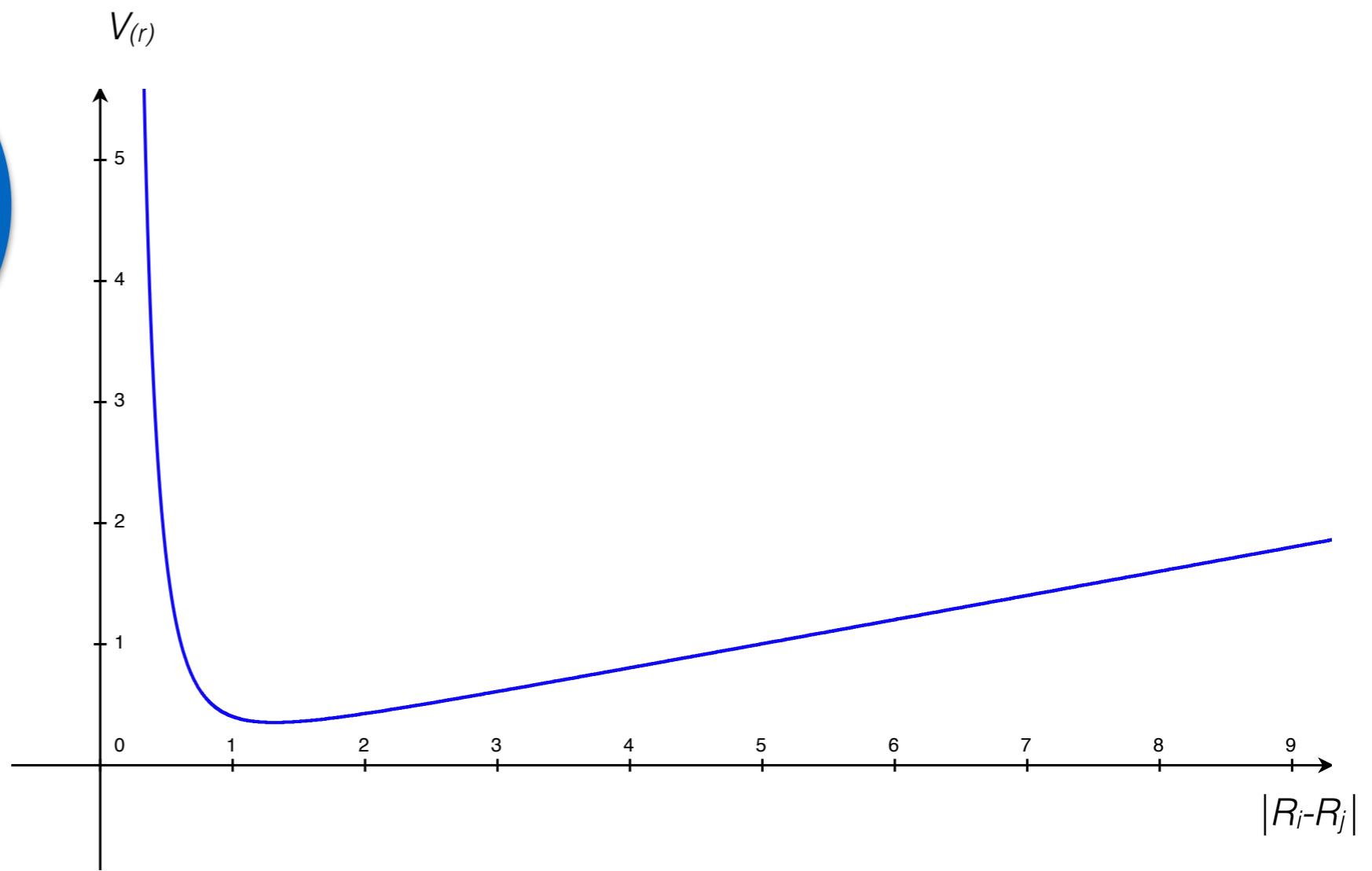
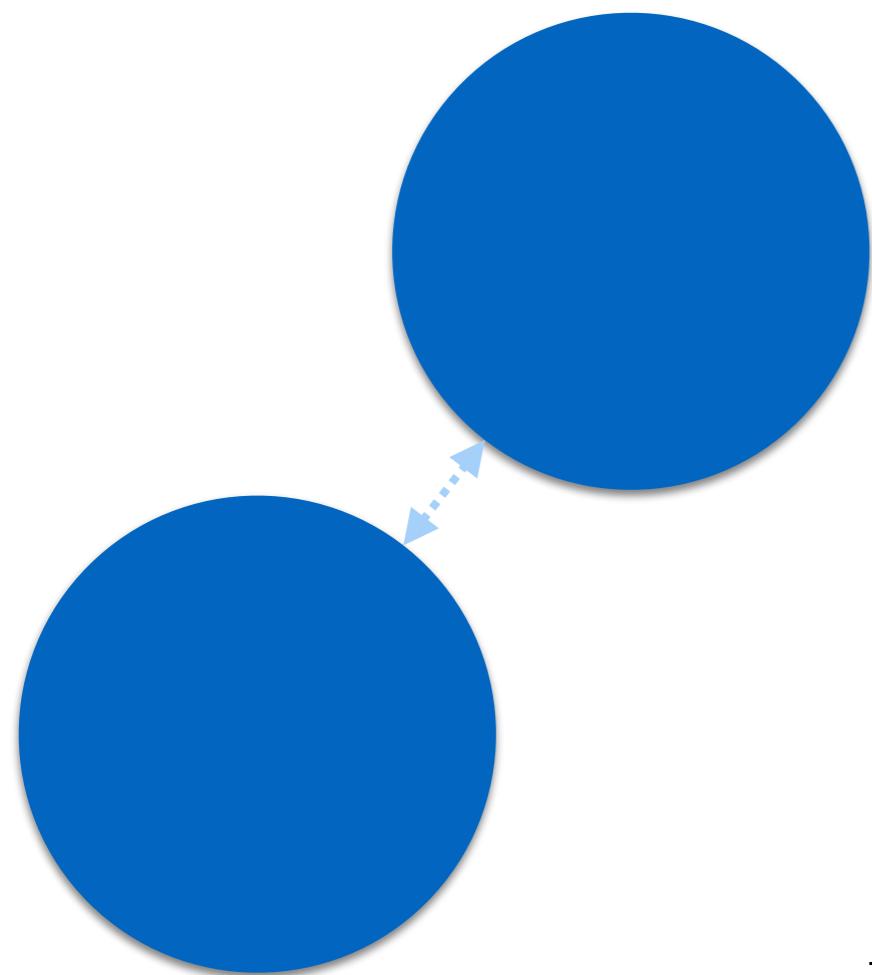
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$$= \vec{R}(t + \Delta t) = 2\vec{R}(t) - \vec{R}(t - \Delta t) + \vec{a}(t)\Delta t^2 + \mathcal{O}(\Delta t^4)$$



# Estabilidade da dinâmica

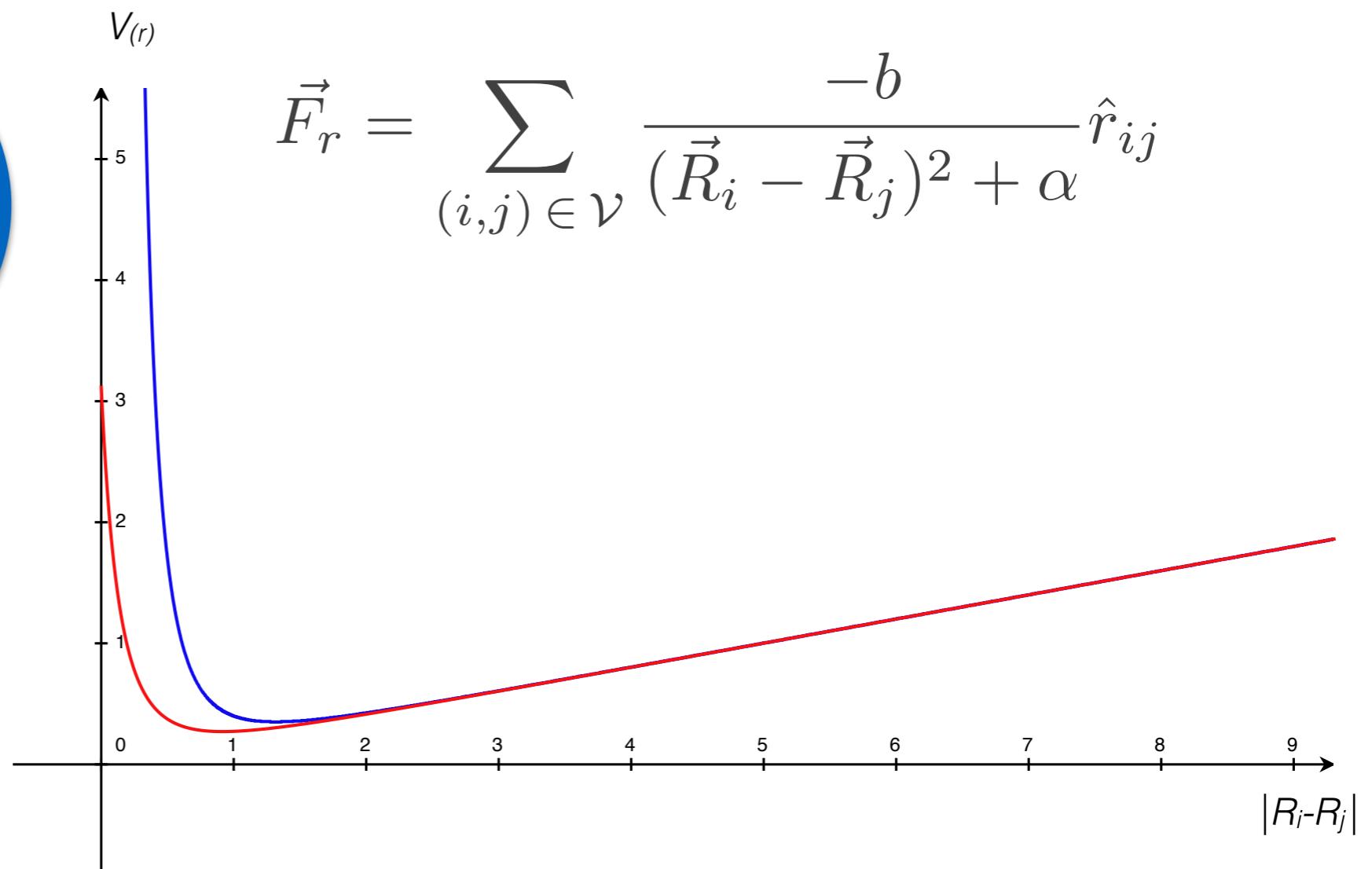
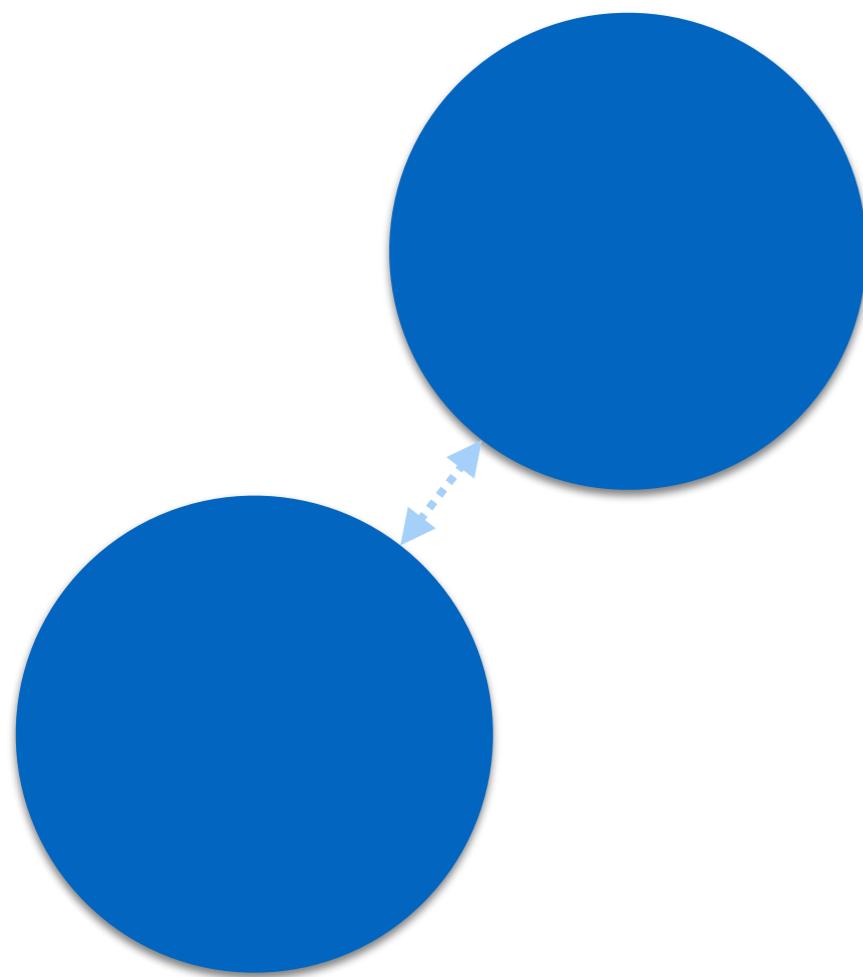
Correção na lei de força





# Estabilidade da dinâmica

Correção na lei de força





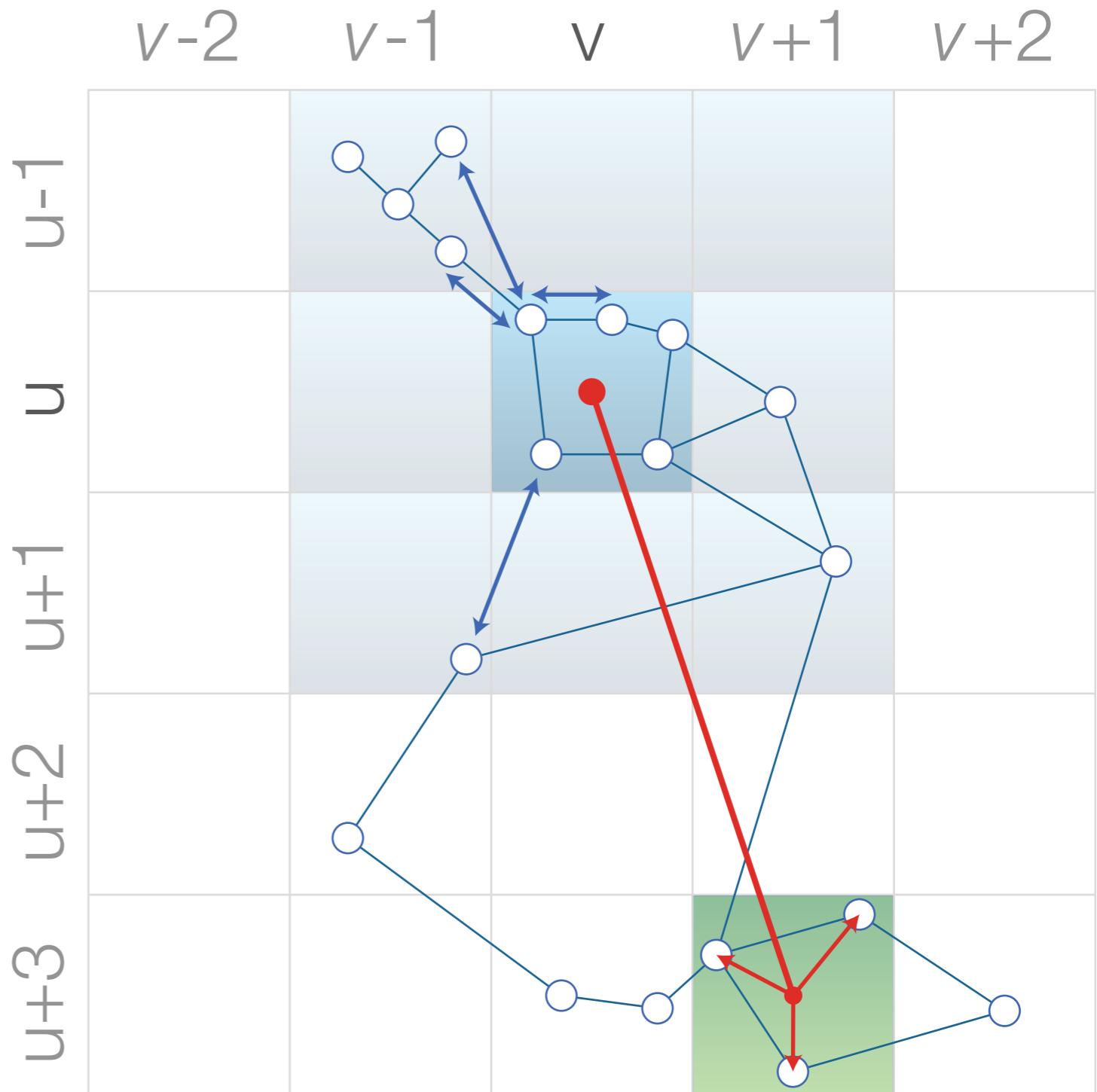
# Optimizações por expansão multipolar

- O problema é  **$O(N^2)$**
- A técnica de **expansão multipolar** aproxima as forças de **objetos distantes**:

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

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

- Onde  $N_{u,v}$ ,  $\vec{p}_{u,v}$  e  $Q_{u,v}$  são os **momentos** de **monopolio**, **dipolo** e **quadrupolo** calculados em cada **caixa**  $(u,v)$ .
- A expansão **até quadrupolo** apresentou **bons resultados** para a maioria das redes.

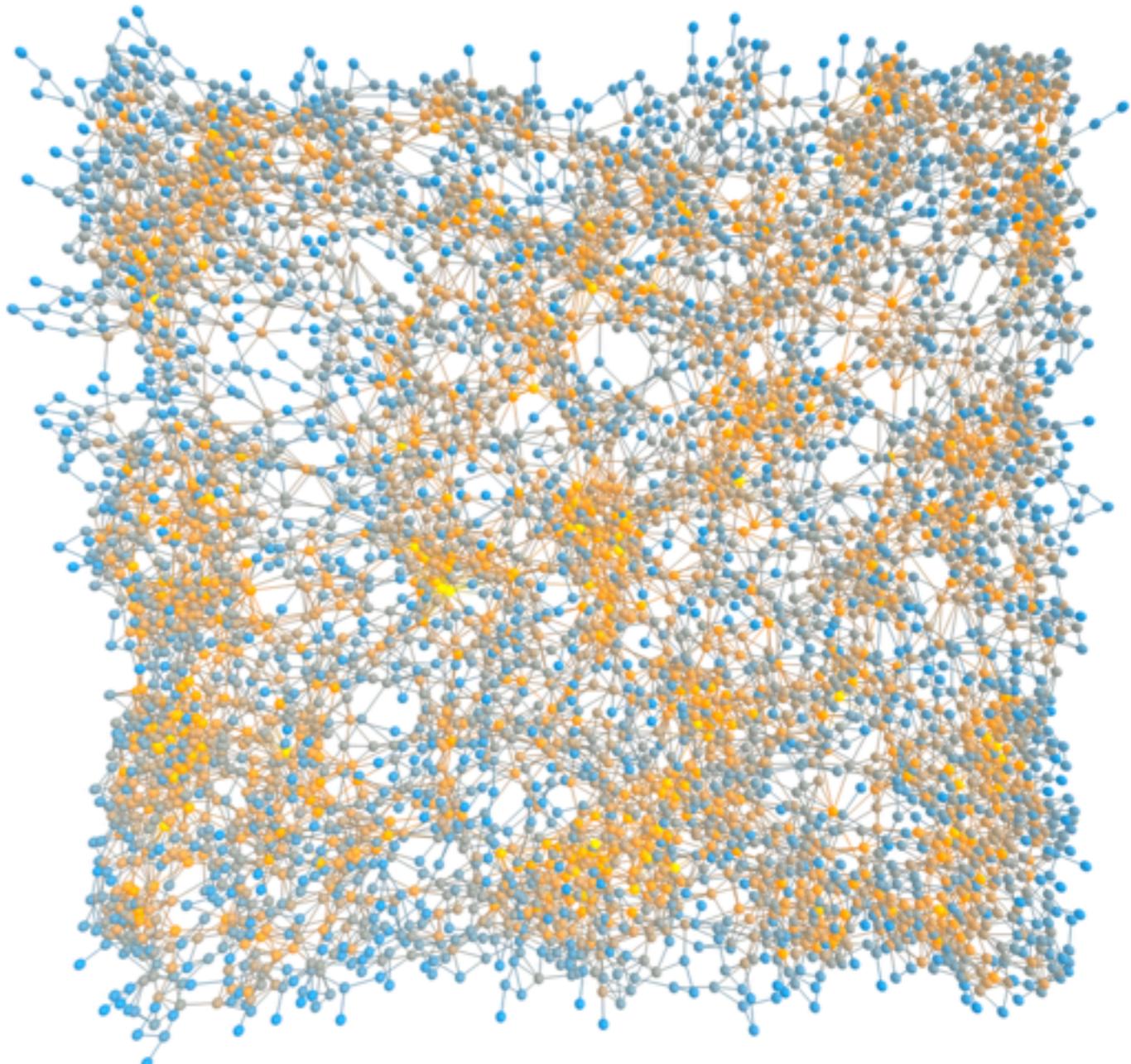
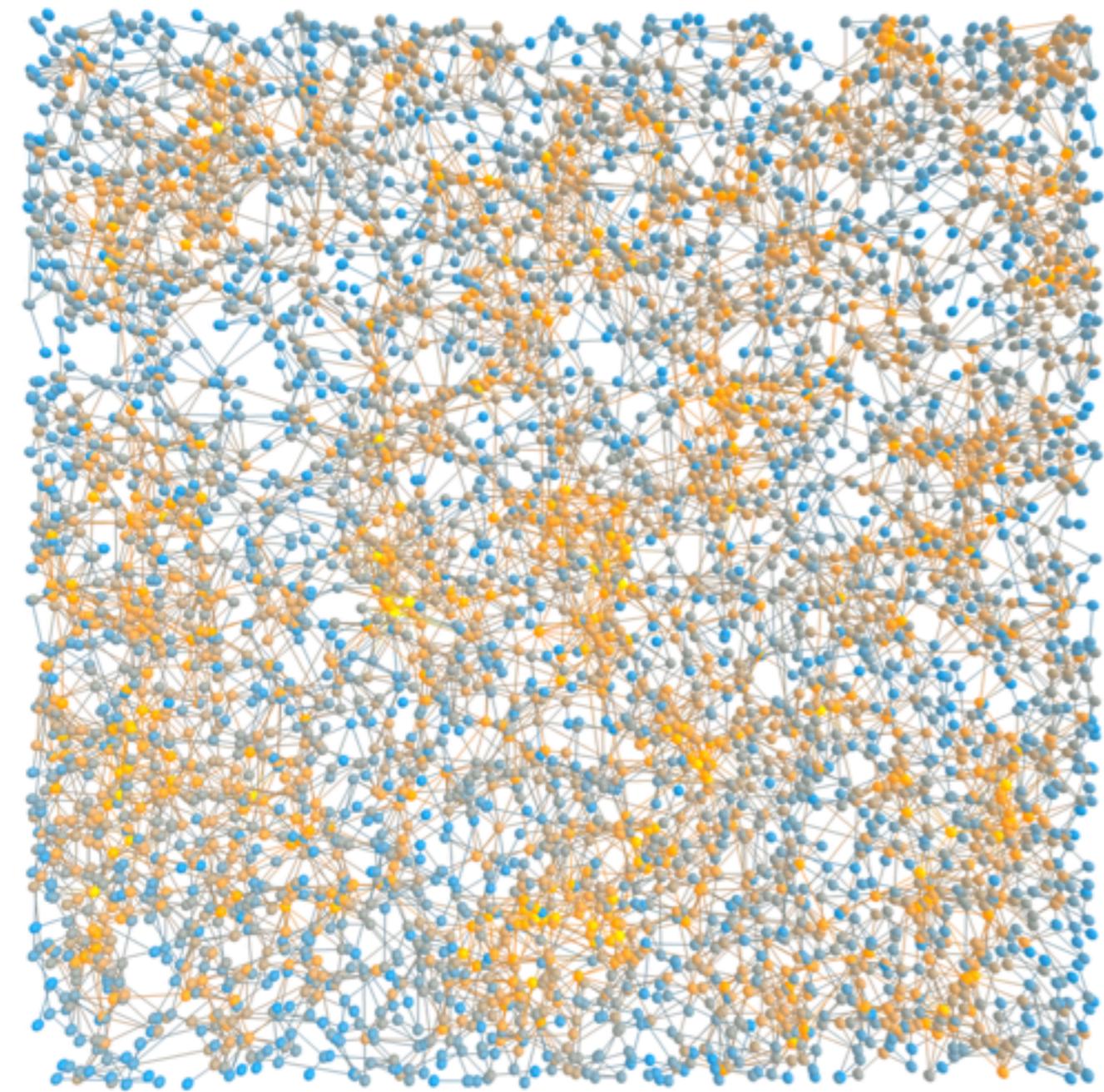




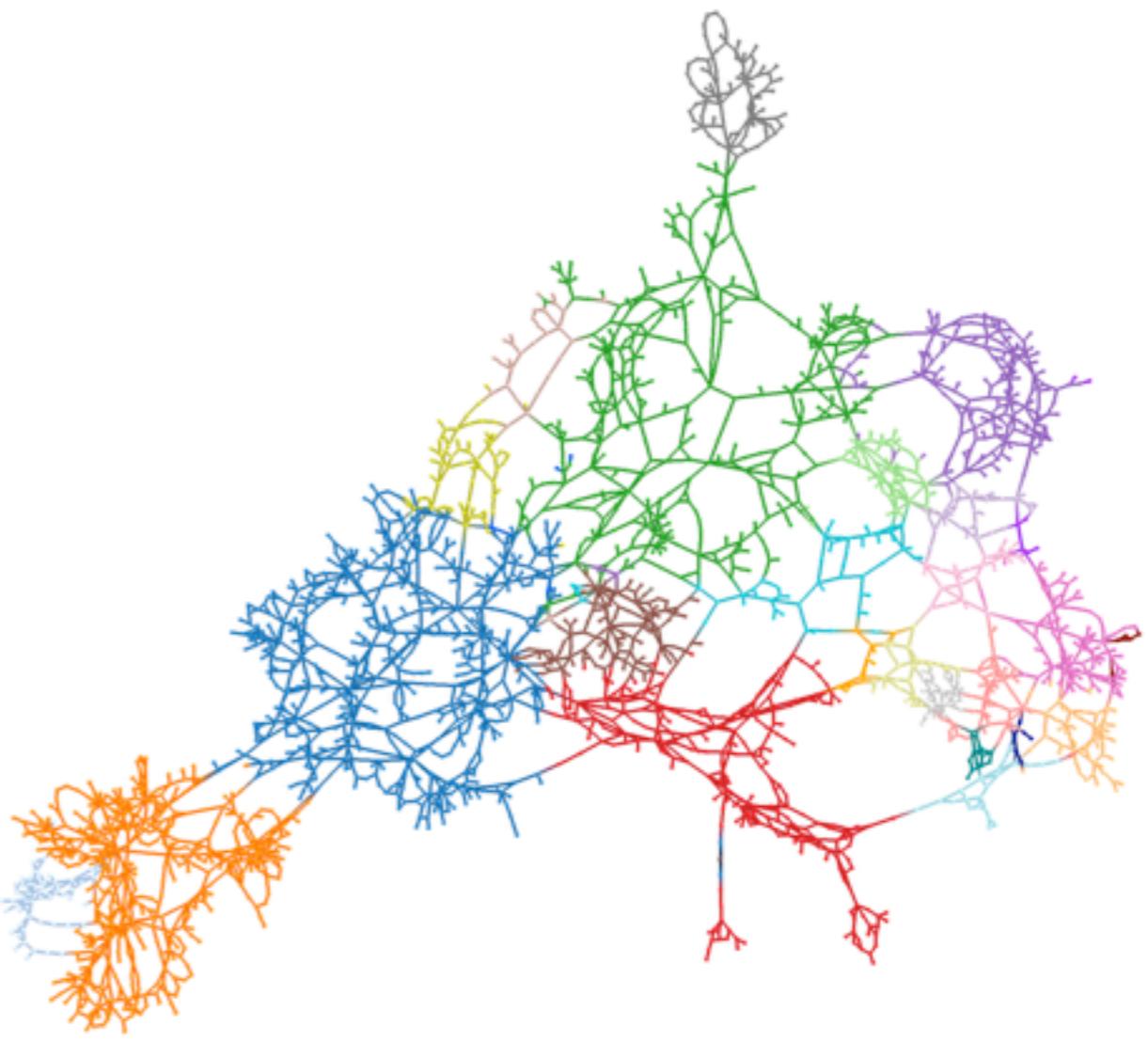


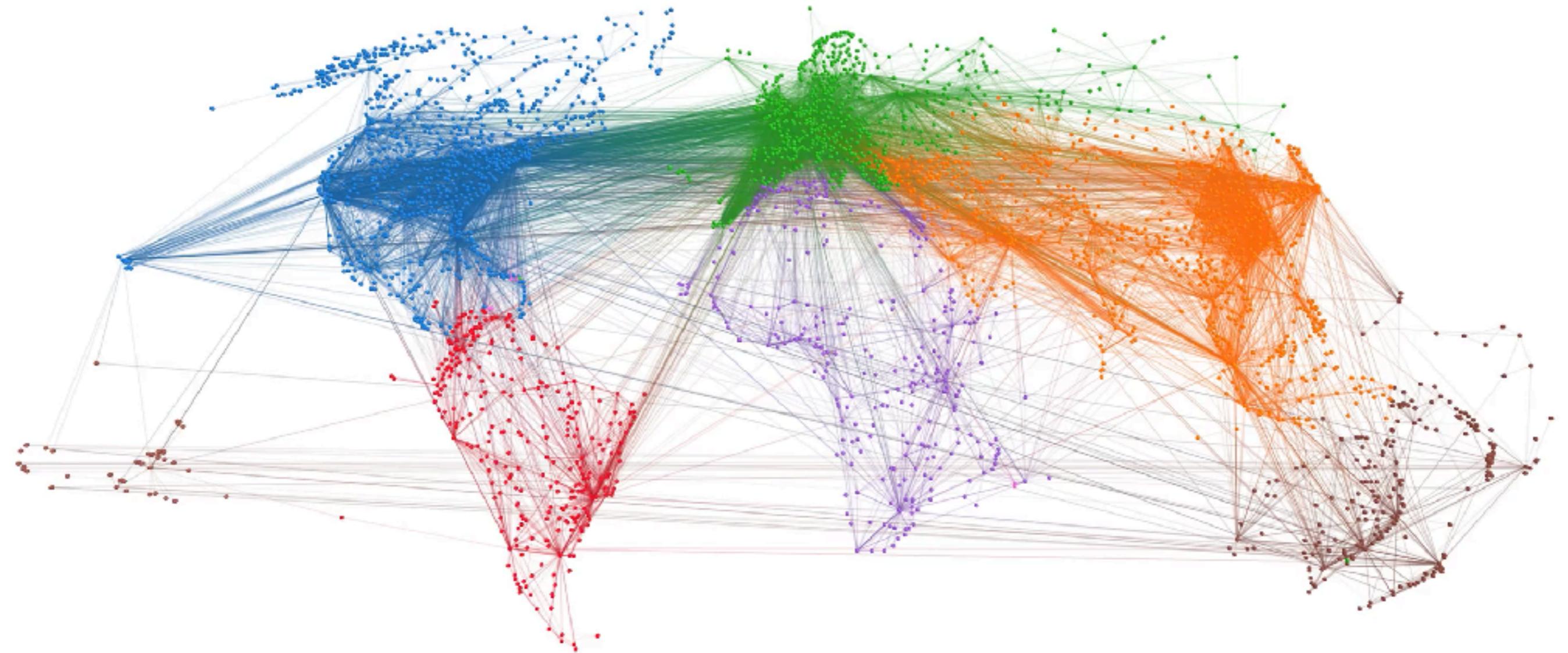




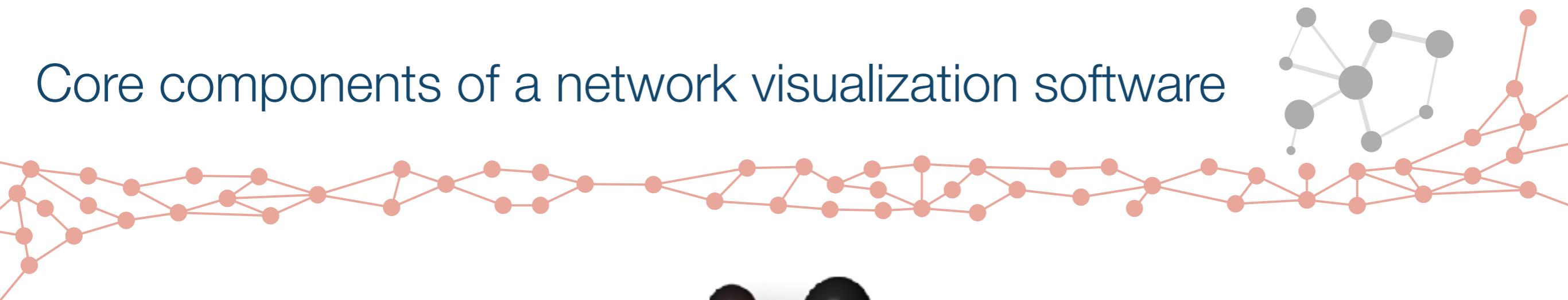




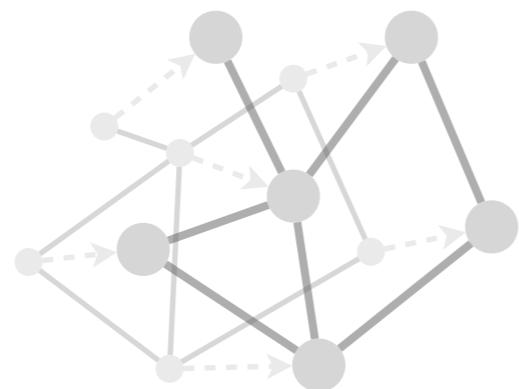




# Core components of a network visualization software



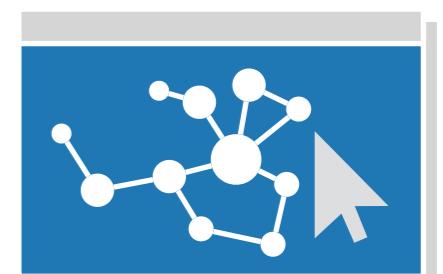
Graph Library



Layout

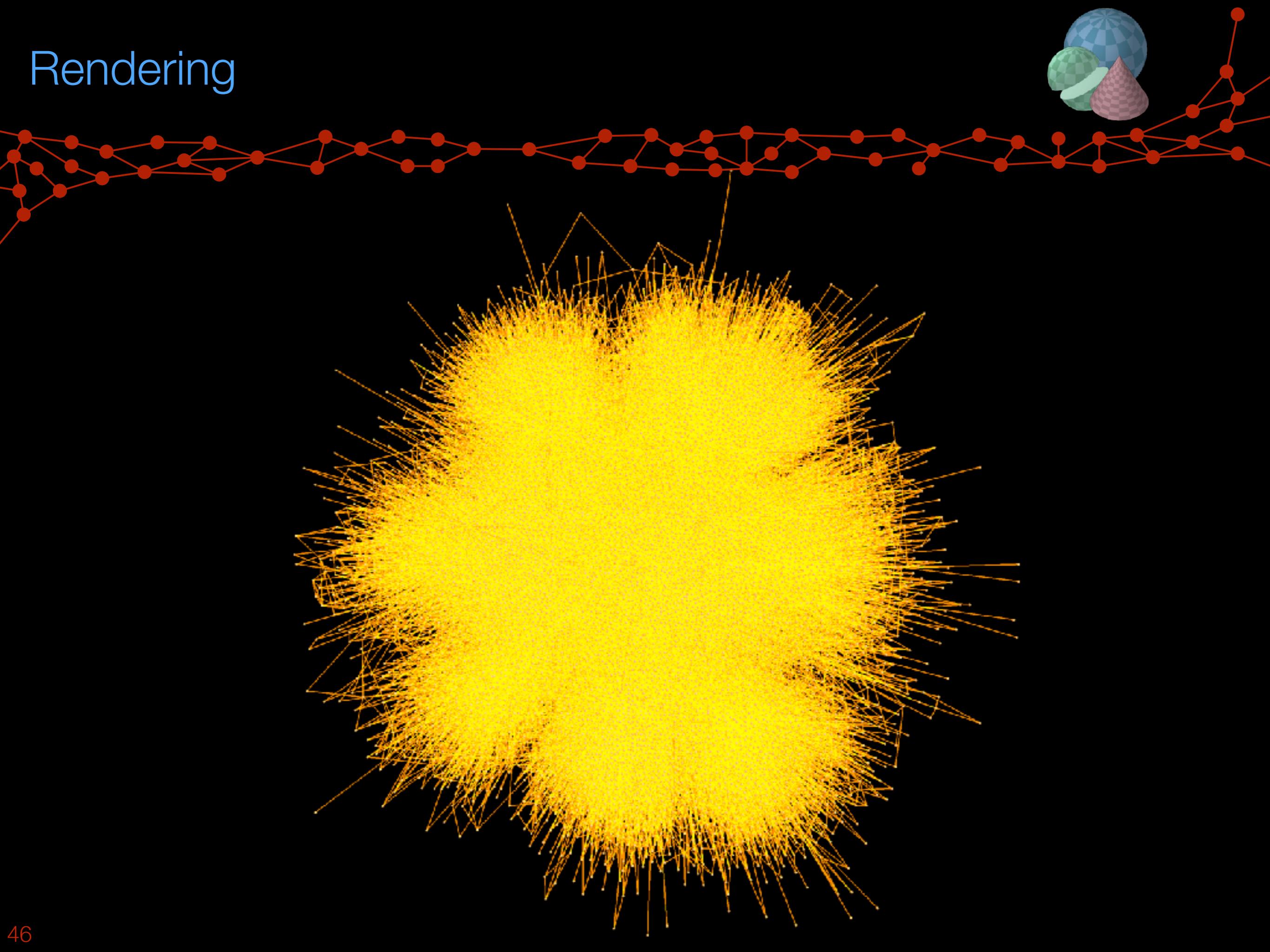


Rendering

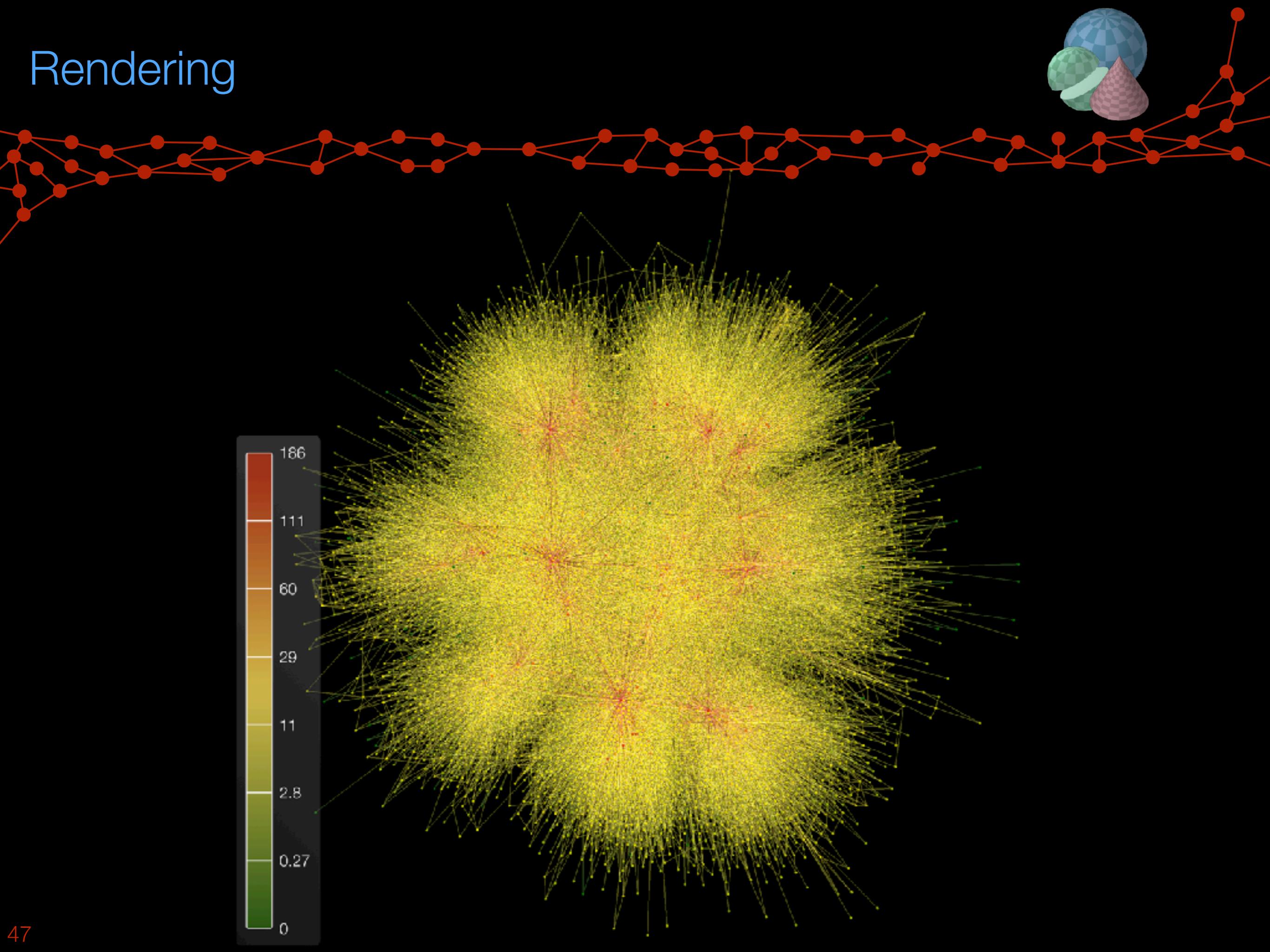


Interface

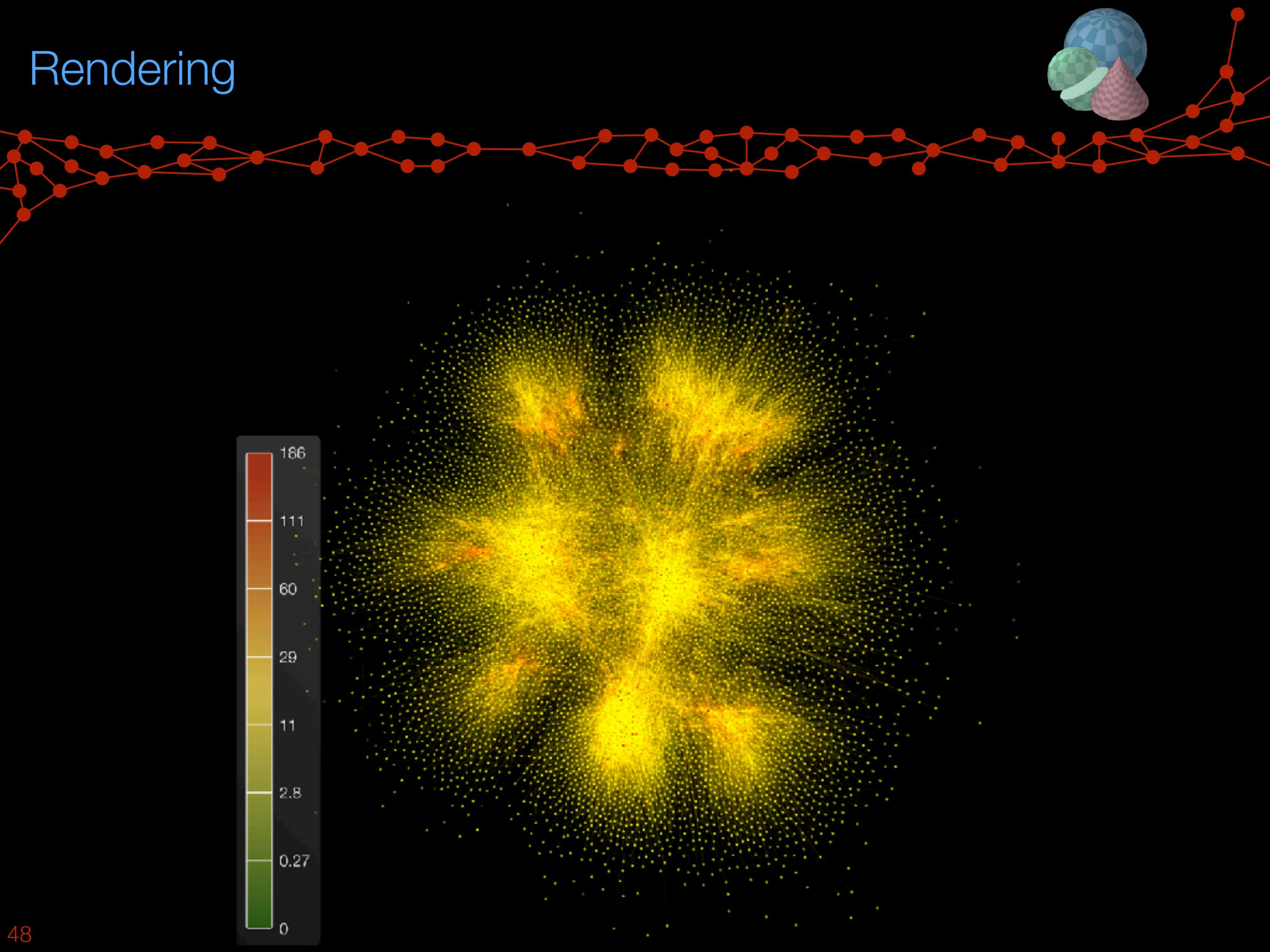
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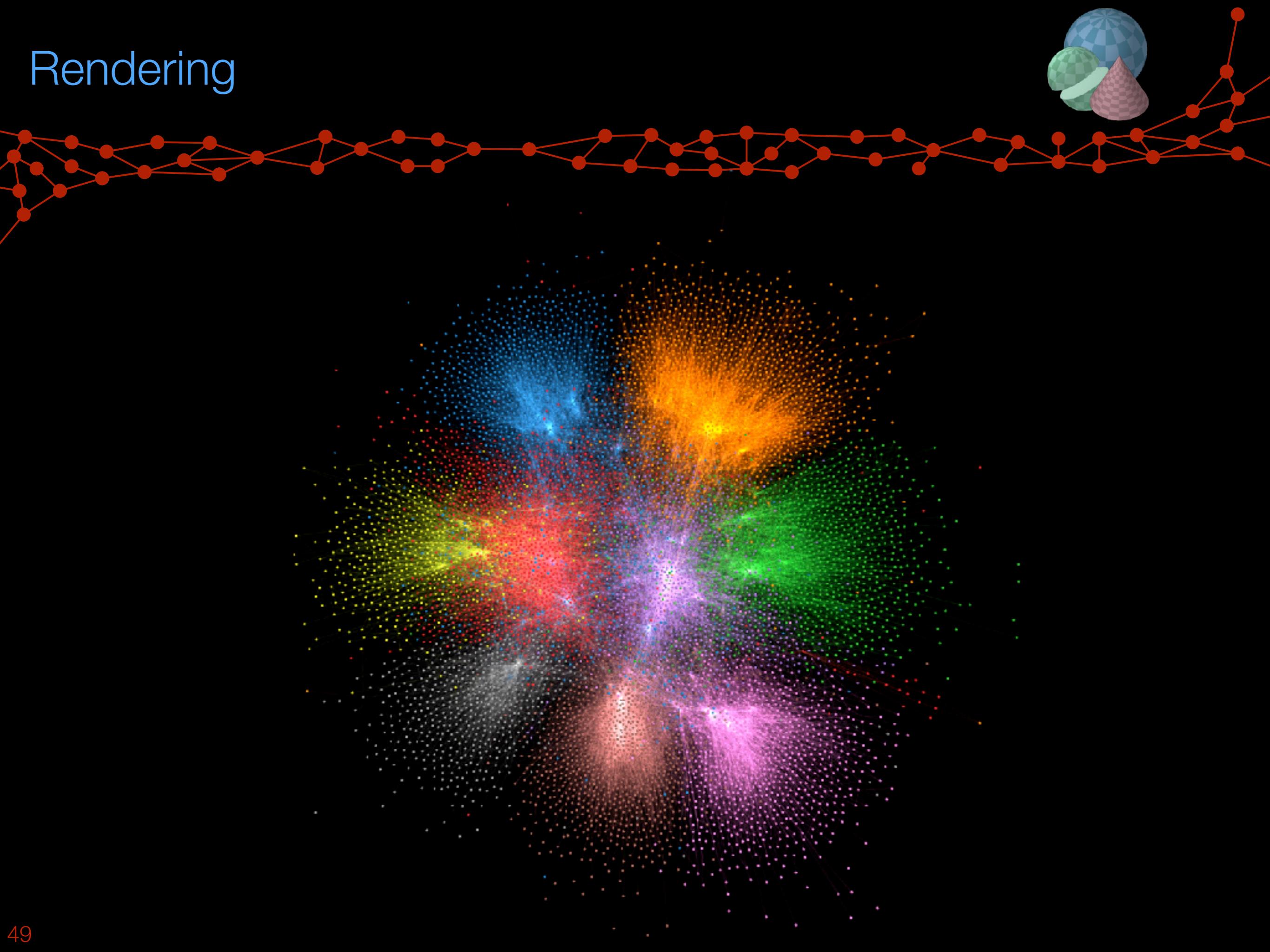
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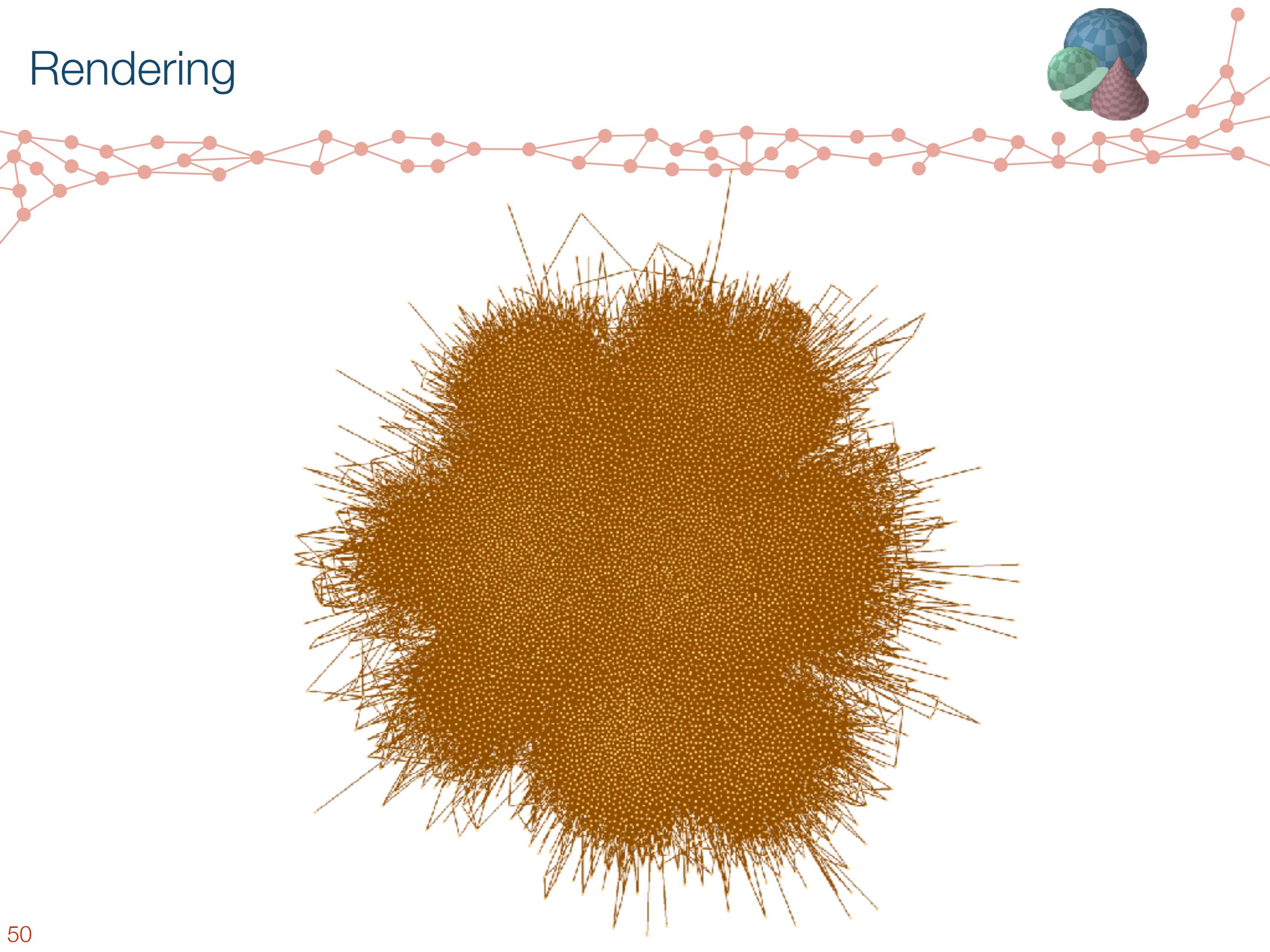
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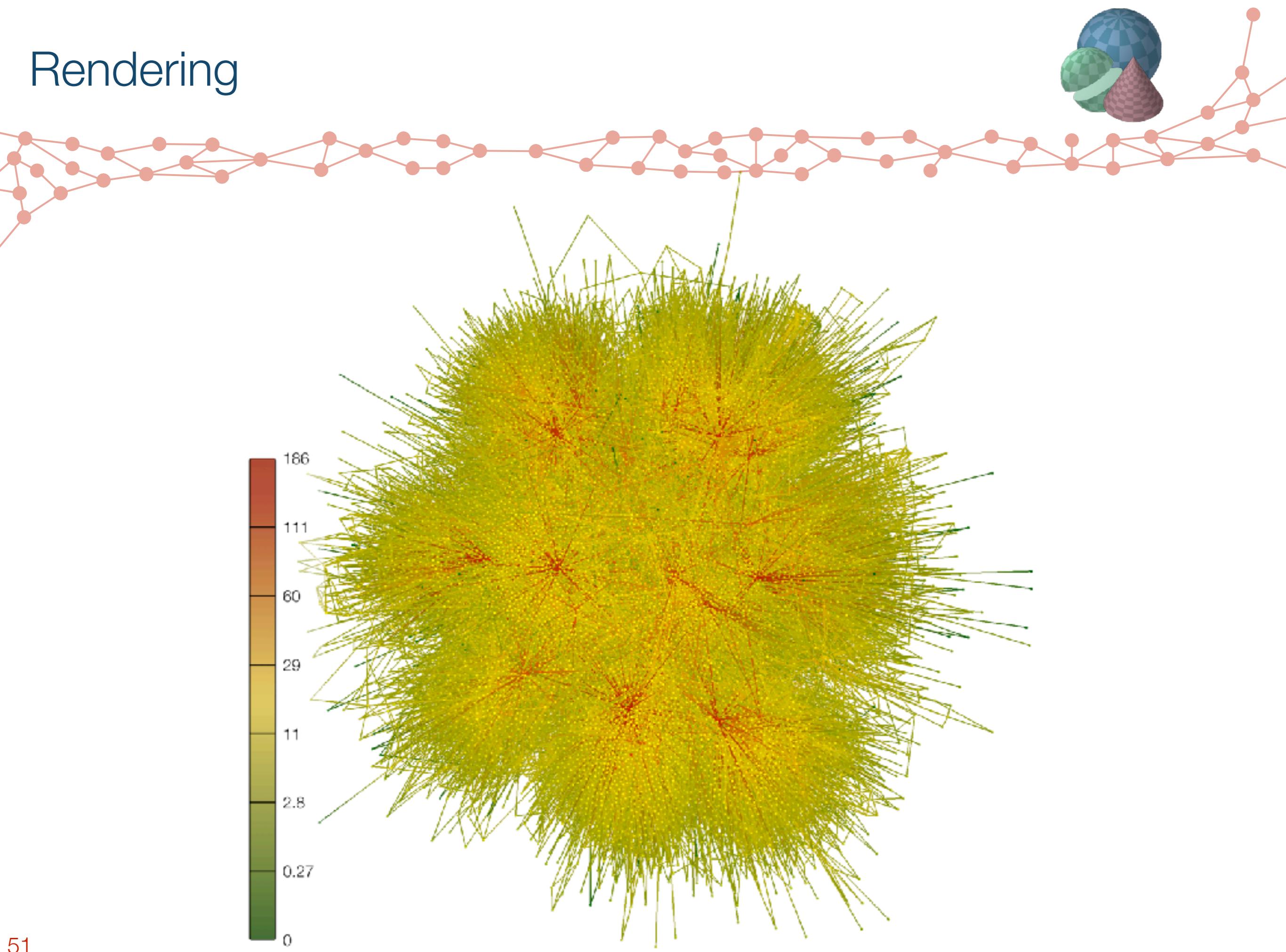
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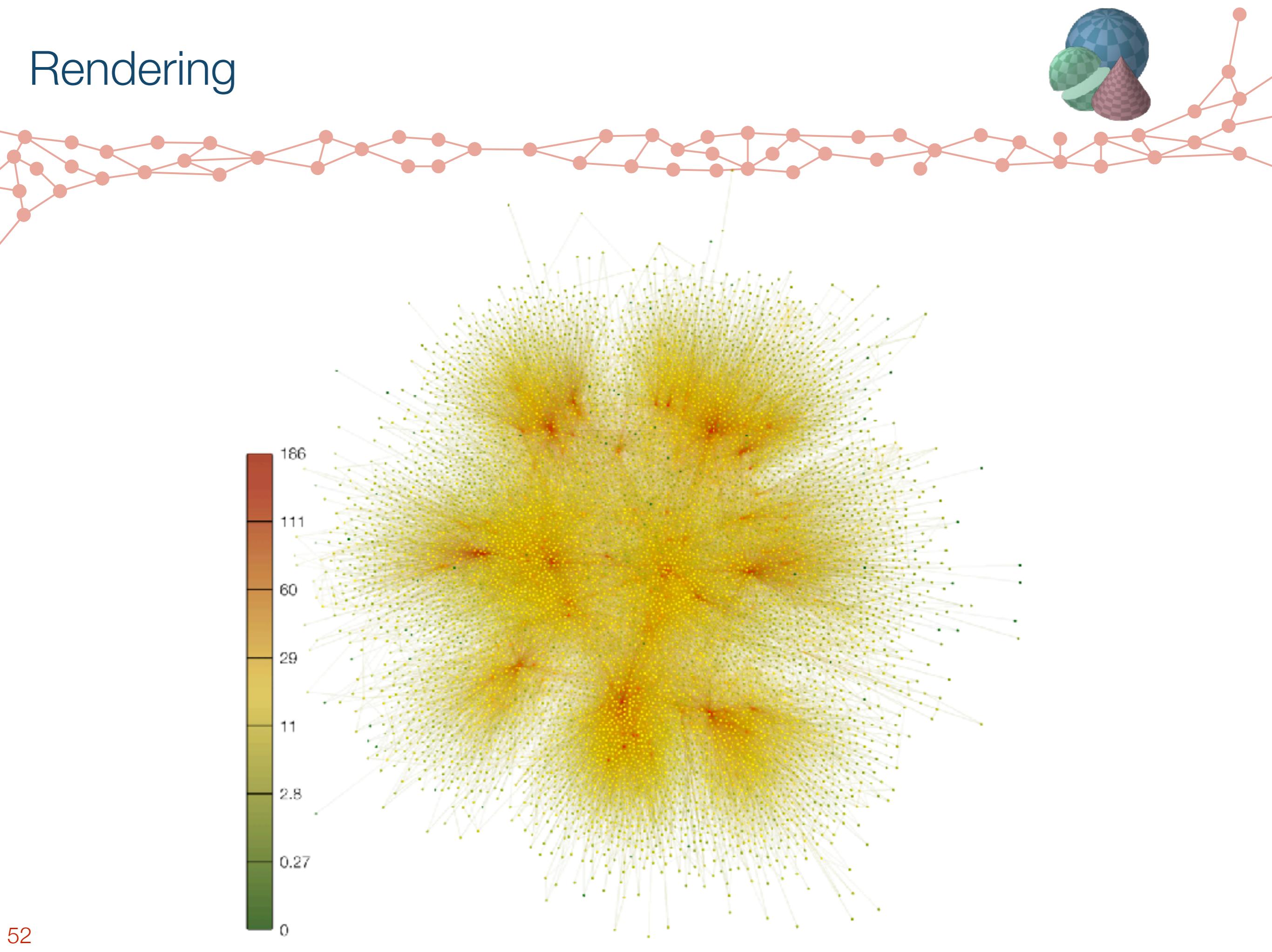
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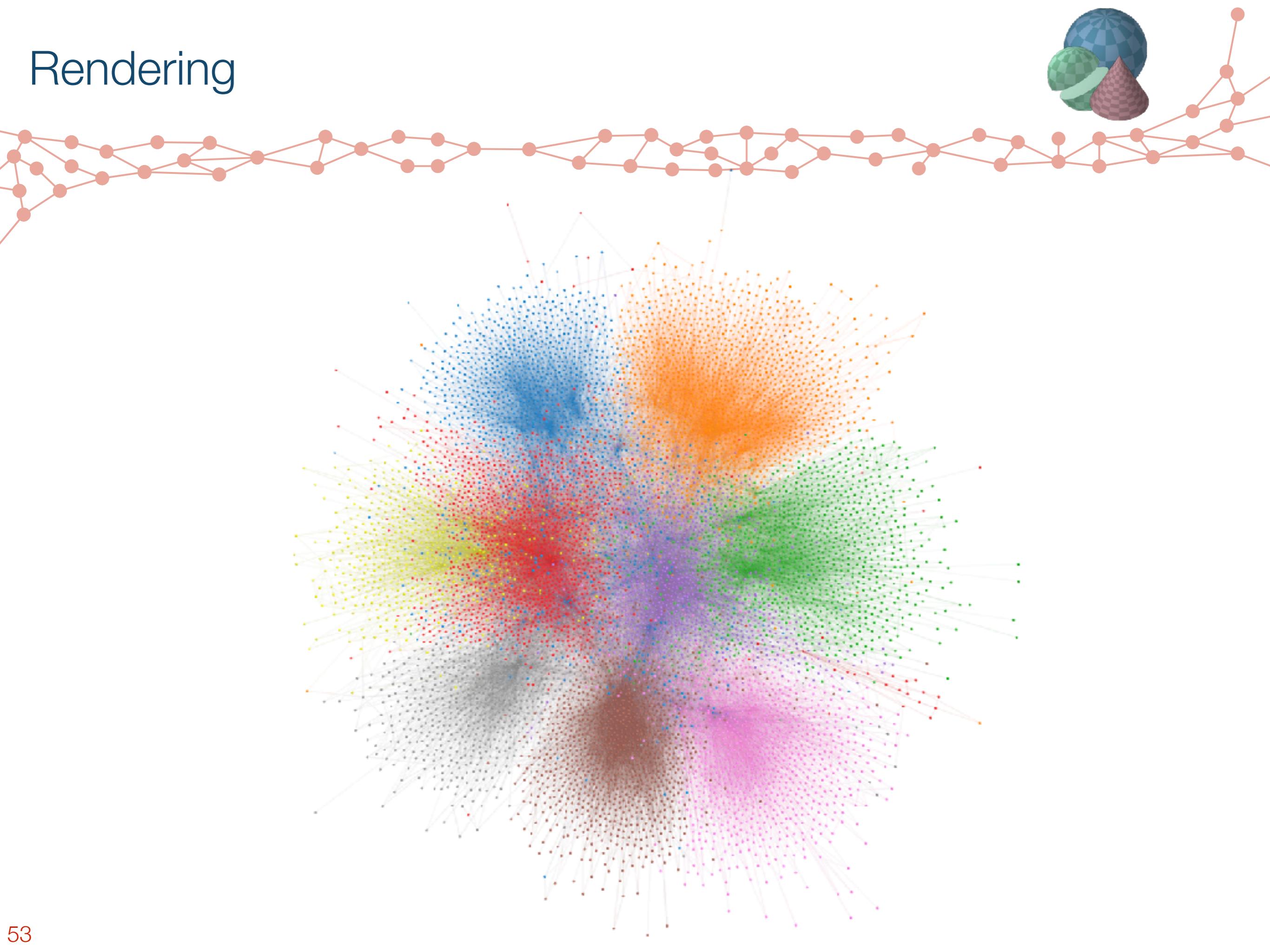
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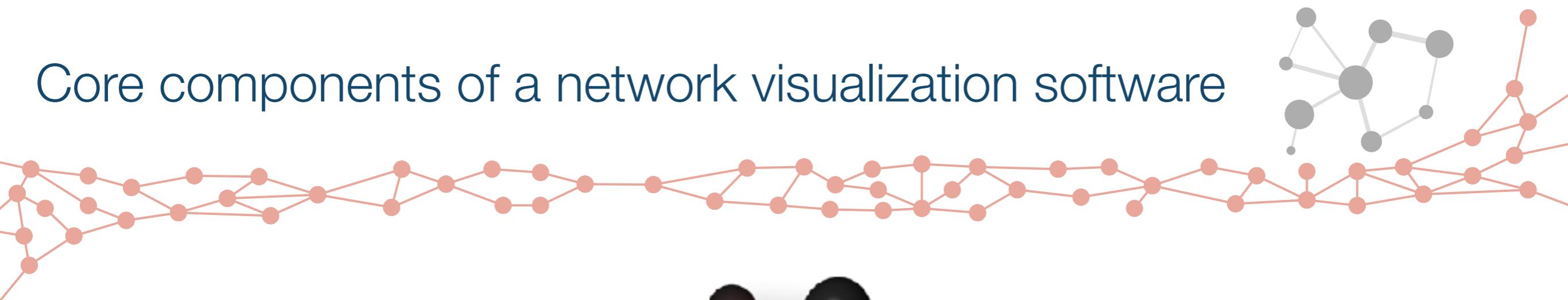
# Rendering



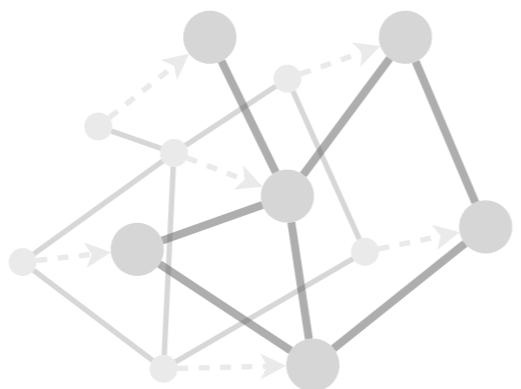
# Rendering



# Core components of a network visualization software



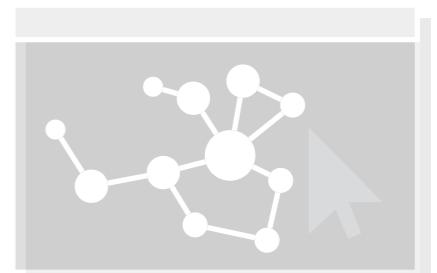
Graph Library



Layout

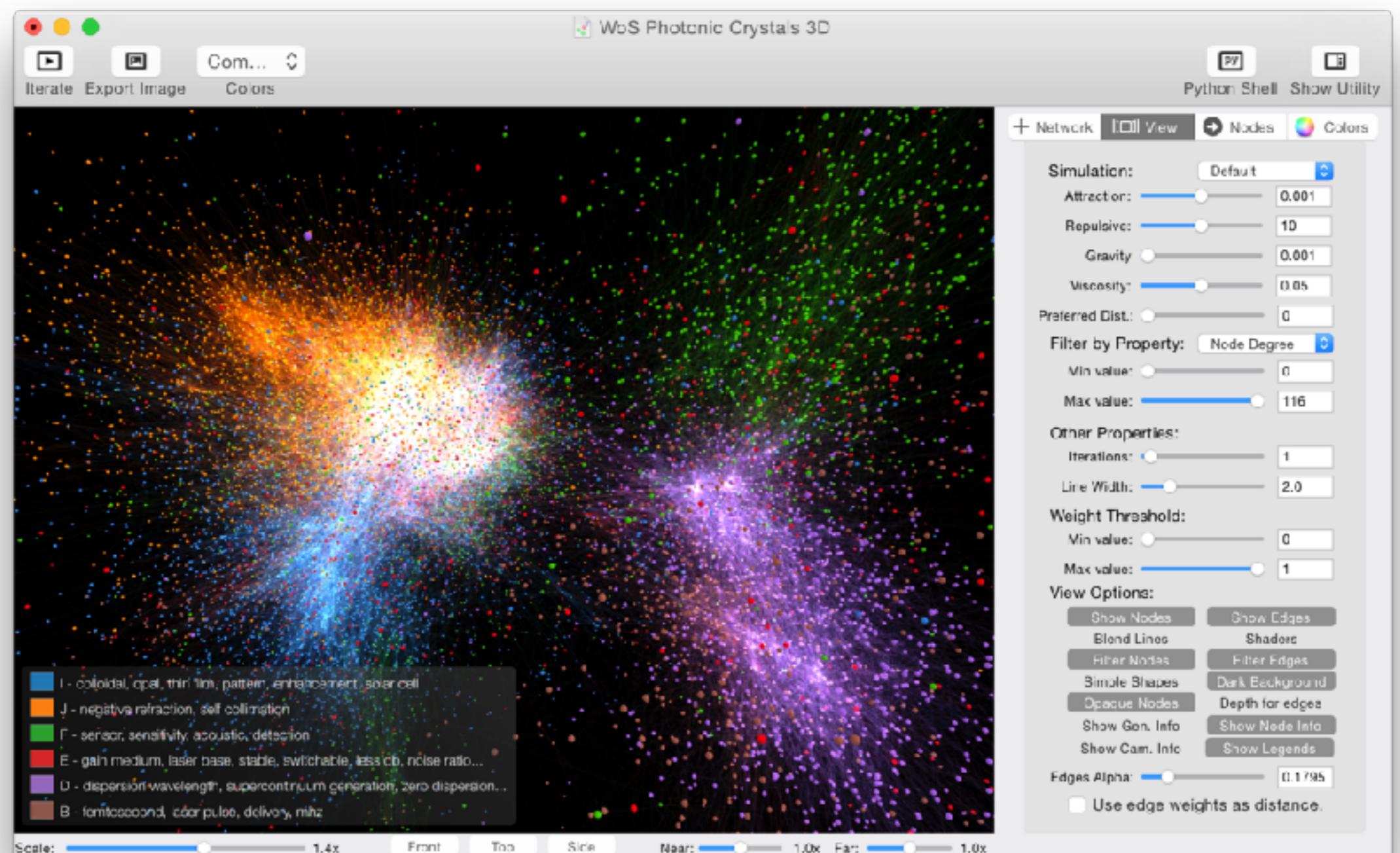
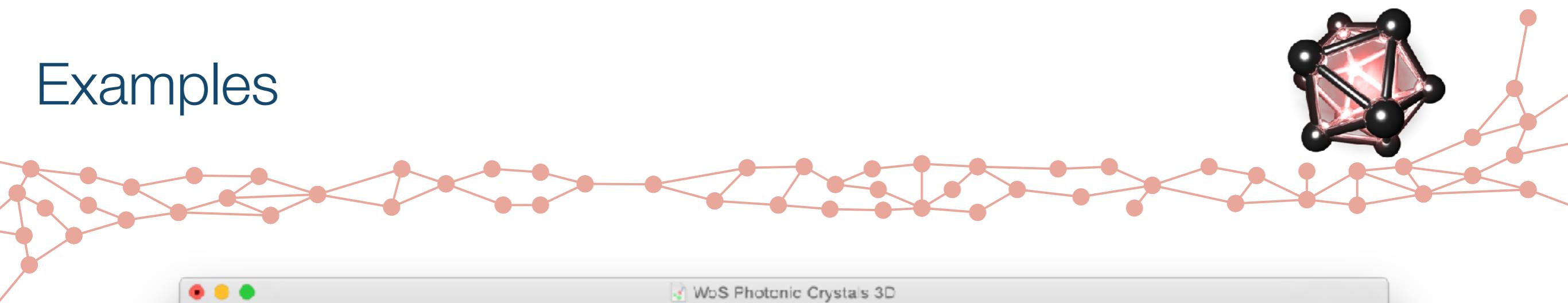


Rendering



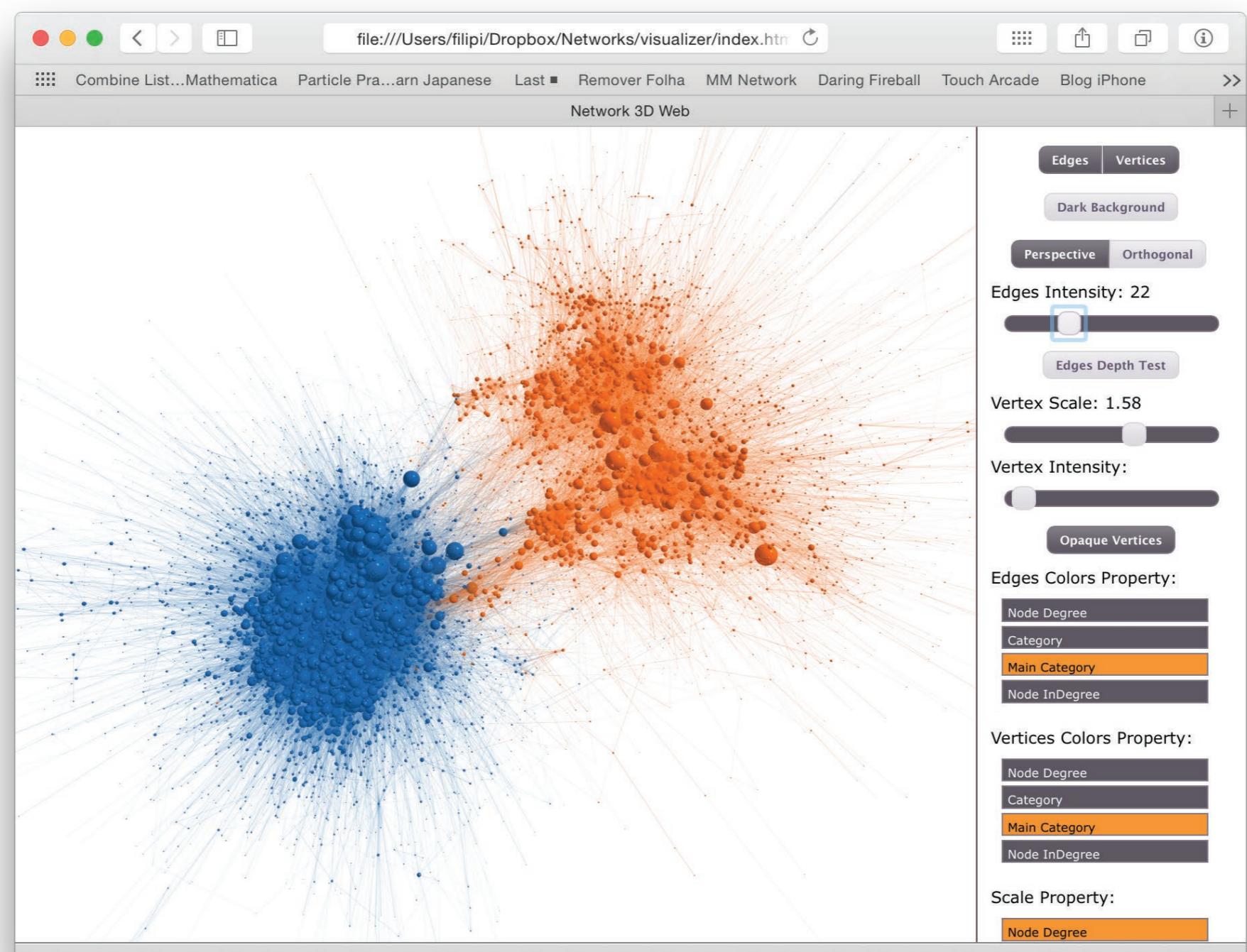
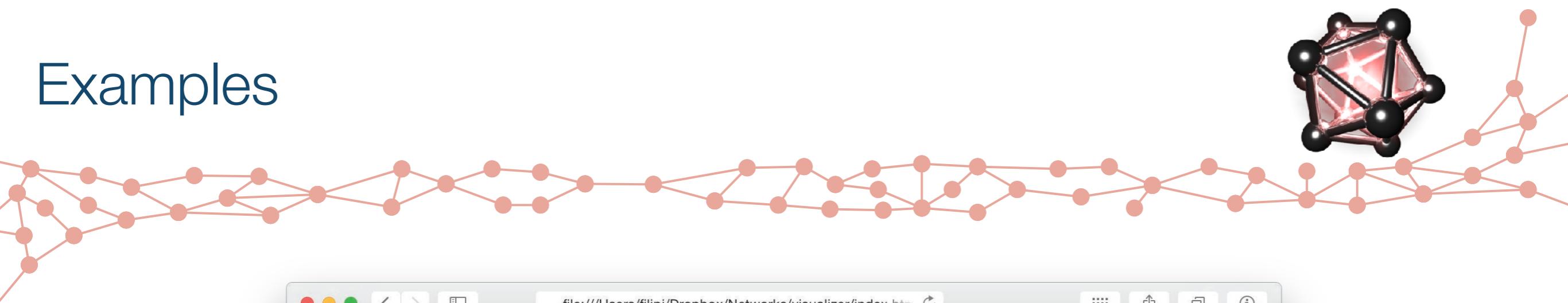
Interface

# Examples



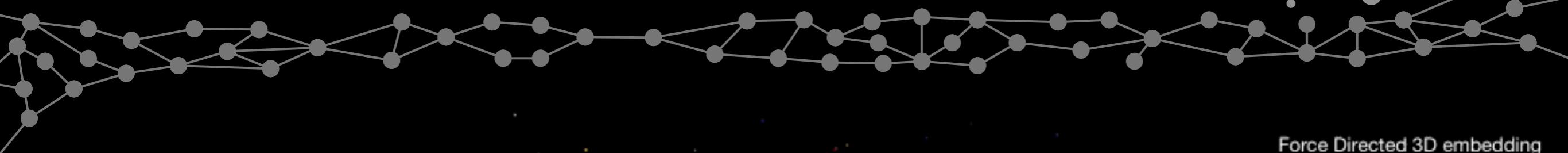
Software Interface

# Examples

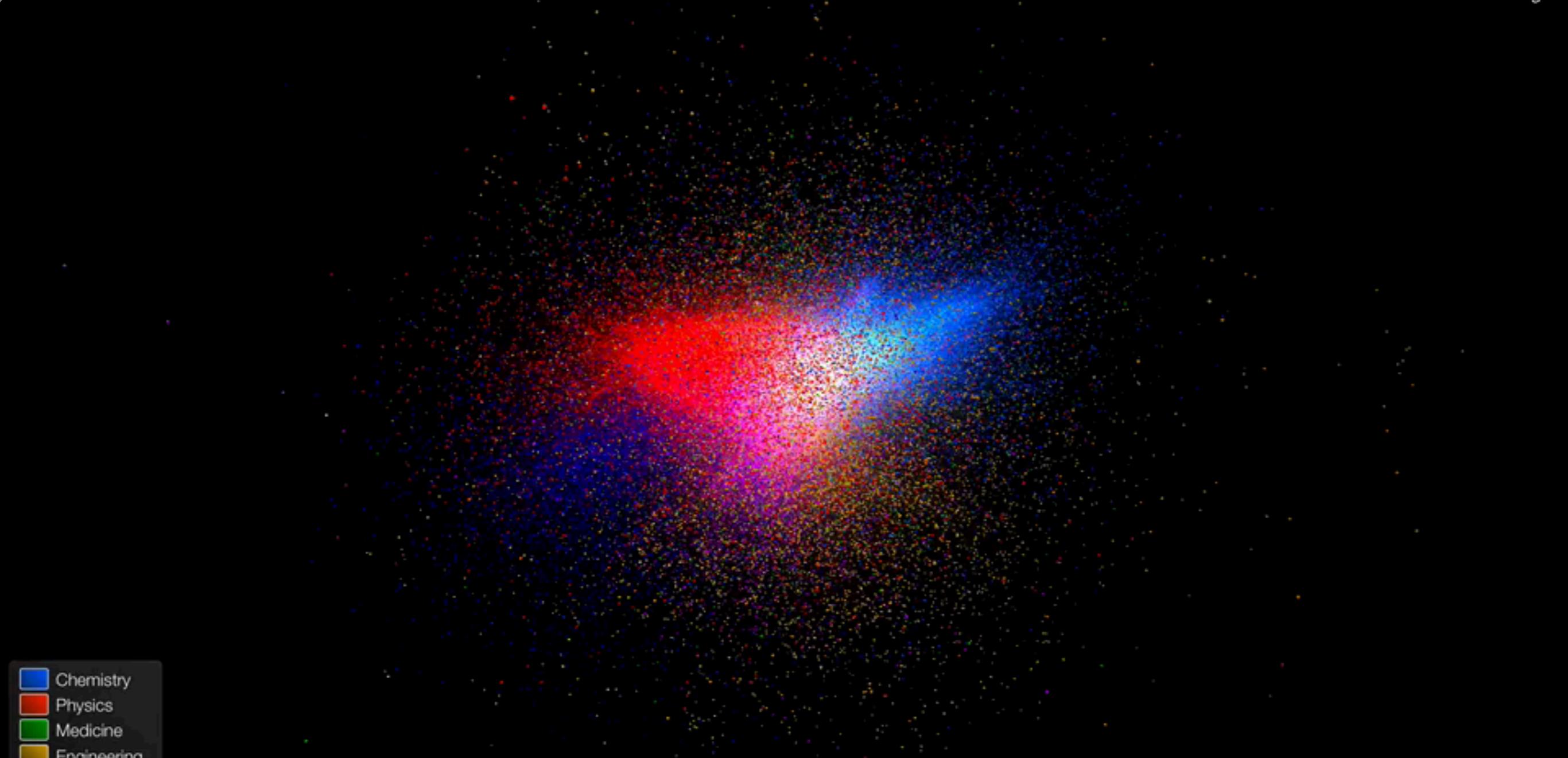


Web interface

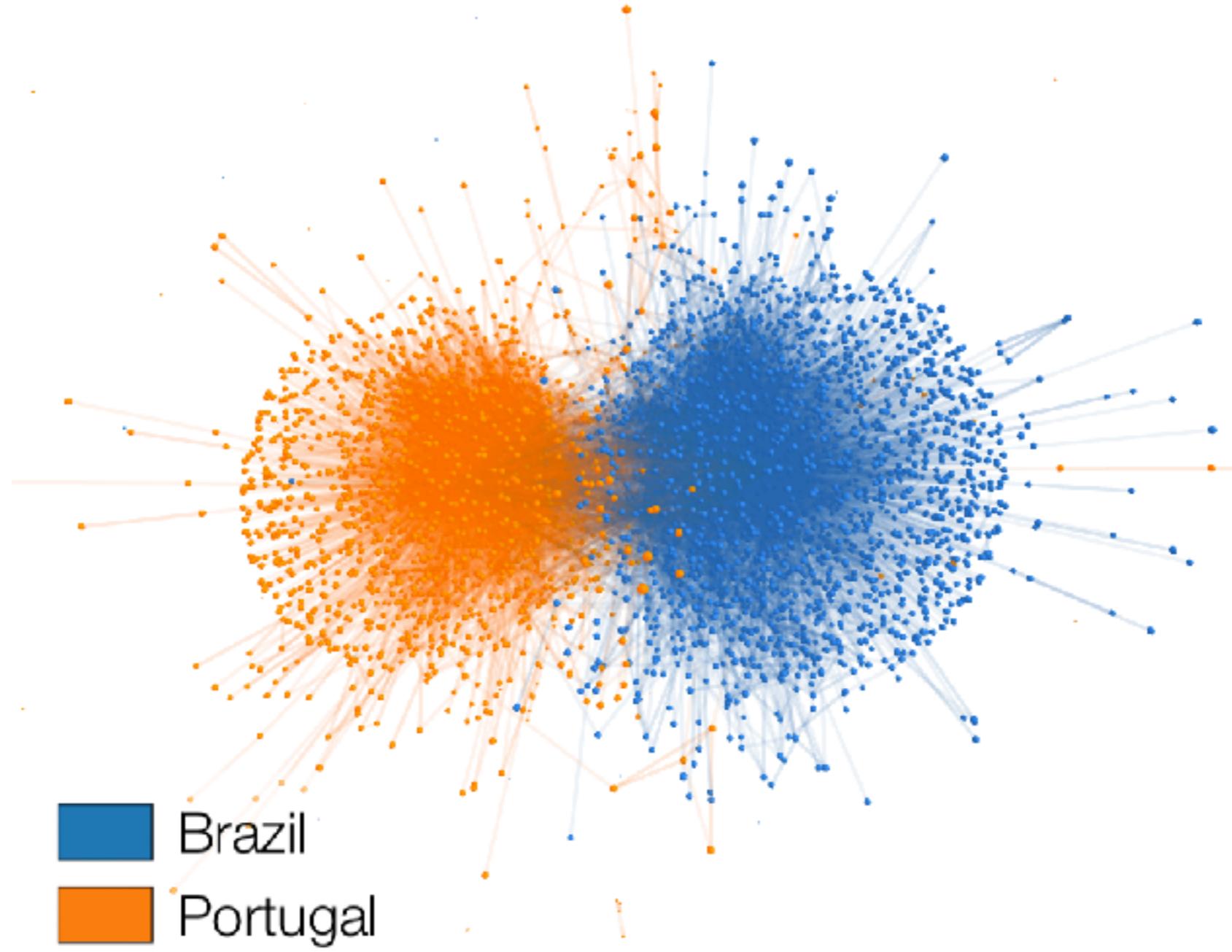
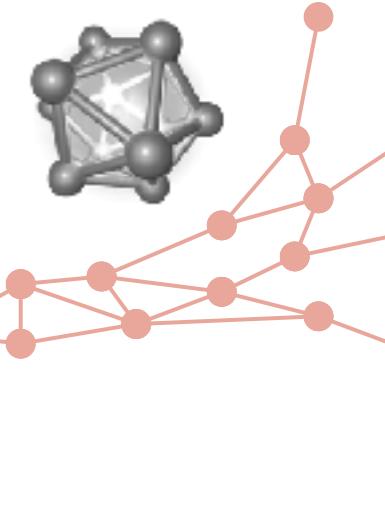
# Visualização de redes



Force Directed 3D embedding

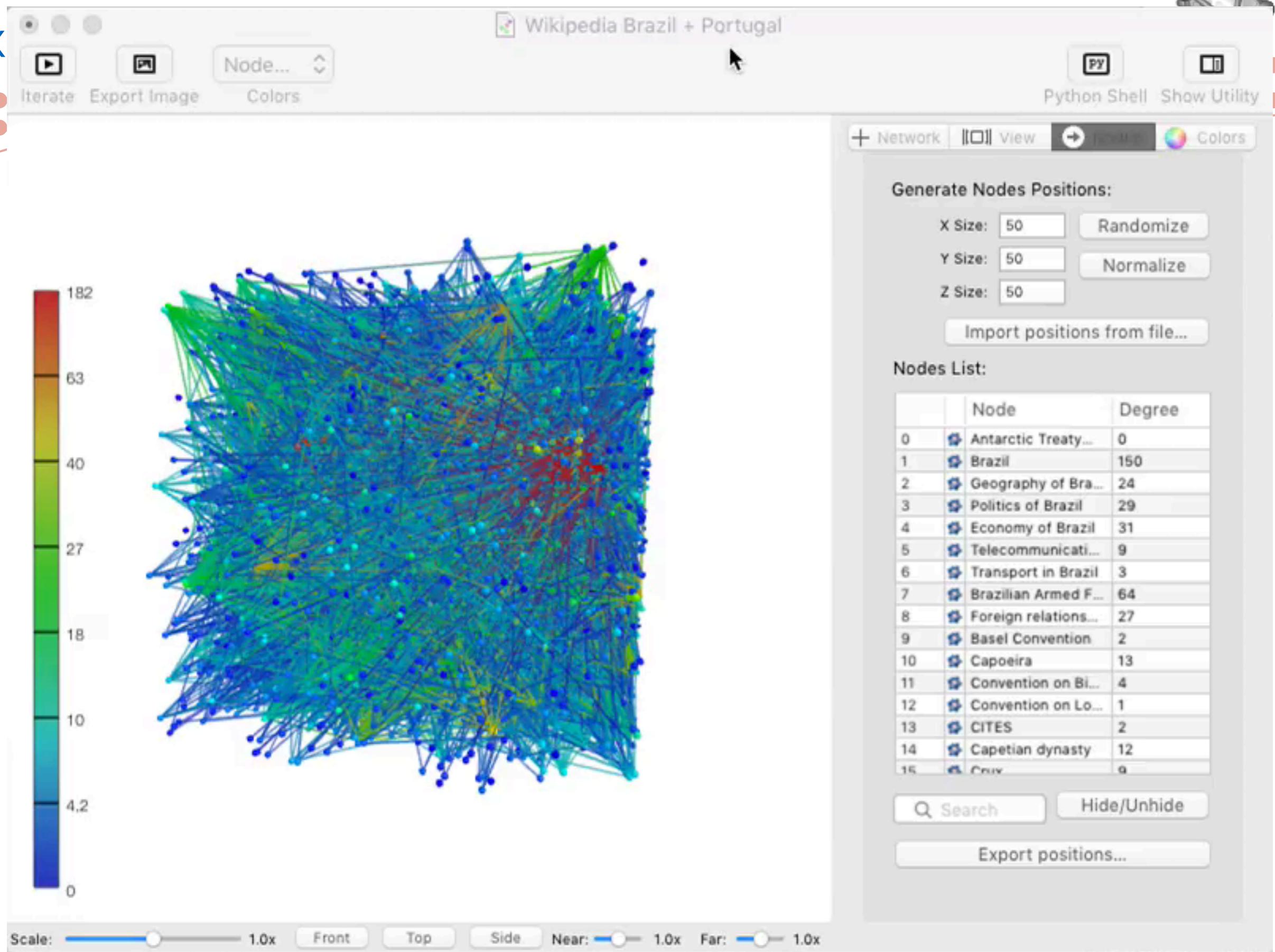


## Exemplos de visualização

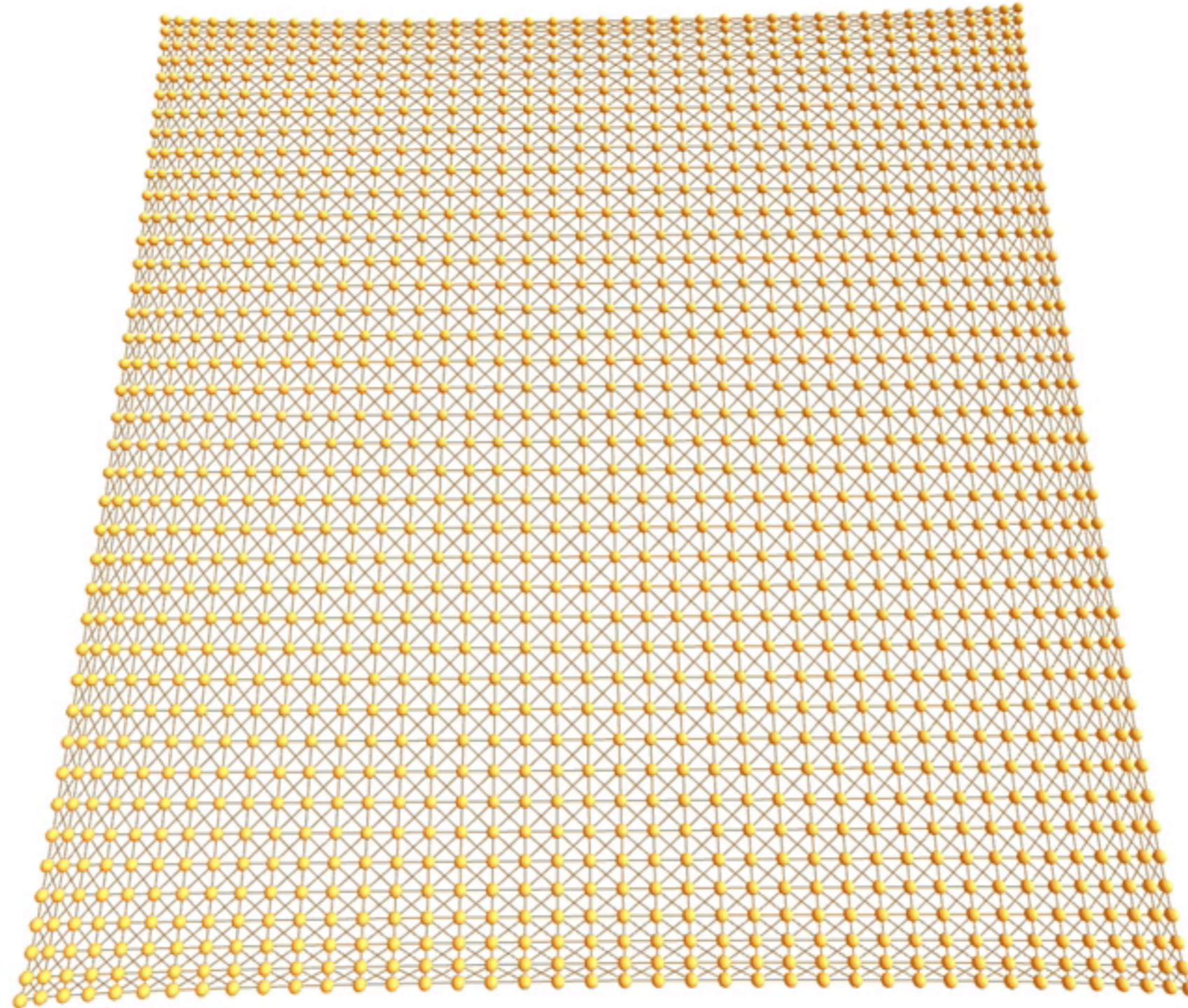
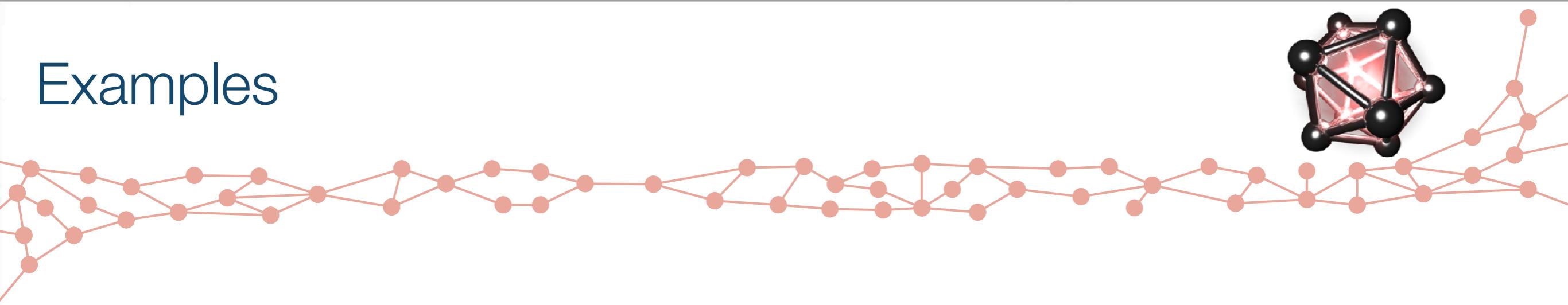




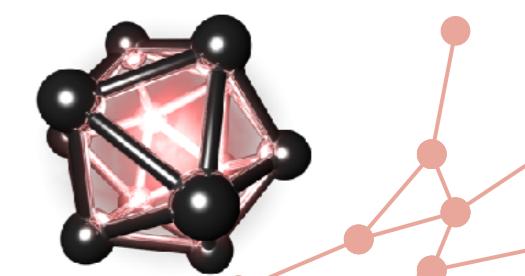
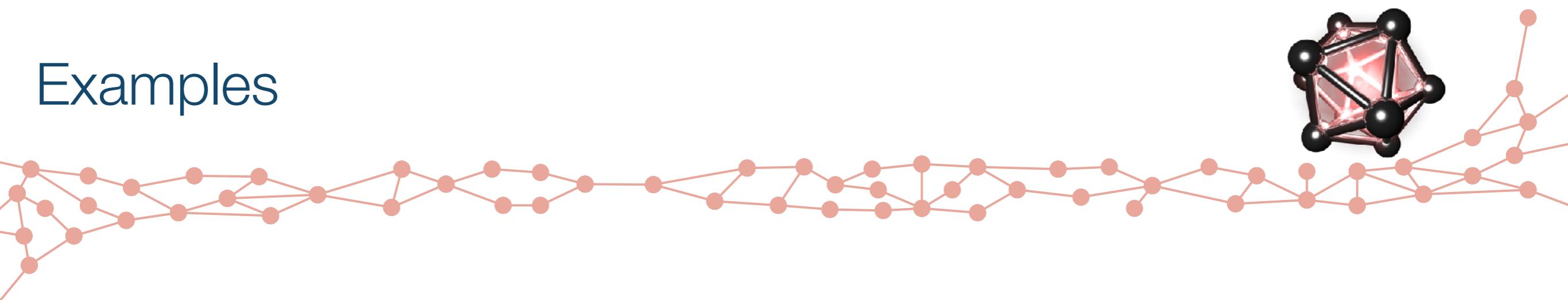
Ex



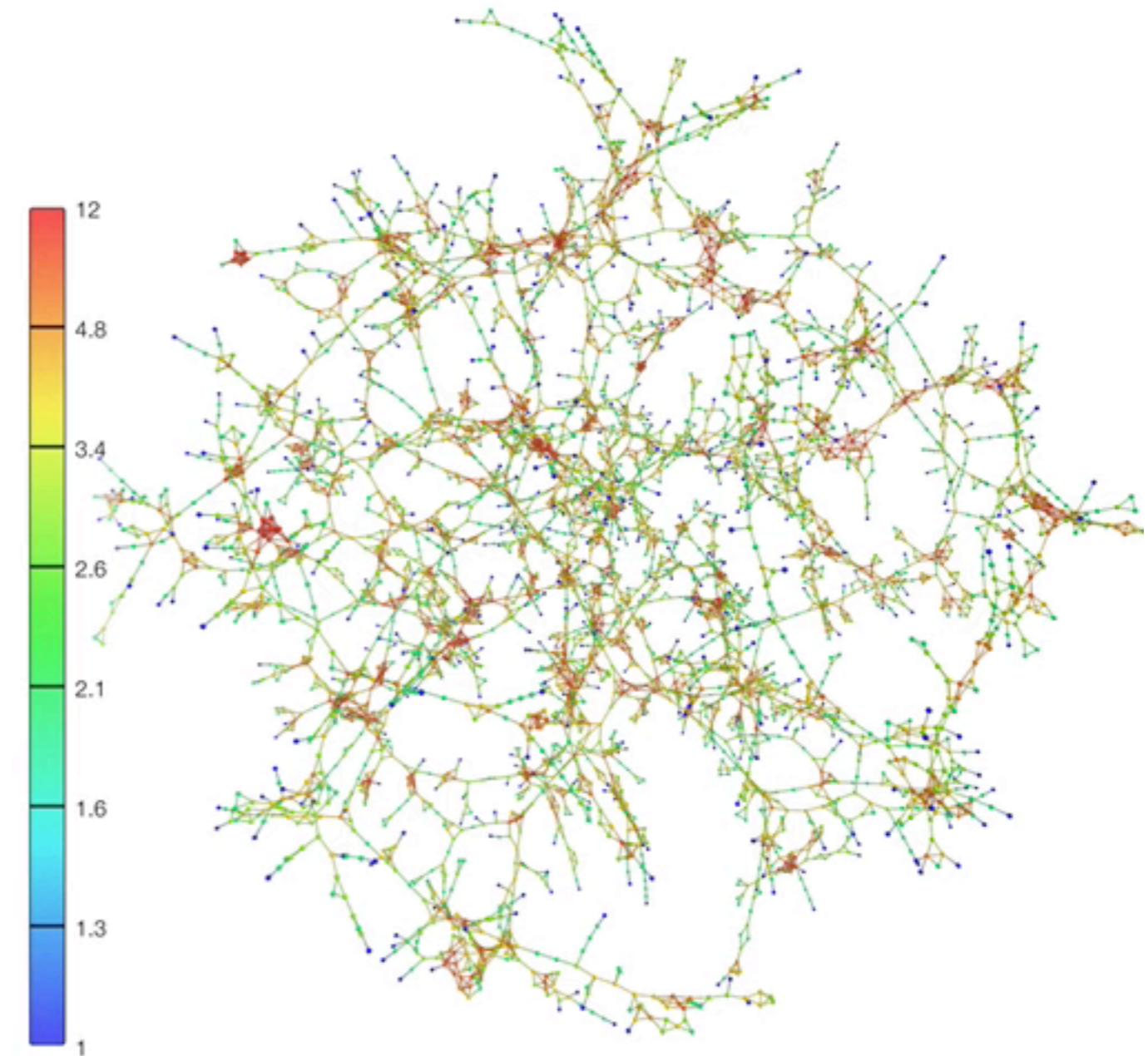
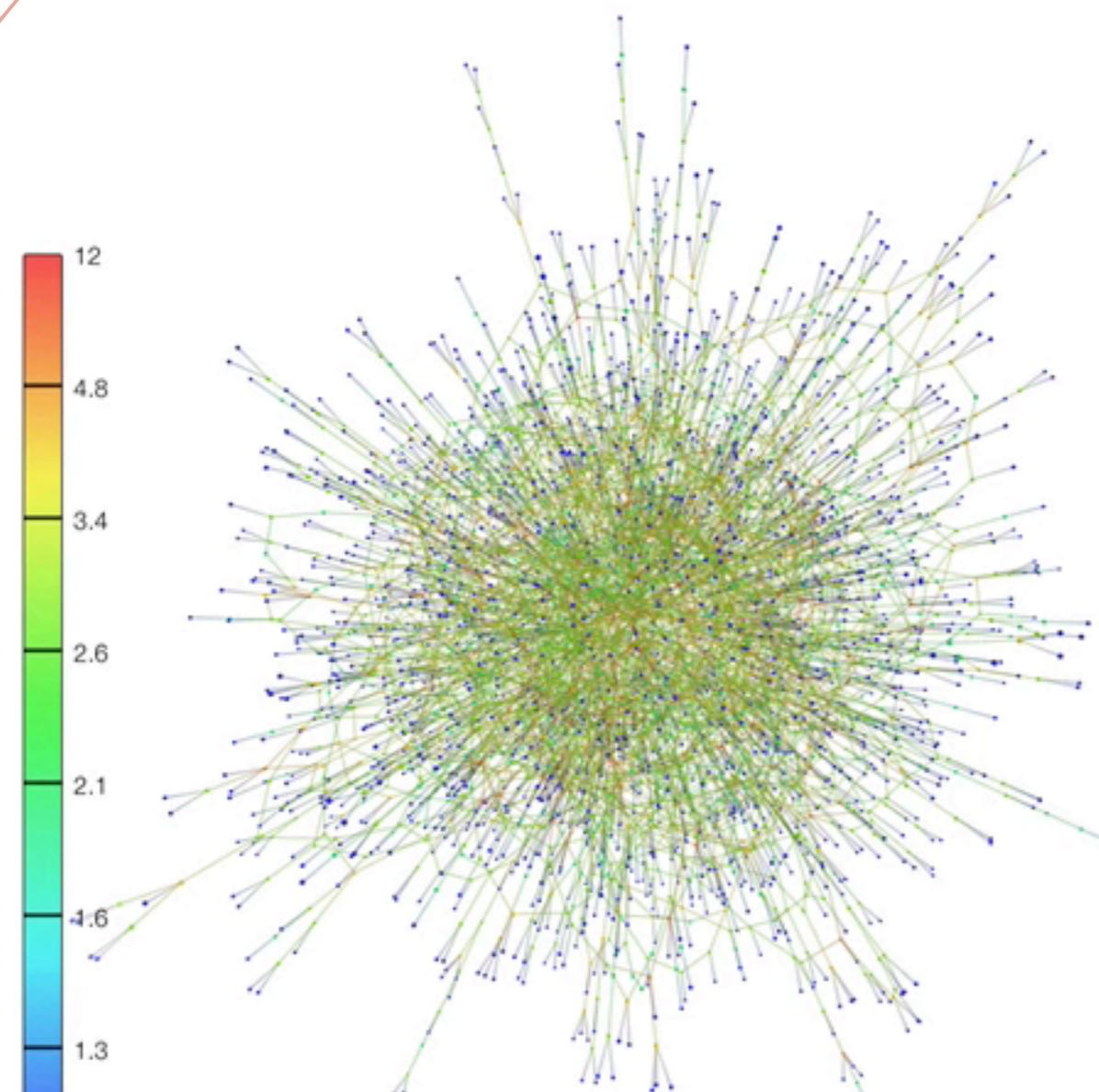
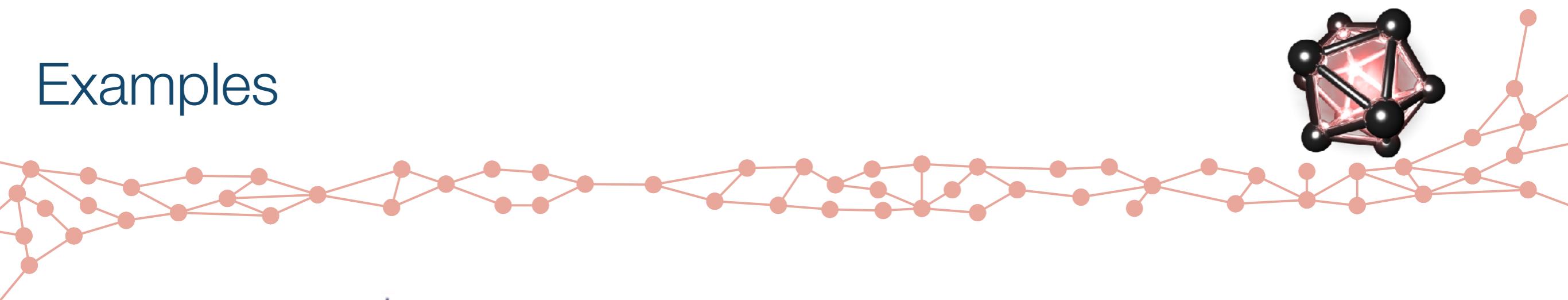
# Examples



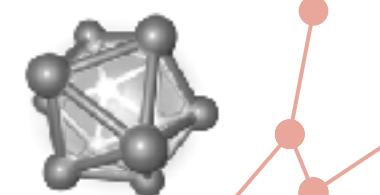
## Examples



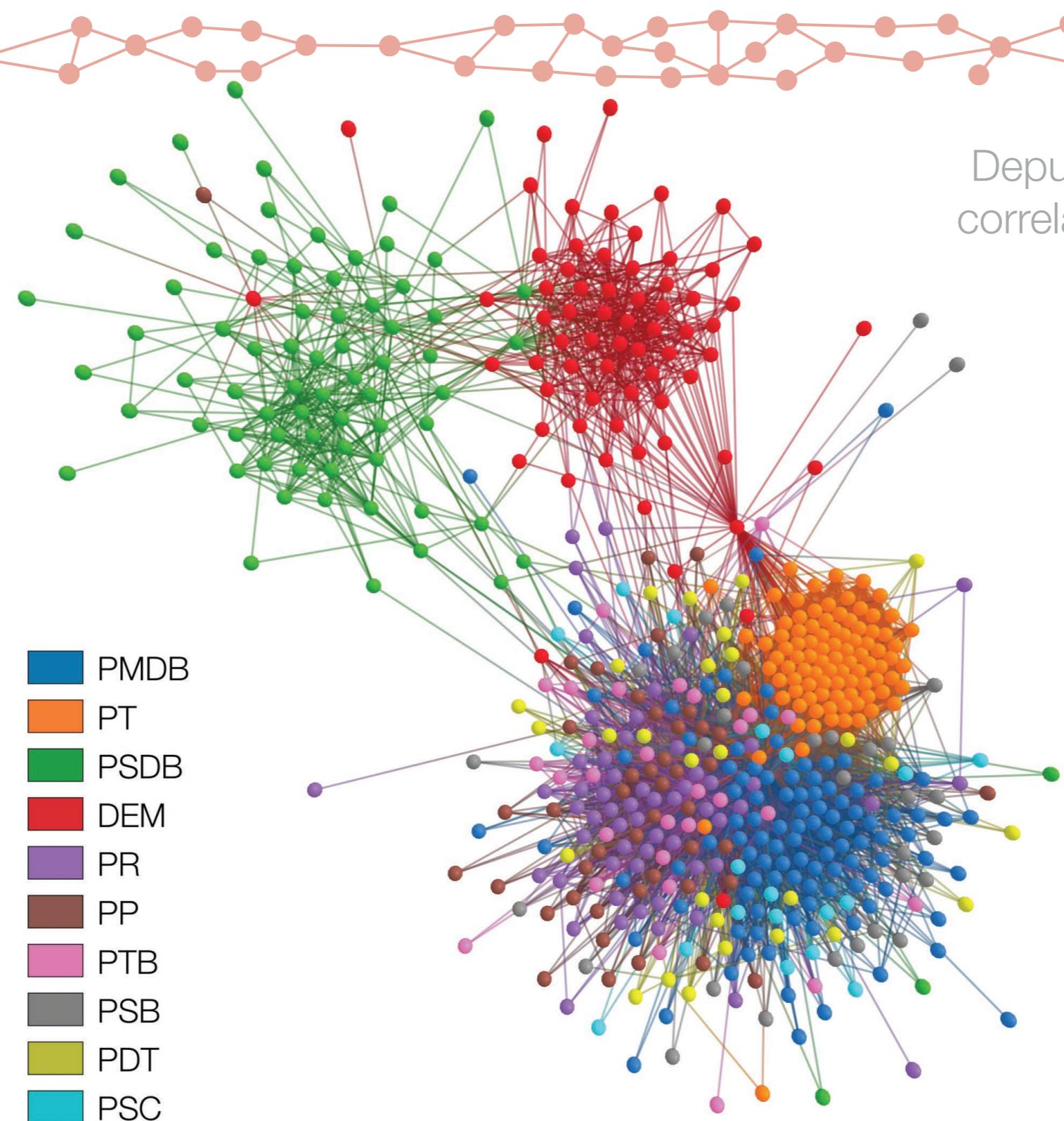
# Examples



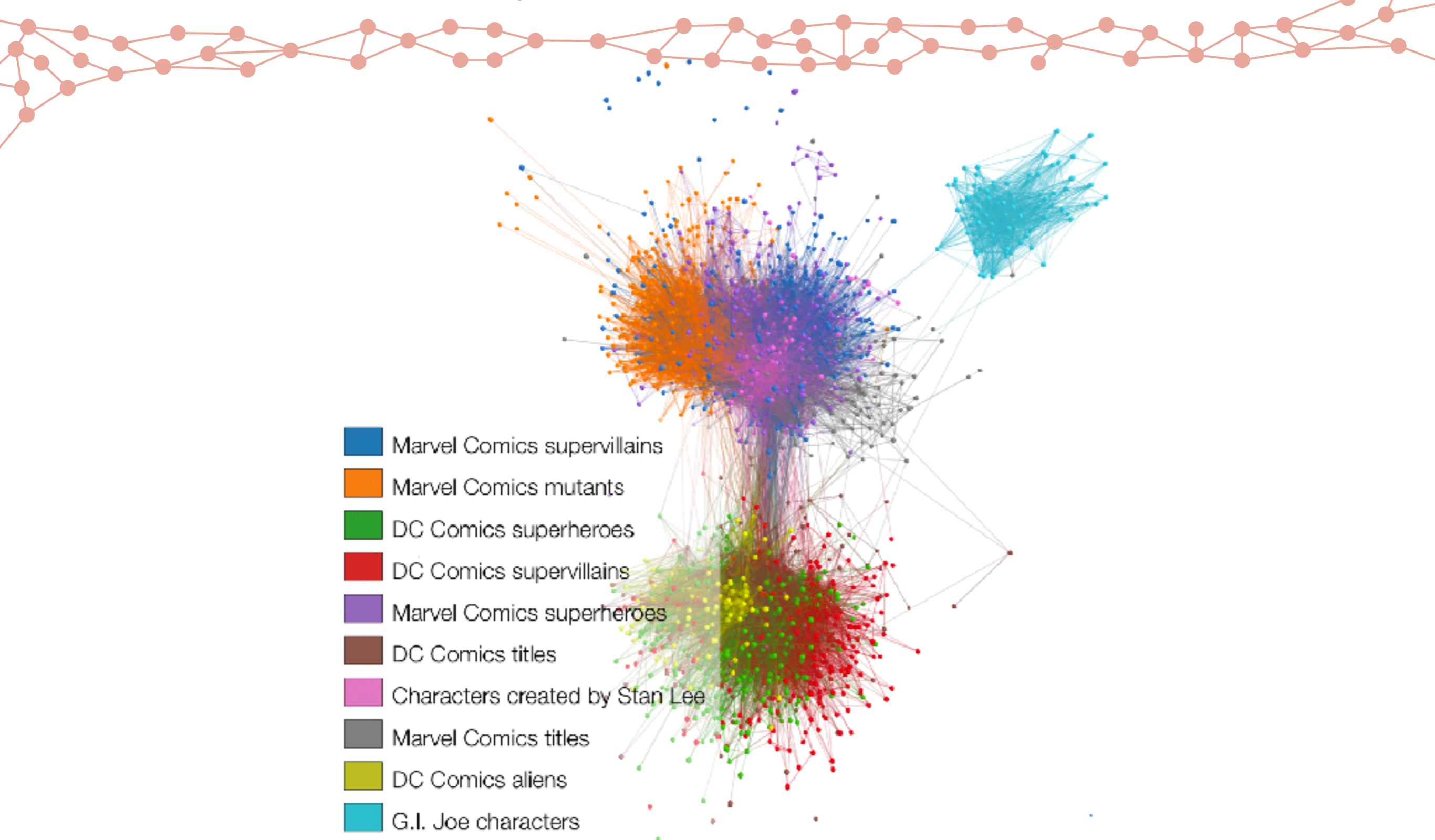
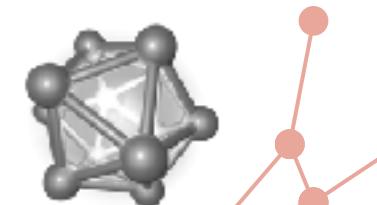
# Exemplos de visualização



Deputados (Brasil)  
correlação de votos



# Exemplos de visualização



# References and Links



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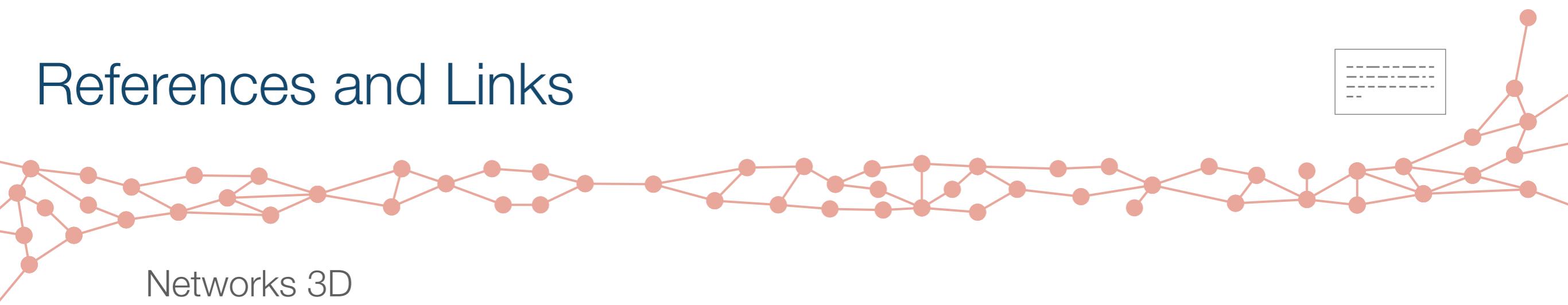
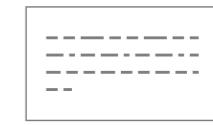
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<http://filipinascimento.github.io/cgicmcprojects/networkviewer/>

Suite Sparse Matrix Collection  
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Visual Complexity  
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Gephi  
<https://gephi.org>

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<https://graph-tool.skewed.de>

GraphViz  
<http://www.graphviz.org>

d3.js  
<http://d3js.org>

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[filipinascimento.github.io](http://filipinascimento.github.io)

Thank you!