BITCOIN NETWORK ANALYSIS

Cazabet Rémy

WHO AM I

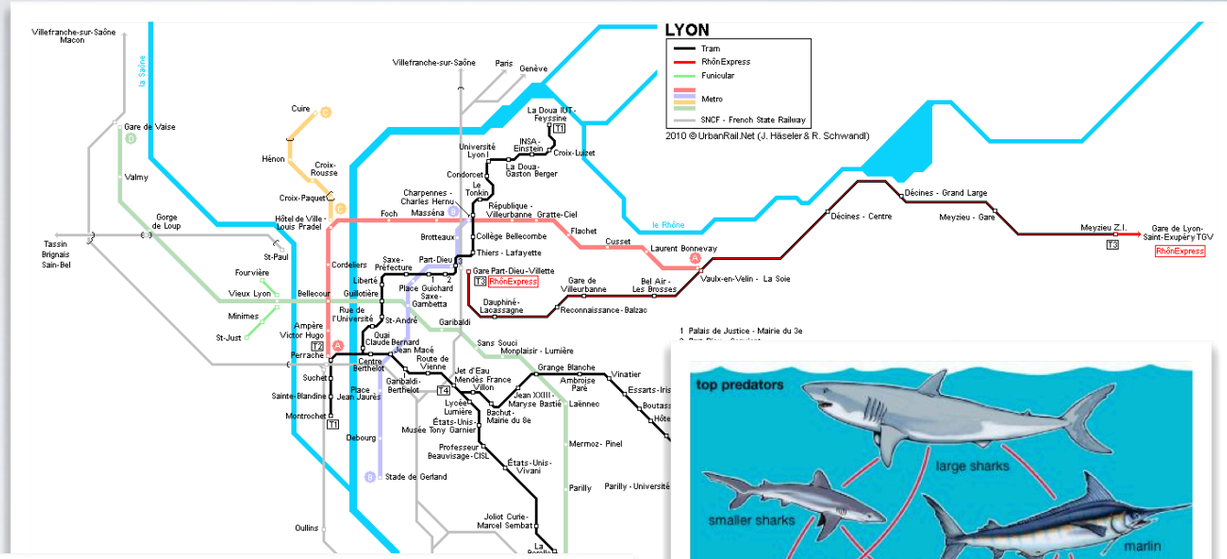
- Rémy Cazabet
- Associate Professor (Maître de conférences)
  - Université Lyon 1
  - LIRIS, DM2L Team (Data Mining & Machine Learning)
- Computer Scientist => **Network Scientist**
- Member of IXXI, Lyon's institute of **Complex Systems**

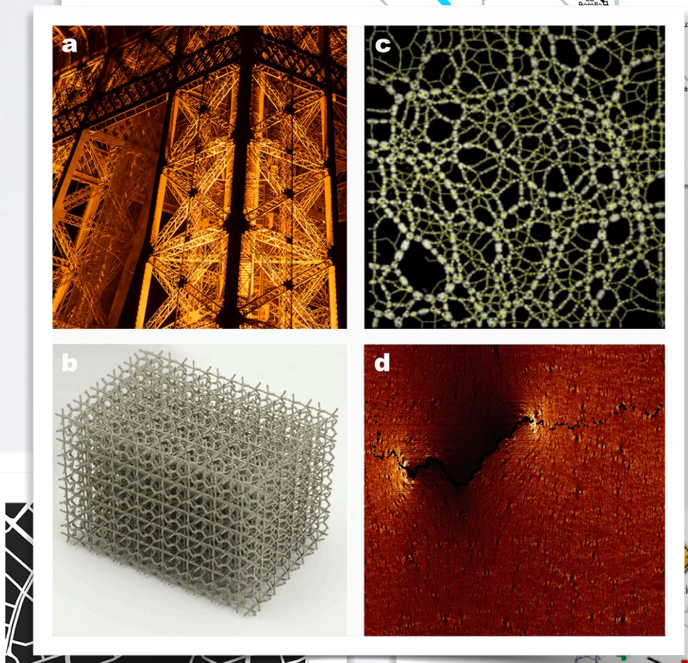
NETWORK SCIENCE

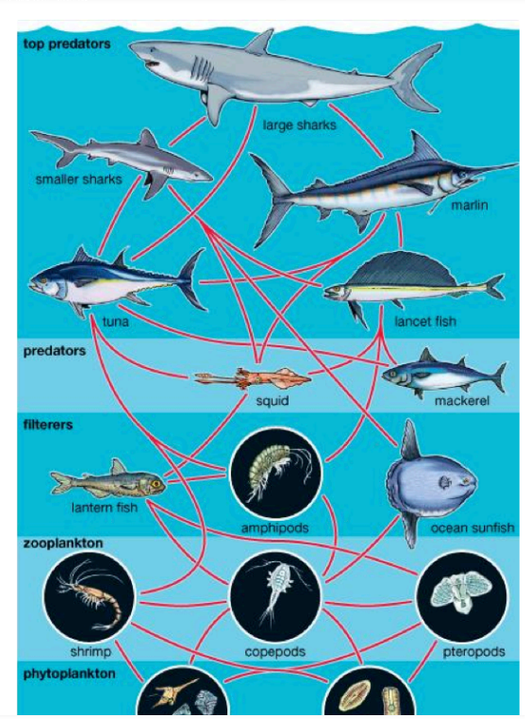
- Study interactions between entities at the micro level => represent interactions as a **network**

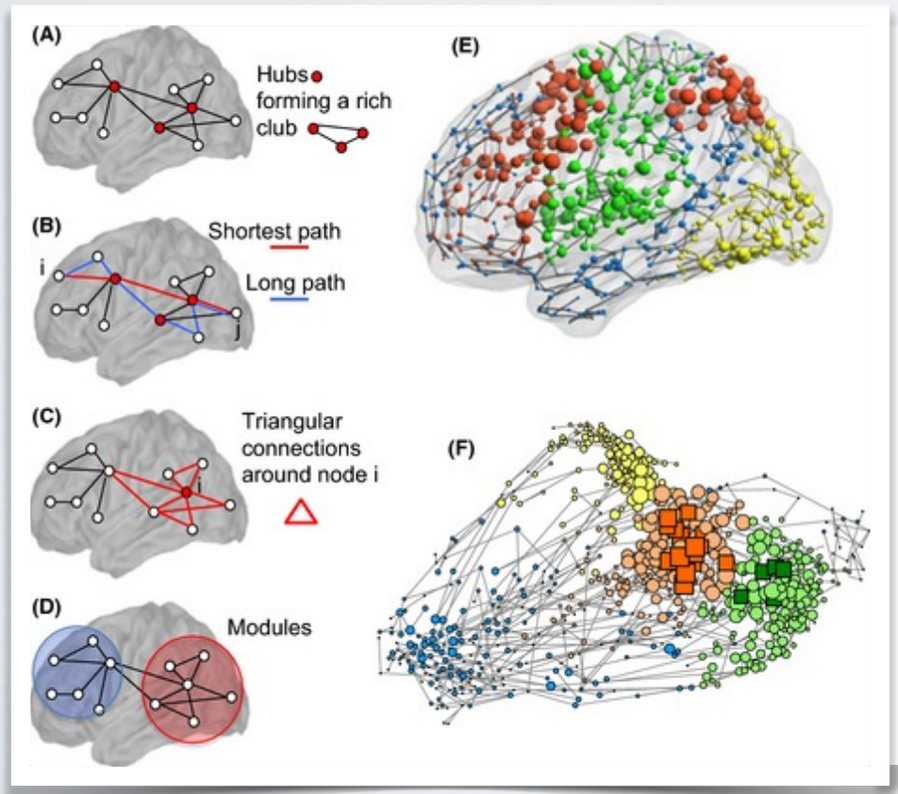
- Analyse this network based on tools from **network science**

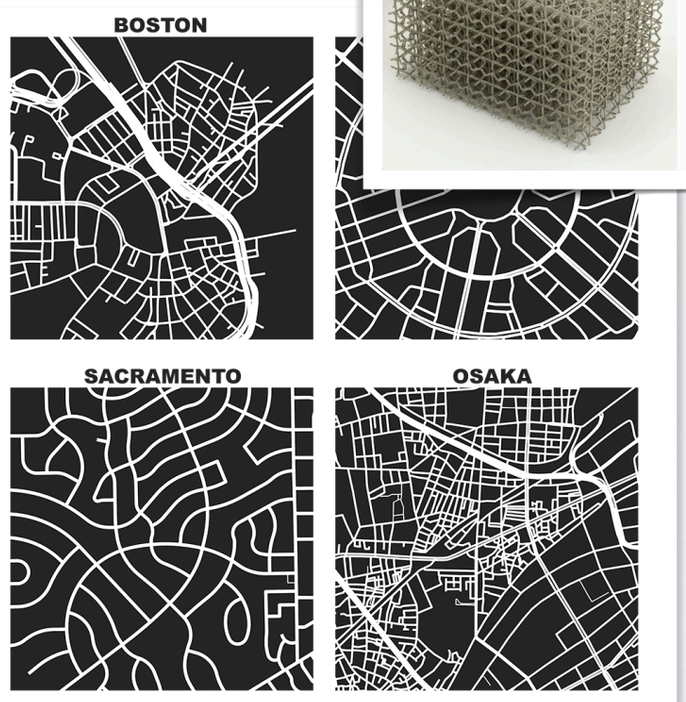
- Vocabulary: network science ≈ Complex/Social network analysis ≈ Graph mining

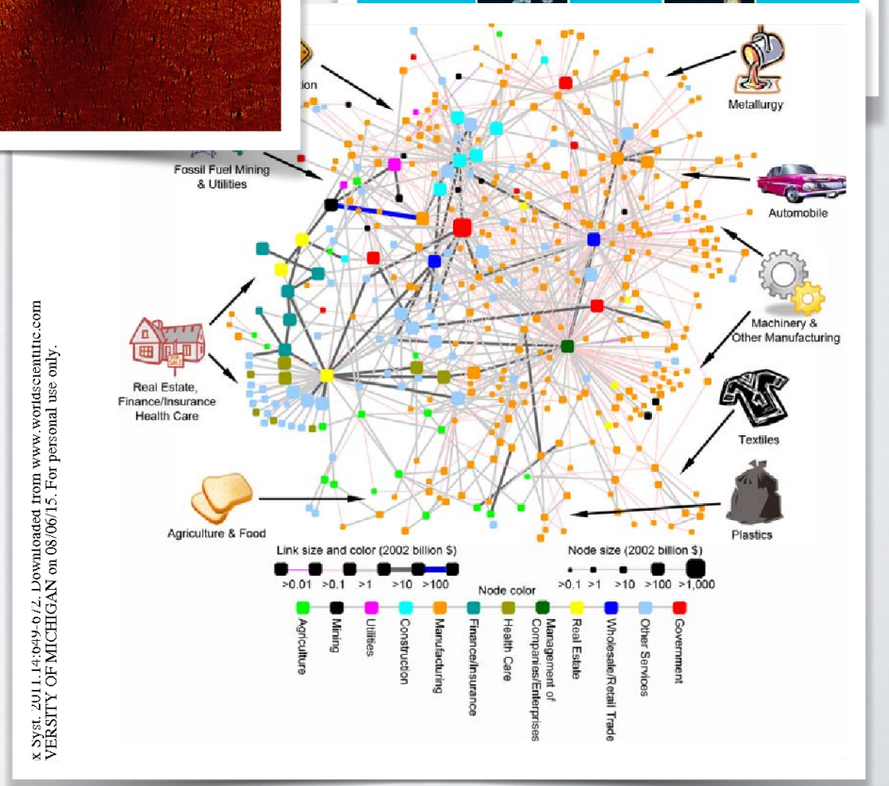










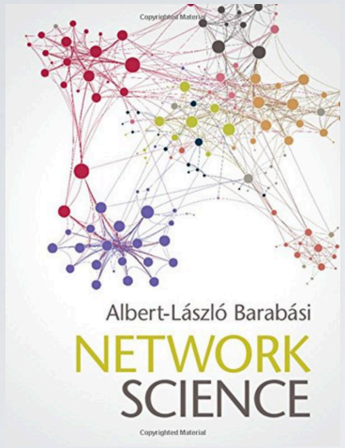


NETWORKS

- Online social networks, e.g., Facebook, Twitter…
  - Nodes: accounts
  - Edges: relations (friend/follow) or interactions (wall post, like, retweet, mentions, etc.)
- Cryptocurrency
  - Nodes: addresses or *actors* (wallet ? Set of addresses ?)
  - Edges: transactions

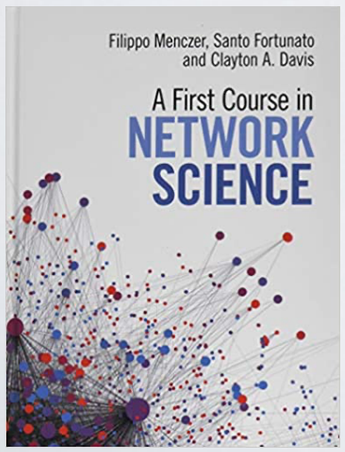
NETWORK DEFINITION

REFERENCES



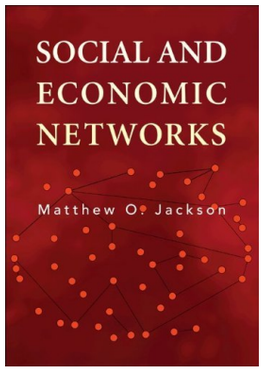
http://networksciencebook.com

https://arxiv.org/abs/2101.00863



https://www.amazon.com/First-Course-Network-Science/dp/1108471137

REFERENCES

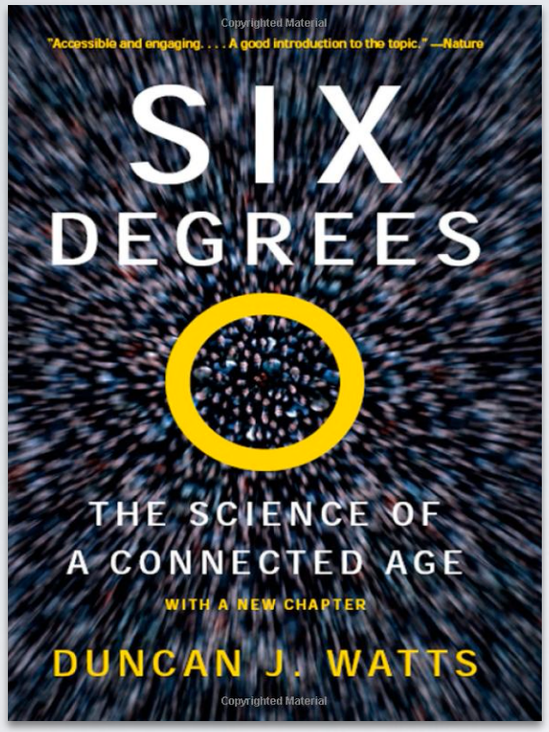


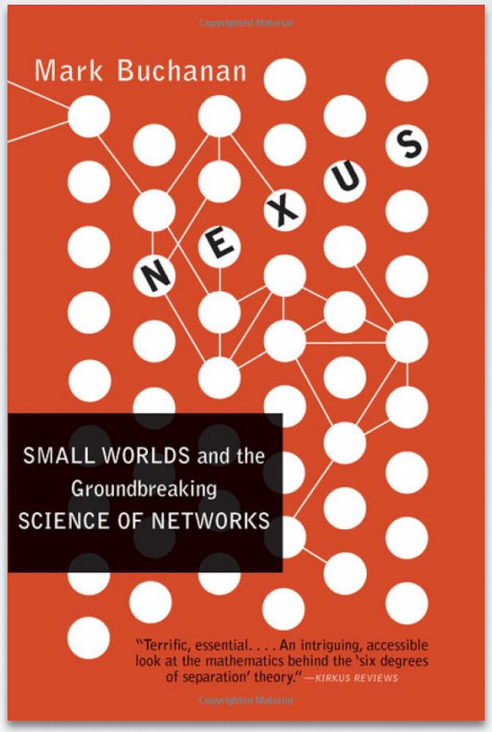
M. O. Jackson, Social and Economic Networks (Princeton University Press, 2010).

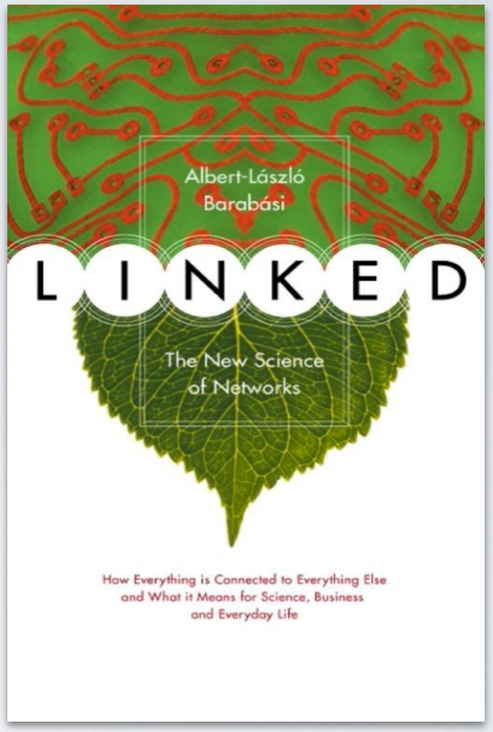
Google: "network science finance"
Or
"network science economy"
=> I'm not an expert in
economic networks :)

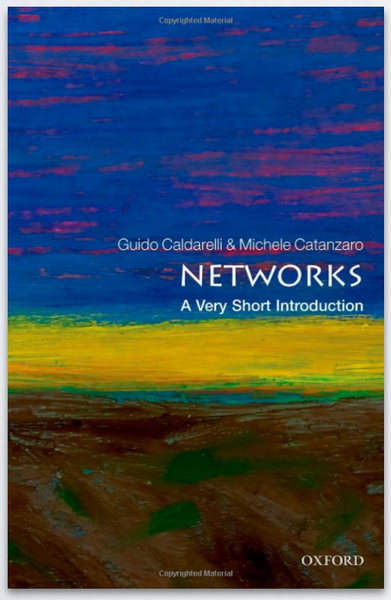
REFERENCES

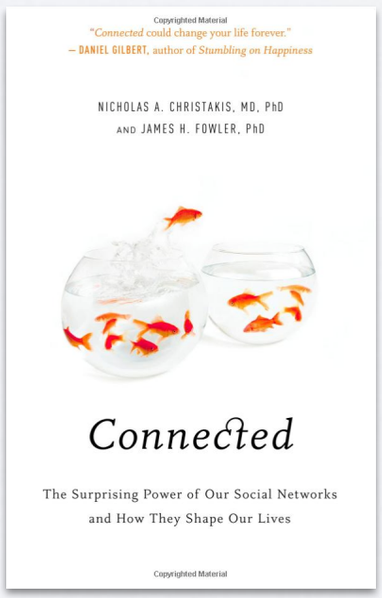
Pop-science books

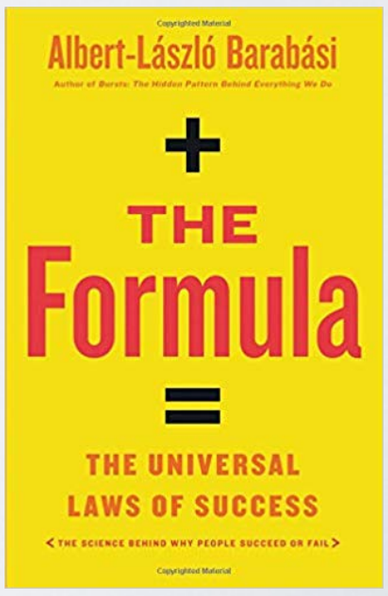




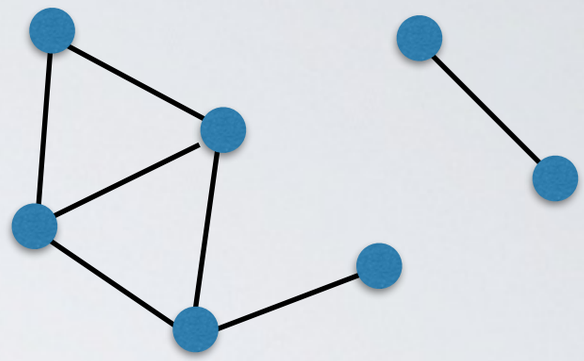








GRAPHS & NETWORKS



Networks often refers to real systems

- www,
- social network
- metabolic network.
- Language: (Network, node, link)

Graph is the mathematical representation of a network

- Language: (Graph, vertex, edge)

Vertex	Edge
person	friendship
neuron	synapse
Website	hyperlink
company	ownership
gene	regulation

In most cases we will use the two terms interchangeably.

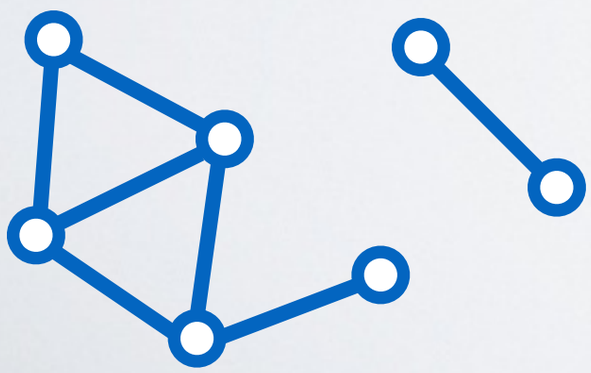
Types of Networks

Undirected networks

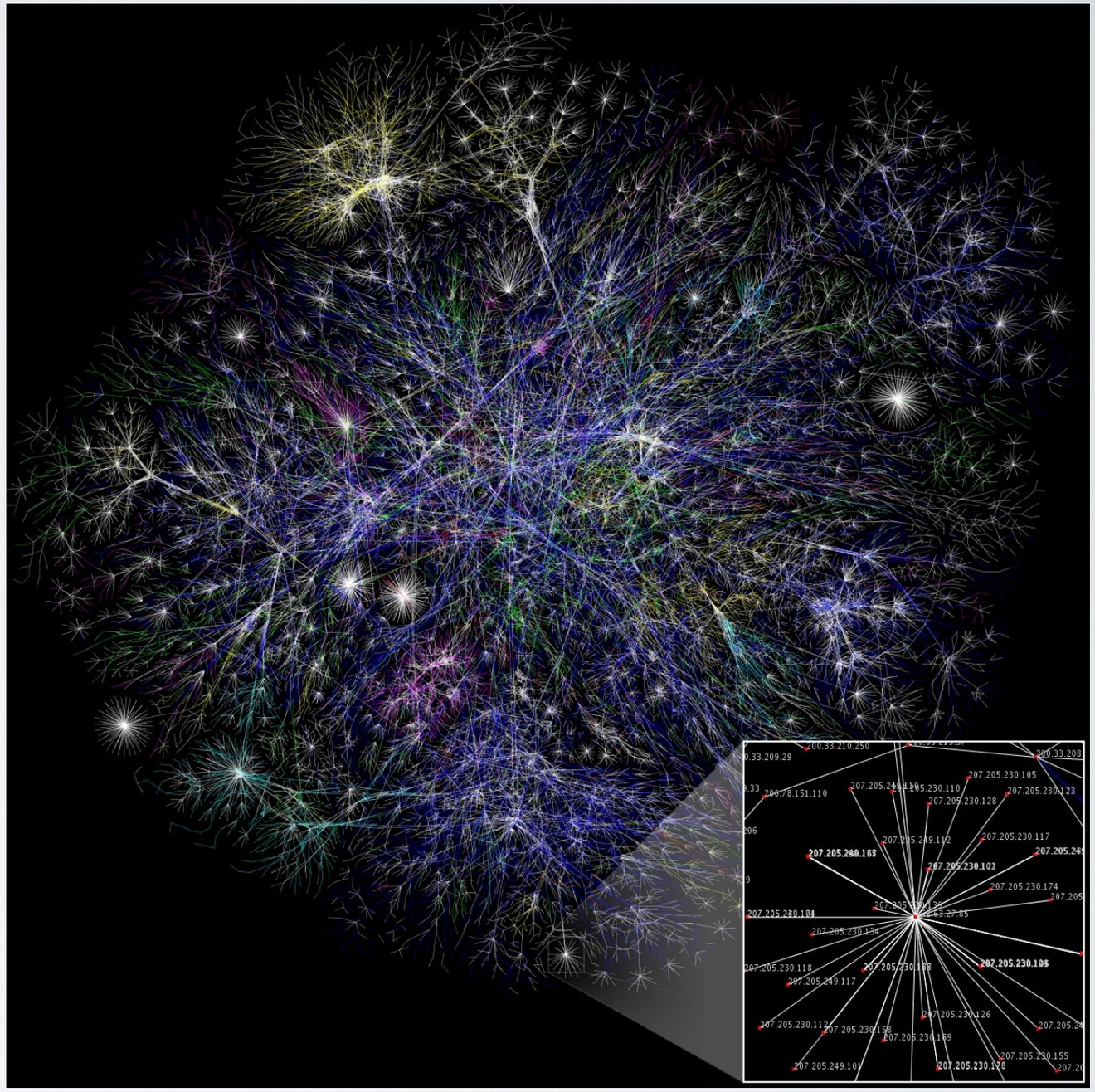
$G=(V, E)$

$(u,v) \in E \equiv (v,u) \in E$

- The directions of edges do not matter
- Interactions are possible between connected entities in both directions



Opte project



The Internet: Nodes - routers, Links - physical wires

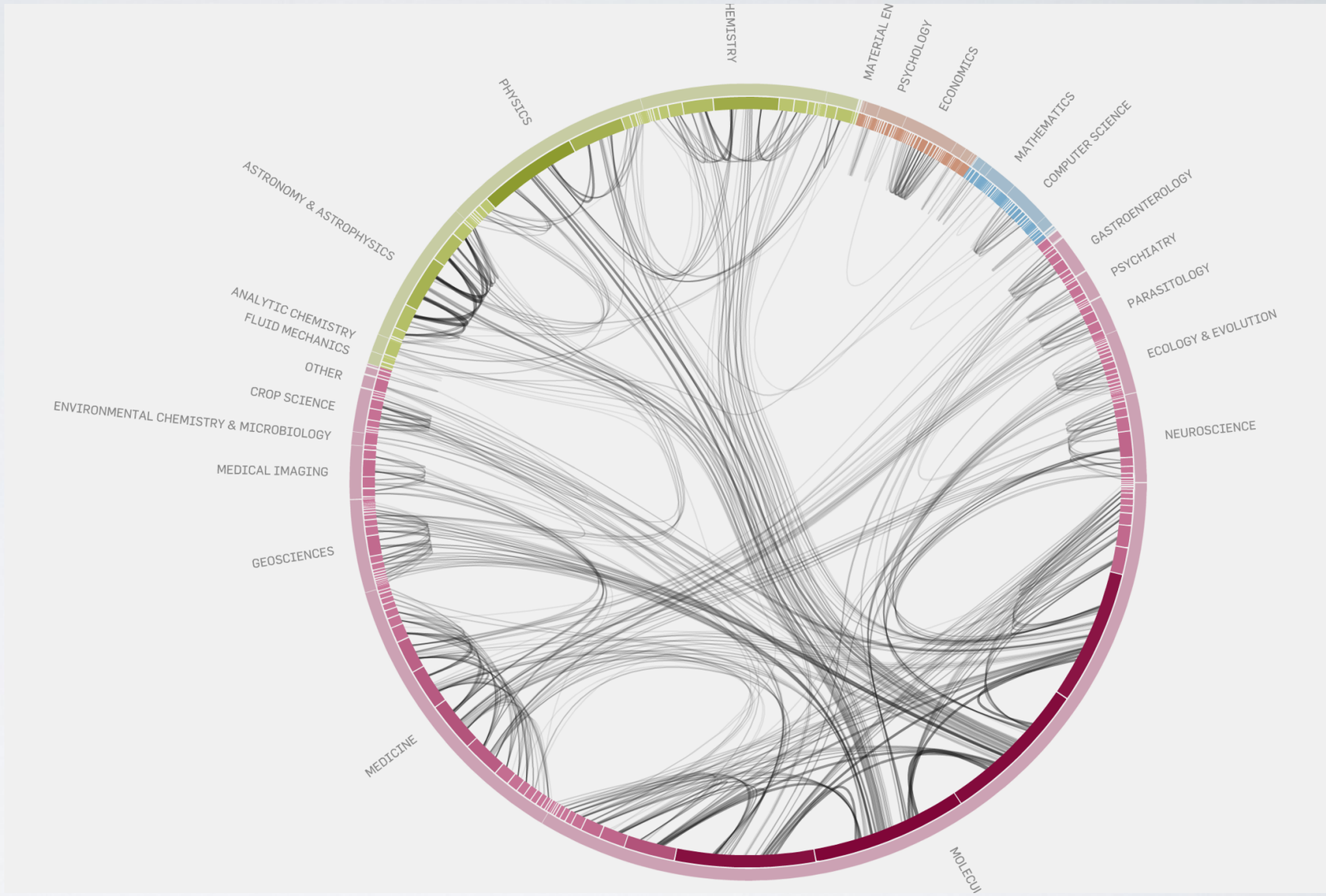
Directed networks

Moritz Stefaner, eigenfactor.com

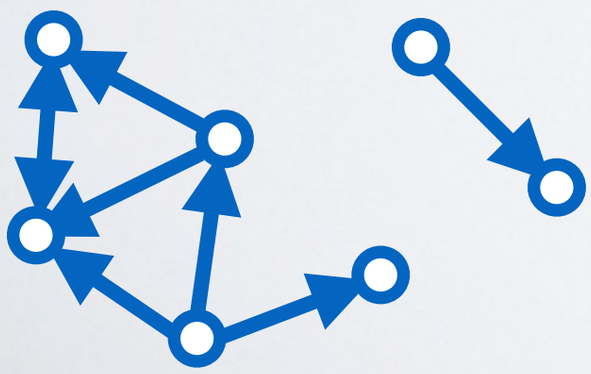
$G=(V, E)$

$(u,v) \in E \not\equiv (v,u) \in E$

- The directions of edges matter
- Interactions are possible between connected entities only in specified directions



Citation network: Nodes - publications, Links - references

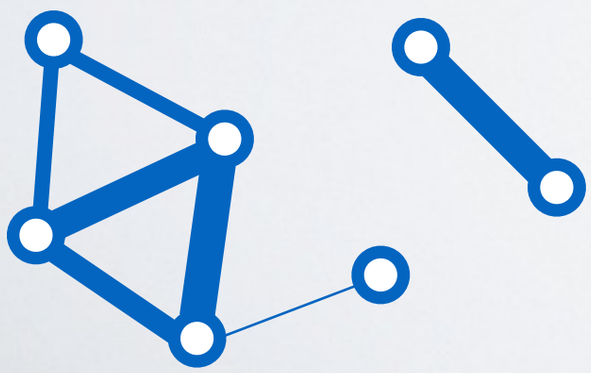


Weighted networks

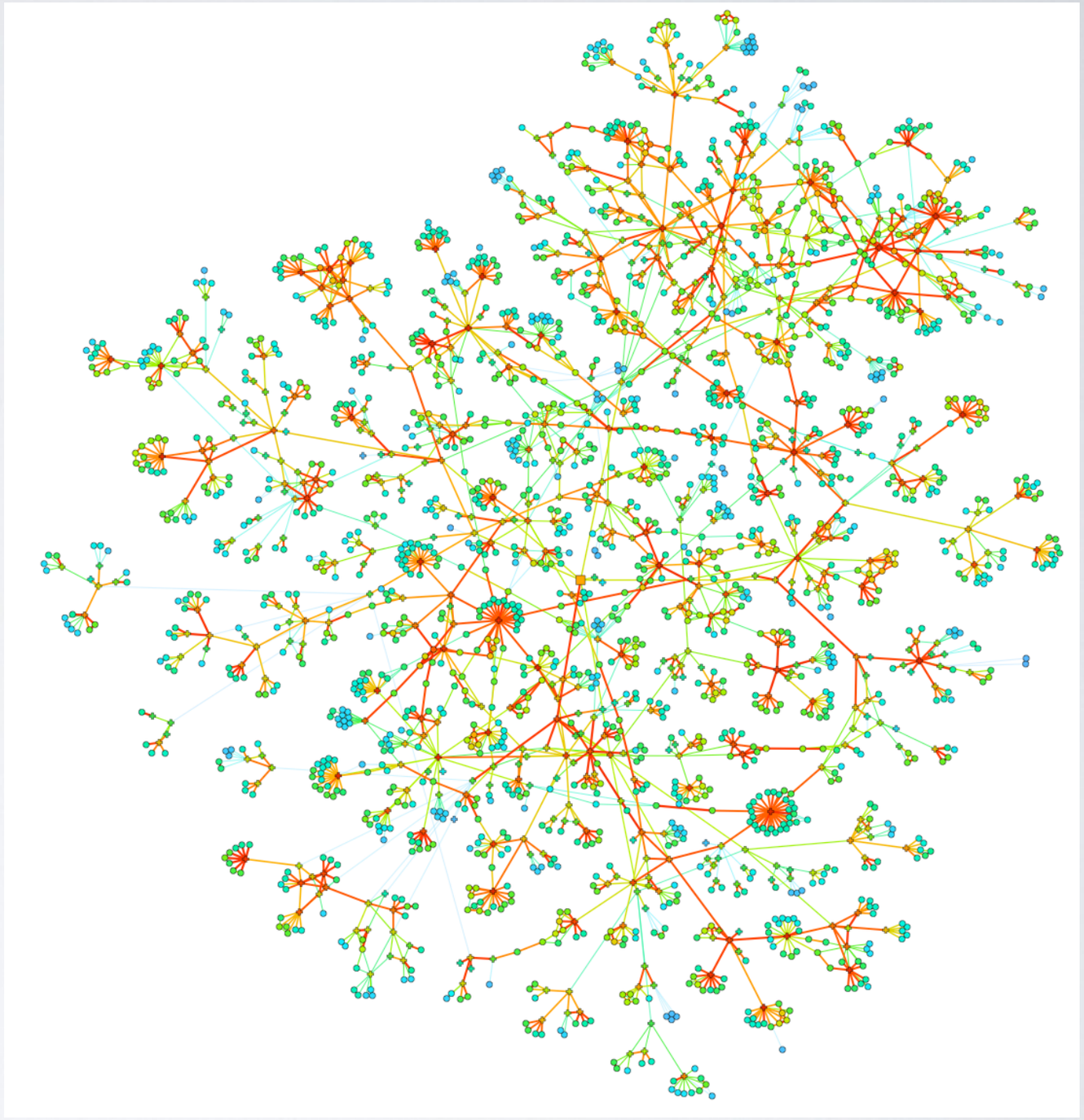
$G=(V, E, w)$

$w: (u,v) \in E \Rightarrow R$

- Strength of interactions are assigned by the weight of links

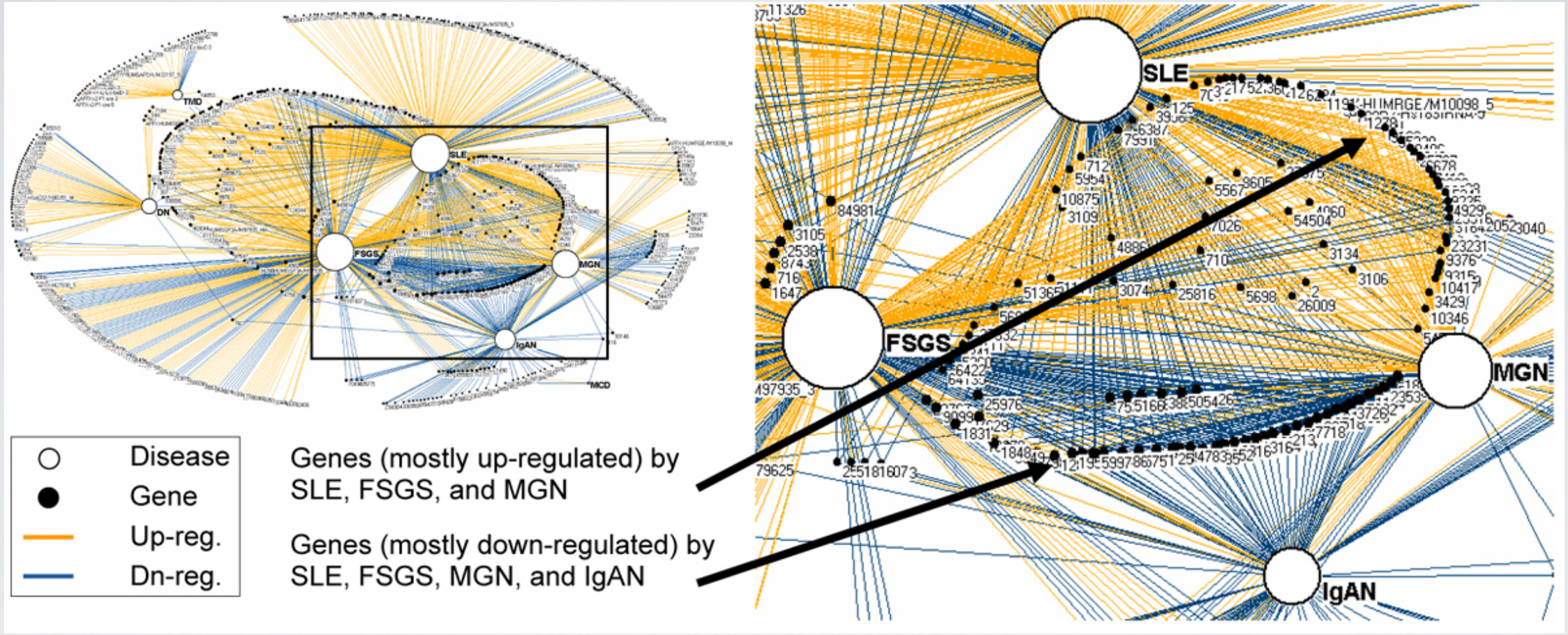


Onnela et.al. New Journal of Physics 9, 179 (2007).

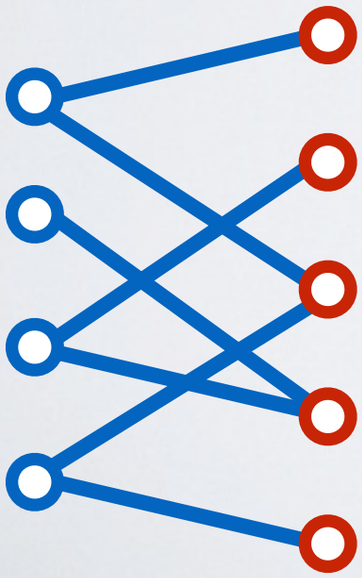


Social interaction network: Nodes - individuals
Links - social interactions

Bipartite network



Bhavnani et.al. BMC Bioinformatics 2009, **10**(Suppl 9):S3



Gene-desease network:

Nodes - Desease (7)&Genes (747)

Links - gene-desease relationship

$$G=(U, V, E)$$

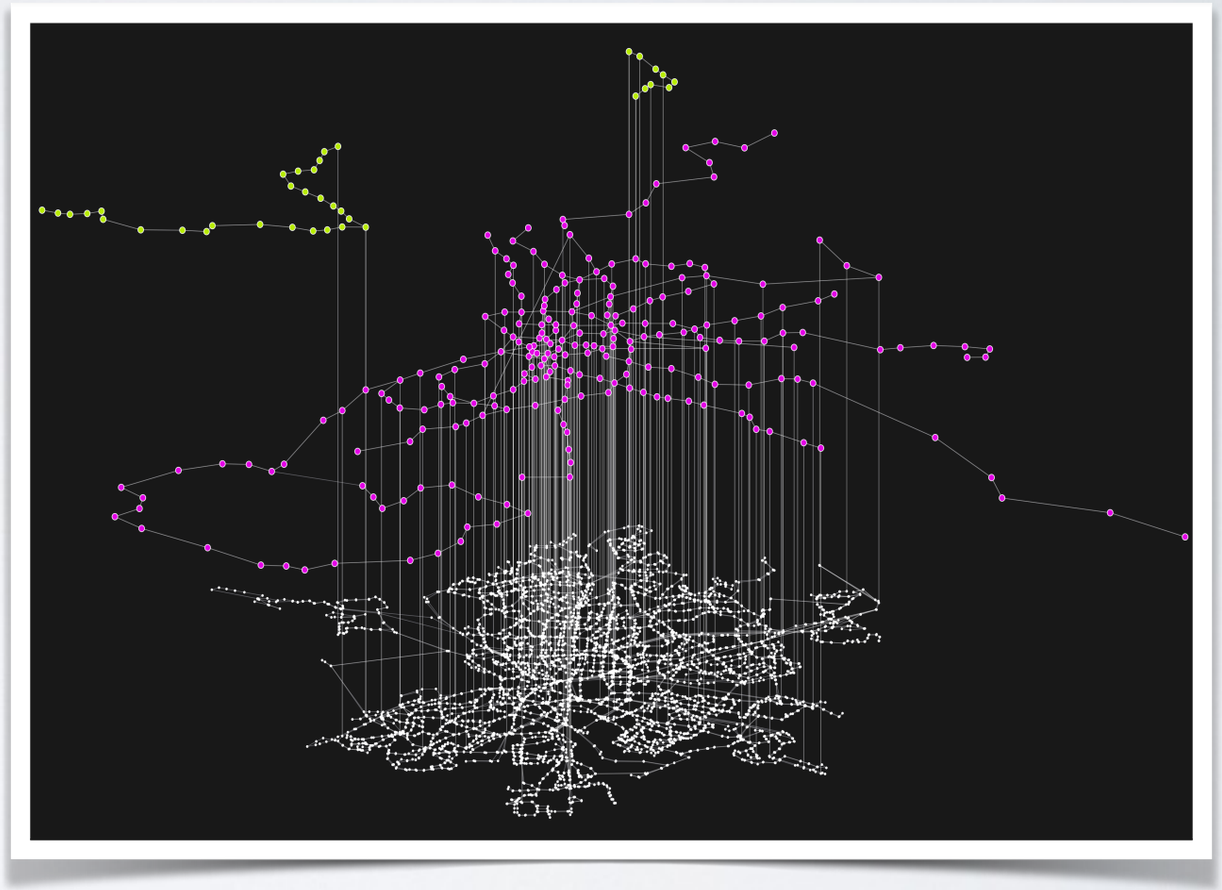
$$U \cap V = \varnothing$$

$$\forall (u,v) \in E,\ u \in U \text{ and } v \in V$$

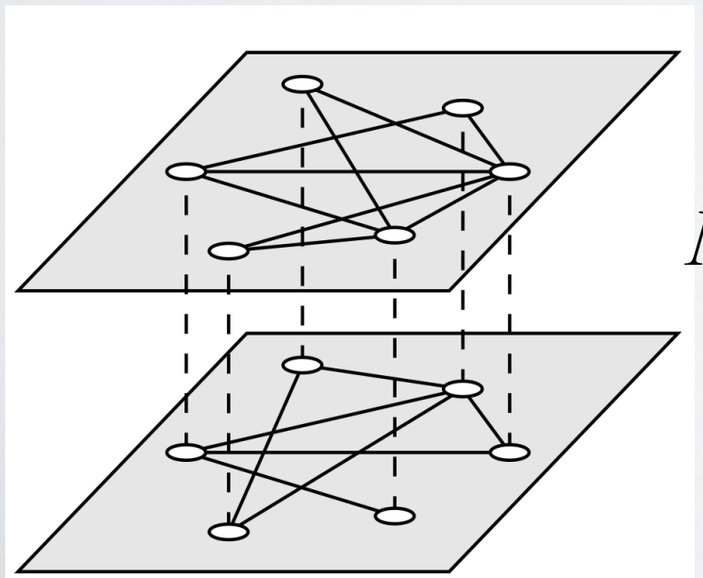
Multiplex and multilayer networks

$G=(V, E_i), i=1 \ldots M$

- Nodes can be present in multiple networks simultaneously
- These networks are connected (can influence each other) via the common nodes



[Mendez-Bermudez et al. 2017]



$M=2$

Gomes et.al. Phys. Rev. Lett. 110, 028701 (2013)

Temporal and evolving networks

$G=(V, E_t), (u,v,t,d) \in E_t$

t - time of interaction (u,v)
d - duration of interaction (u,v,t)

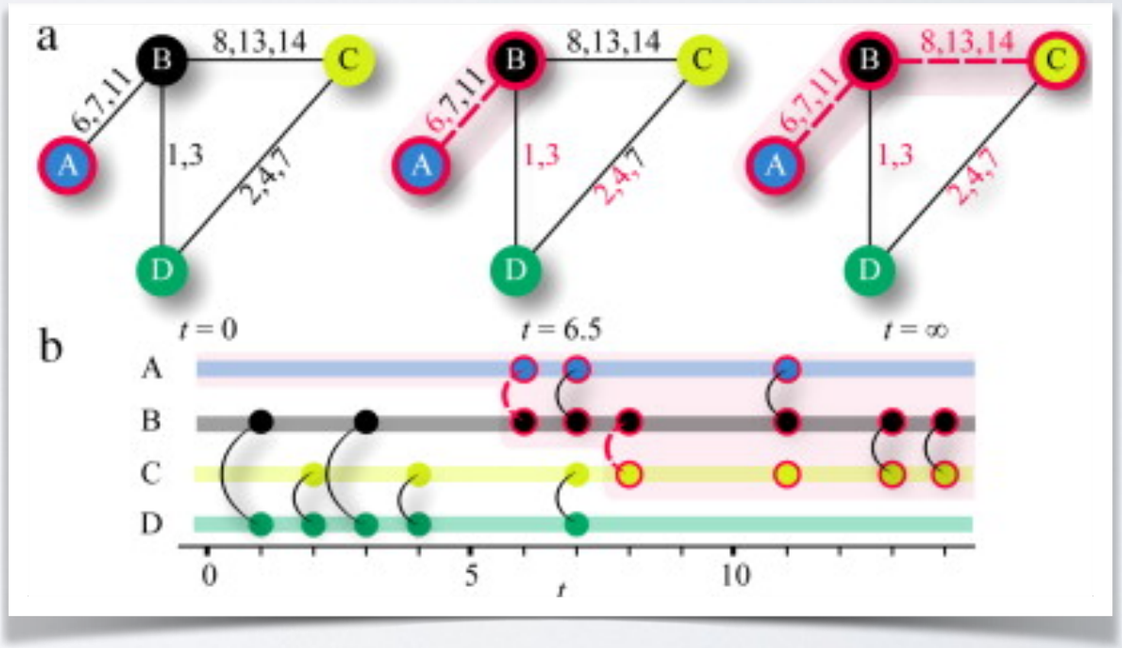
- Temporal links encode time varying interactions

$G=(V_{t'}, E_{t'})$

$v(t) \in V_{t'}$

$(u,v,t) \in E_{t'}$

- Dynamical nodes and links encode the evolution of the network



Mobile communication network
Nodes - individuals
Links - calls and SMS

COURSE OBJECTIVES

COURSE OBJECTIVES

- Theory:
  - Learn the basics of network science and network analysis, + some machine learning/data science concepts
- Practice:
  - Learn how to apply those concepts to graphs of small/medium size
  - Practice some data science tools
- Project:
  - Apply what you learnt on a subset of the bitcoin transaction network

ROADMAP

- Class 1:
  - Theory:
    - Bitcoin transaction network
    - Basic Network Description measures
  - Practice:
    - Python data Manipulation
    - Networkx and Gephi

- Class 2:
  - Theory: Advanced network concepts: node clustering, dynamic networks, etc.
  - Practice: Bitcoin transaction data manipulation + Project

- Class 3:
  - Theory: Machine Learning on Graph
  - Practice: Project