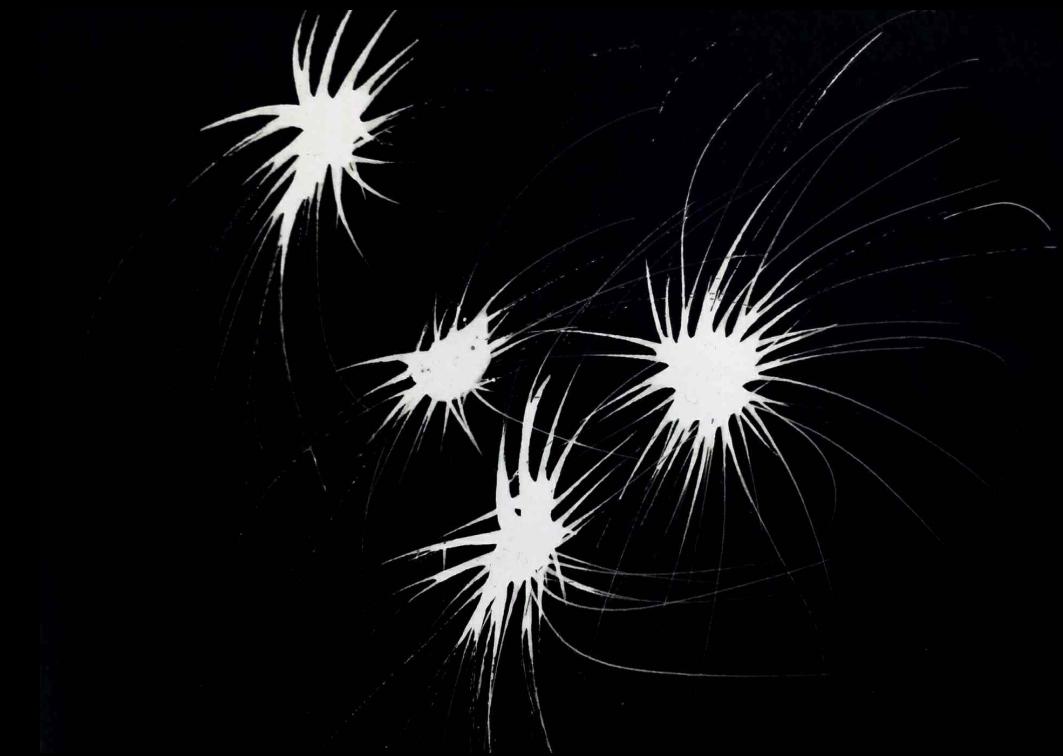
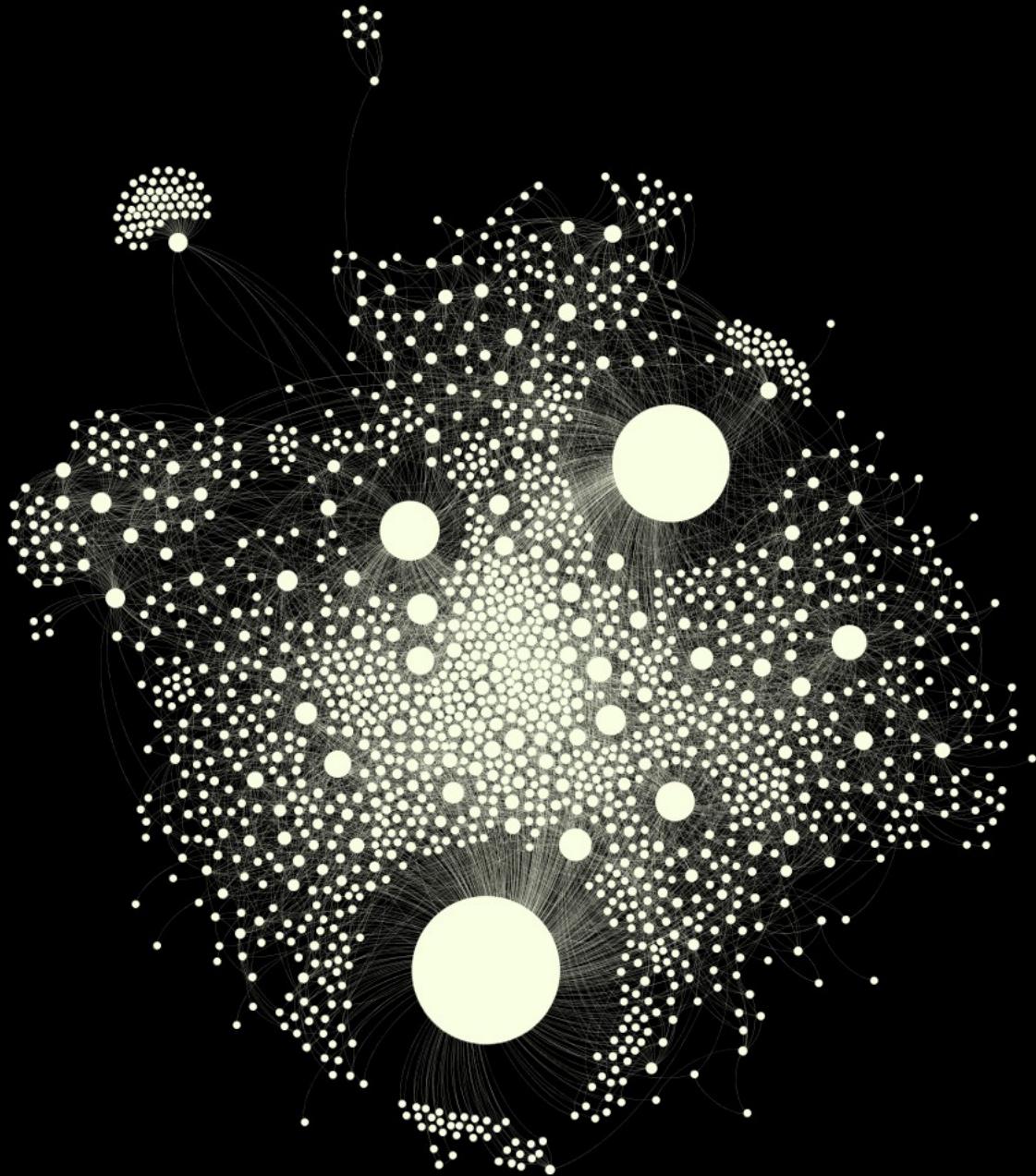


Marc Santolini, Liubov Tupikina, Marina Saburova,  
Roberto Toro, Katja Heuer, CRI  
ISCPiF ARTEX event  
October 12<sup>th</sup>, 2019

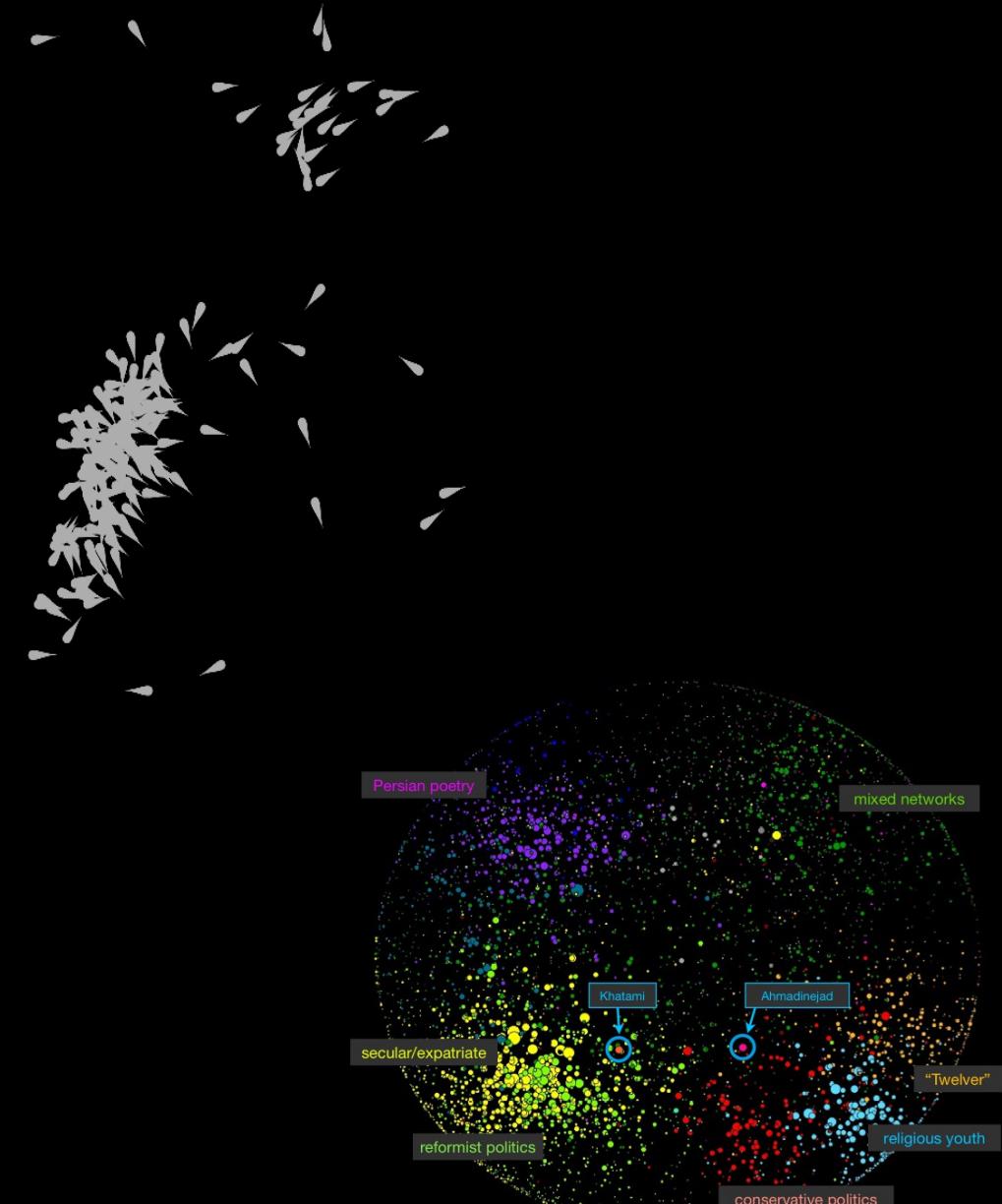


**"I think the next century will be the century of complexity."**  
**Stephen Hawking, 2000**

# Workshops:

## I Collective phenomena

## II Random networks



<https://journals.sagepub.com/doi/full/10.1177/2056305117691545>

# Collective phenomena:



# Collective phenomena:



In physics:

“In order to understand dynamics of a physical system we need to focus on the macro level and not on its parts: we look at flocking birds as one organism to understand its dynamics.”

Japanese art:

“In order to draw flocking birds or schools of fishes, one should not concentrate on each small part but instead to concentrate on the movement and depiction of one element which can express the whole”

# Collective phenomena:



Examples of numerical simulations:

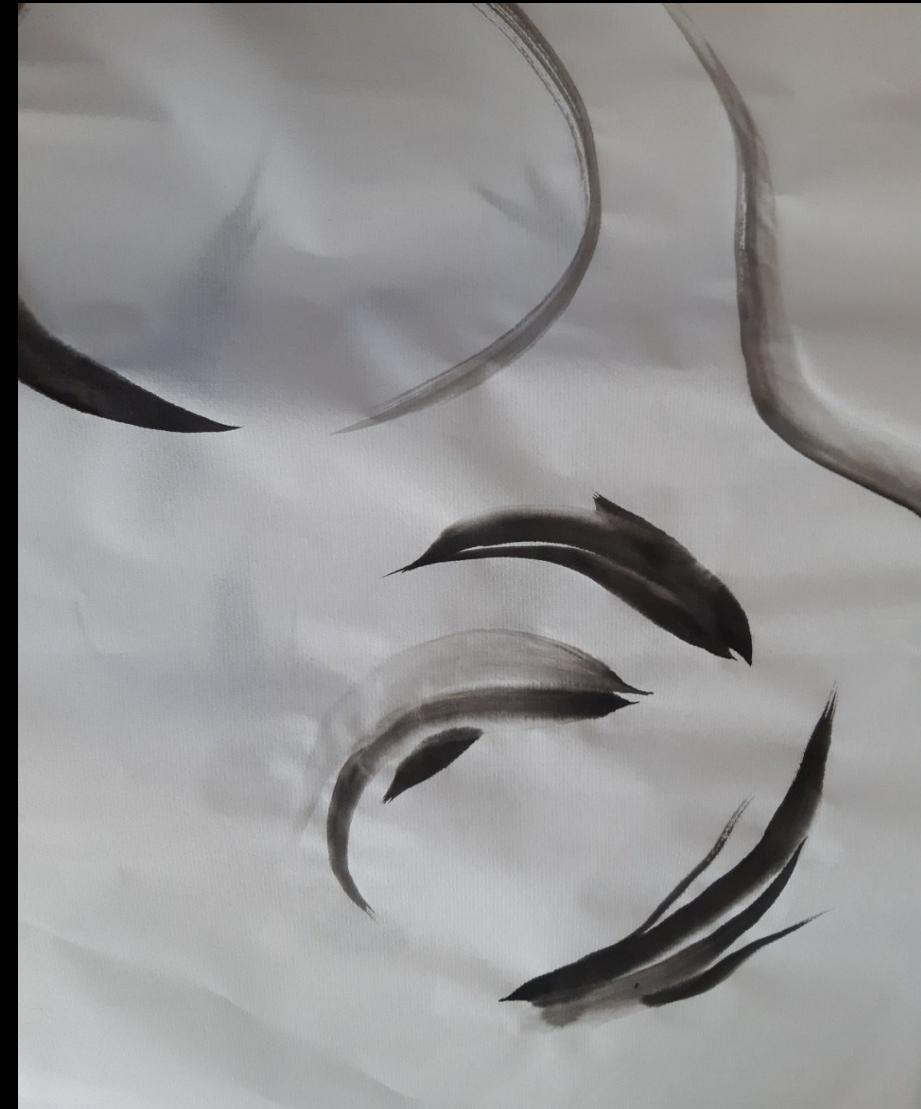
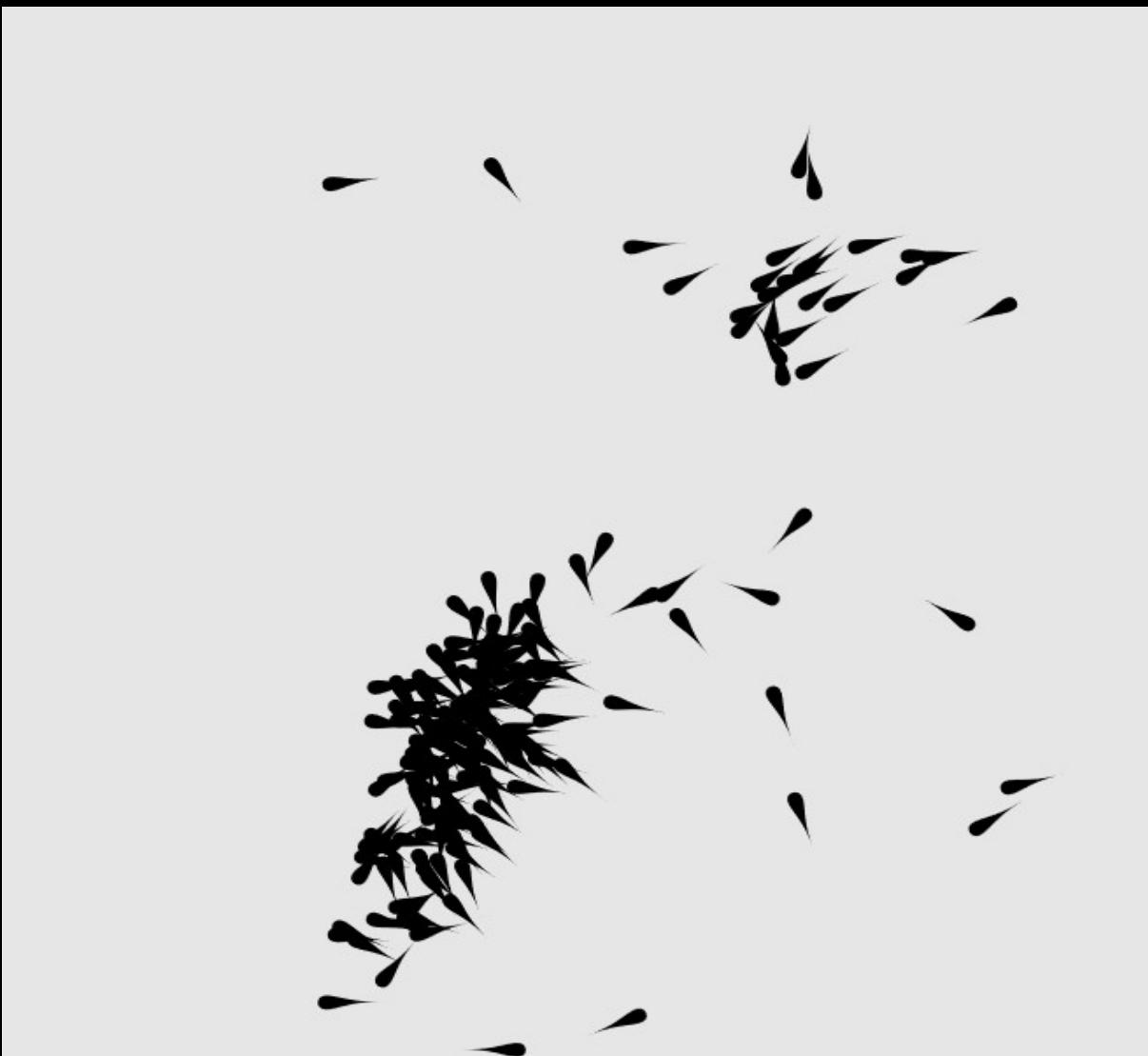
Complexity explorer from Pr.Brockman group <http://rocs.hu-berlin.de/>

<http://www.complexity-explorables.org/explorables/thrilling-milling-schelling-herings/>

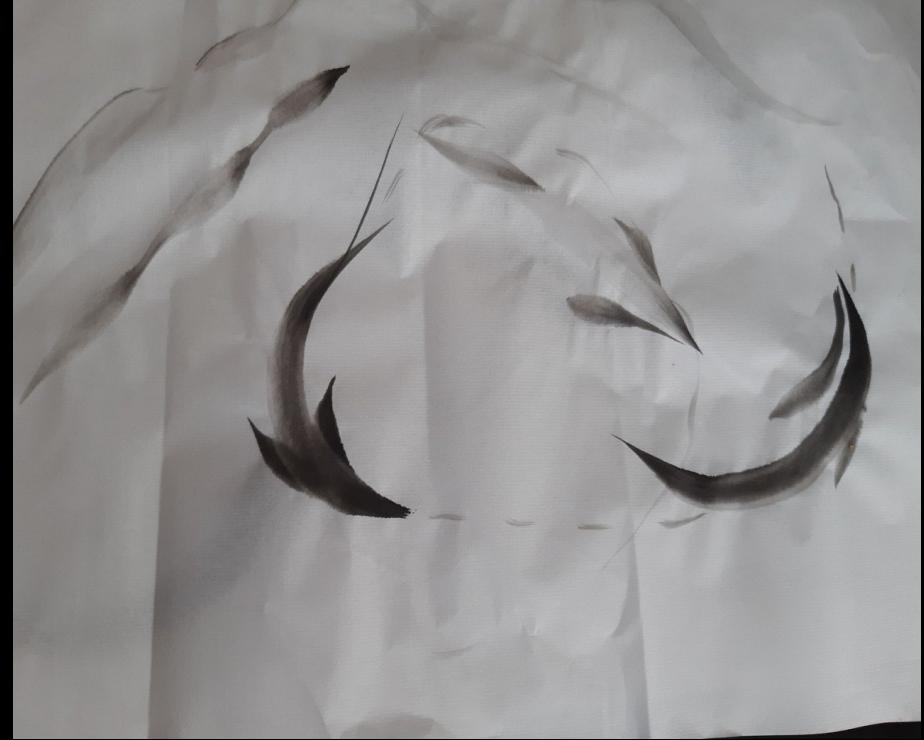
<https://www.sciencedirect.com/science/article/pii/S0022519302930651?via%3Dihub>

Flocking birds behaviour <http://www.xavibou.com/index.php/project/ornitographies/>

# Collective phenomena:



# Collective phenomena:

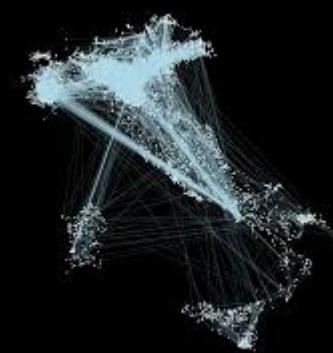
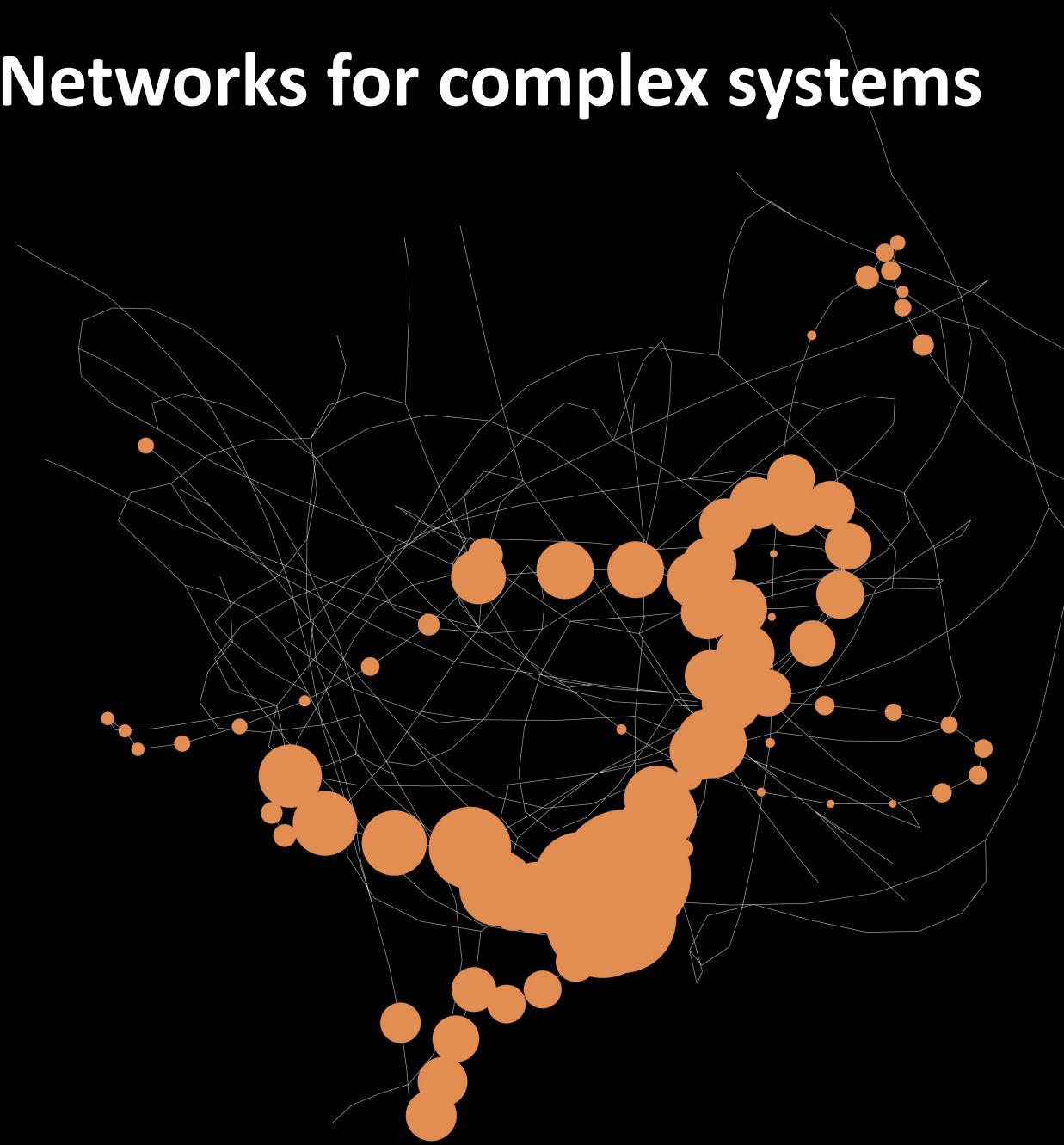


# **Networks science**

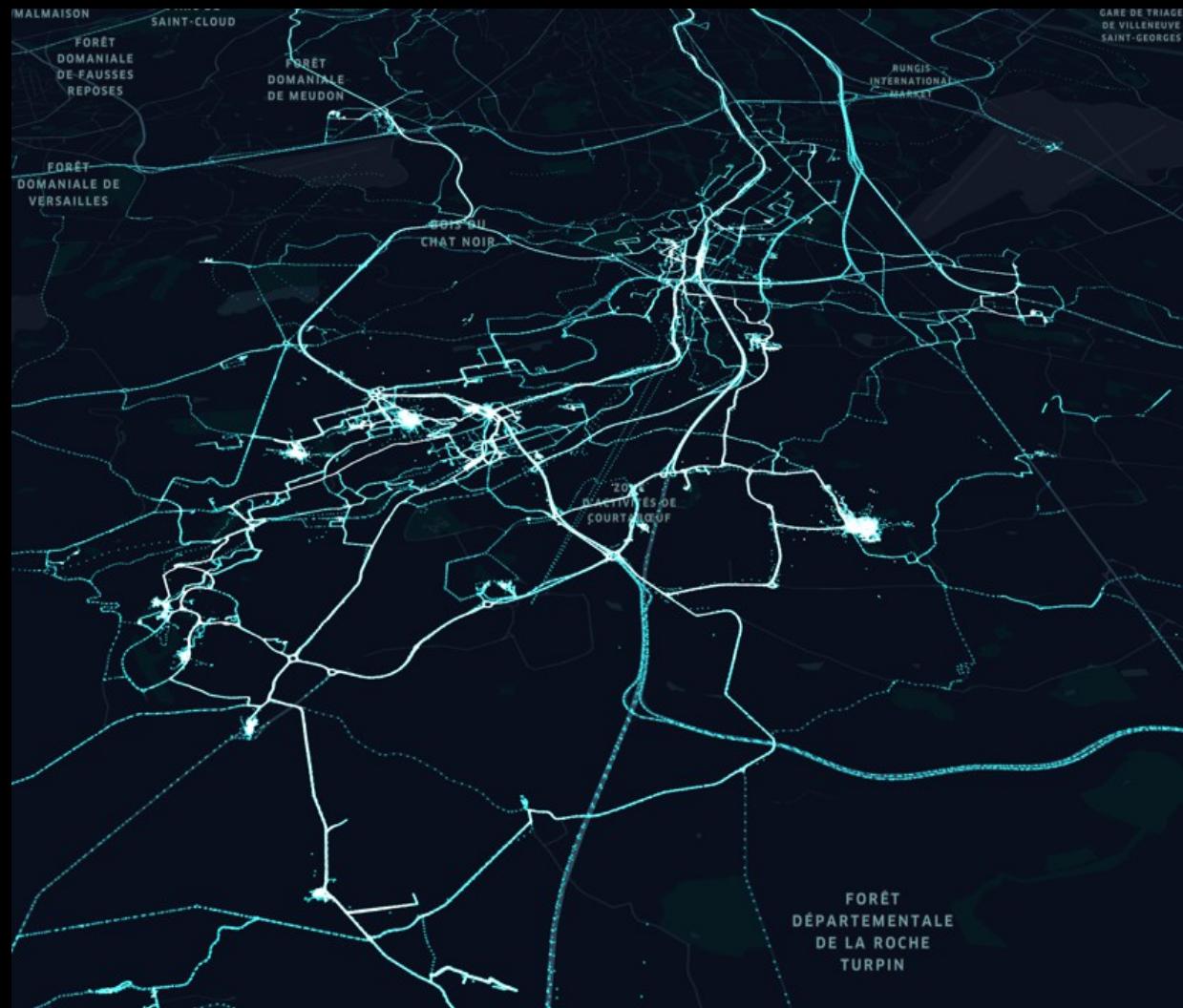
# Complex networks in nature



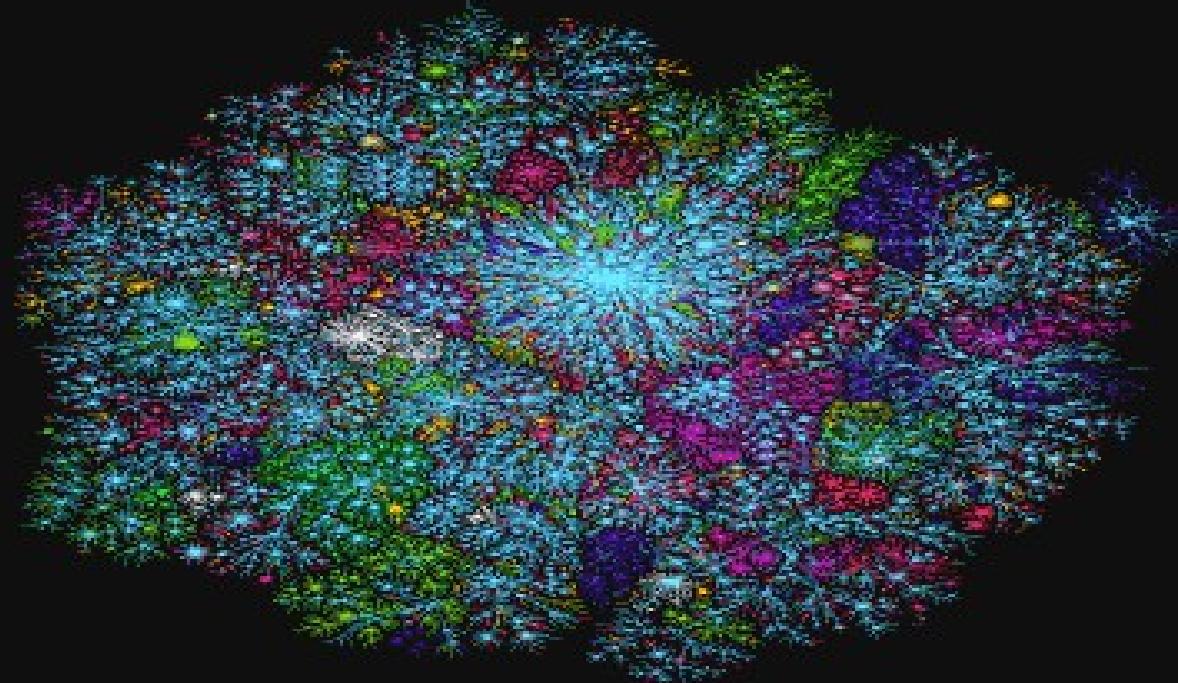
# Networks for complex systems



# Networks for complex systems

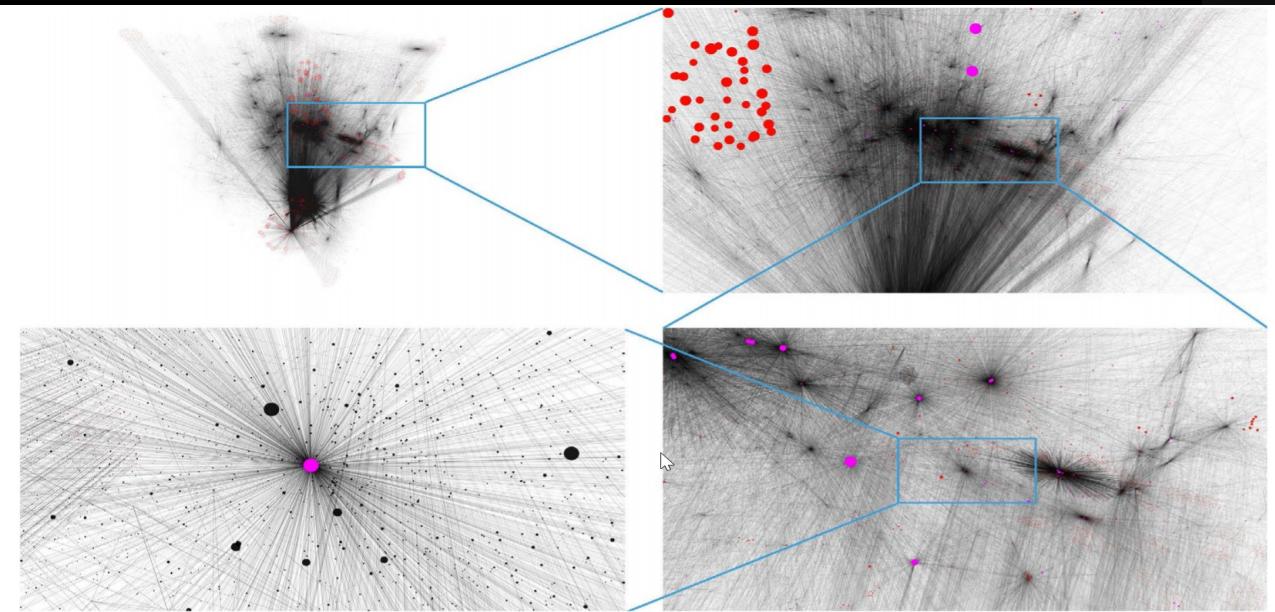
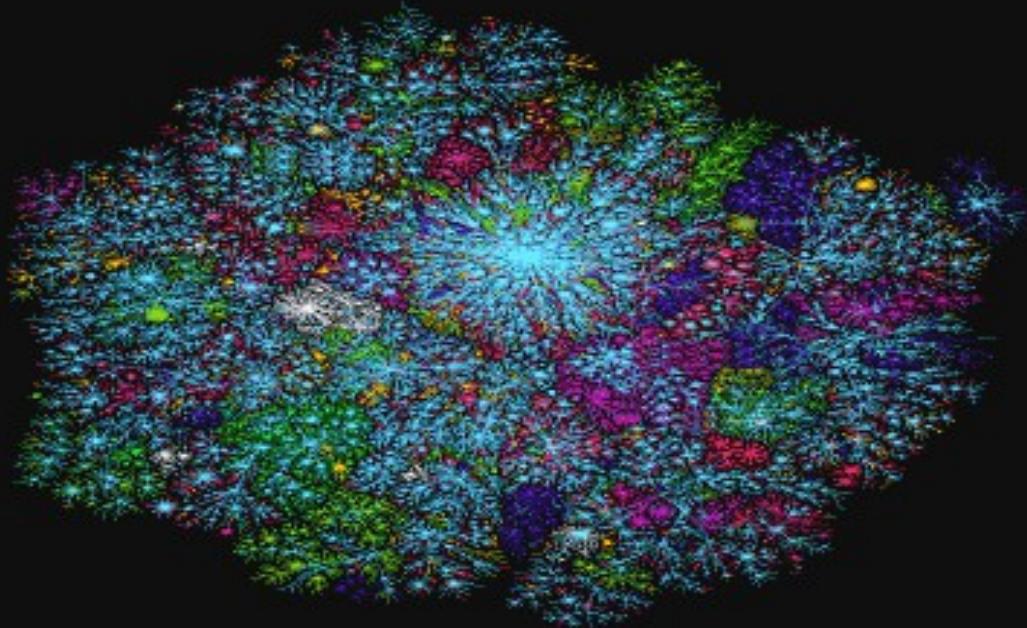


T H E   W H O L E   I N T E R N E T



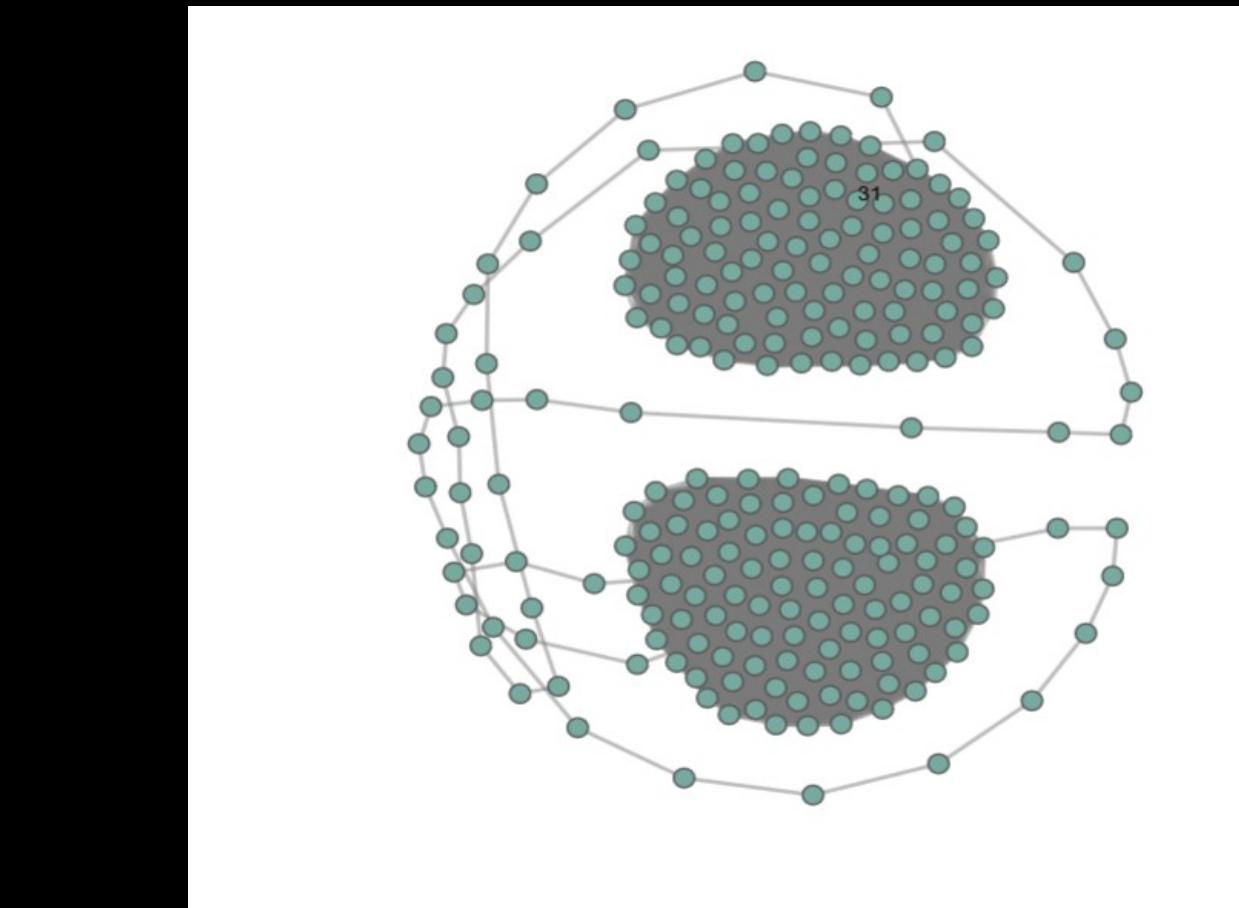
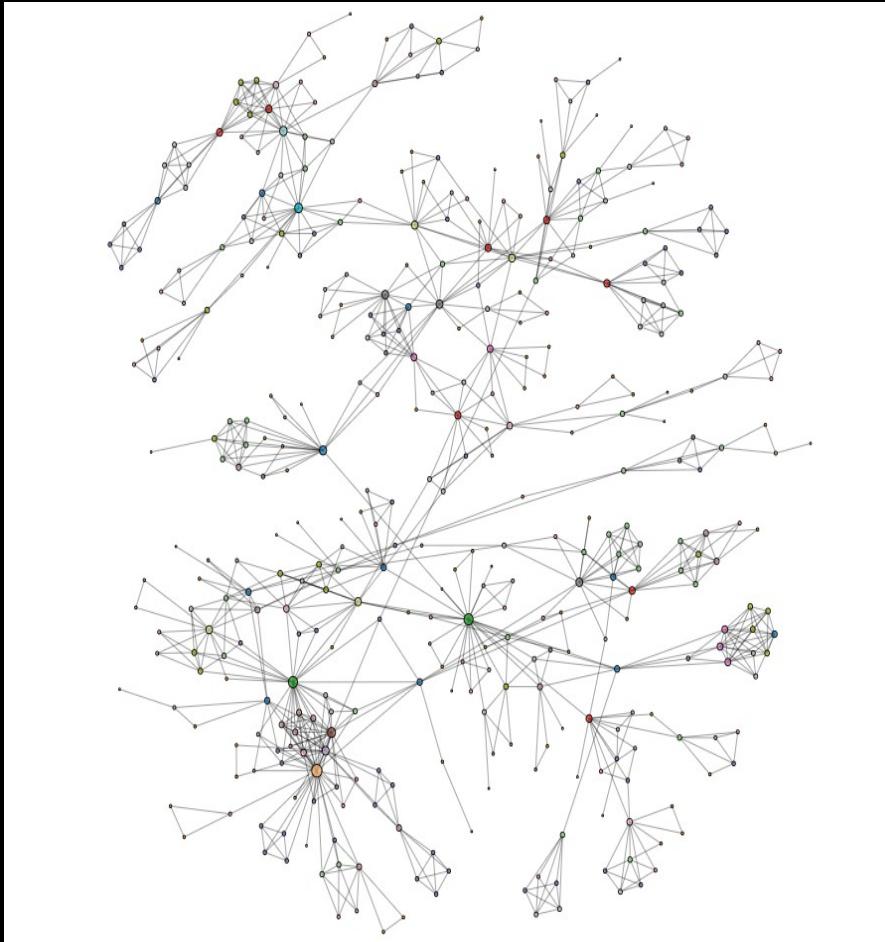
# Network resources

THE WHOLE INTERNET



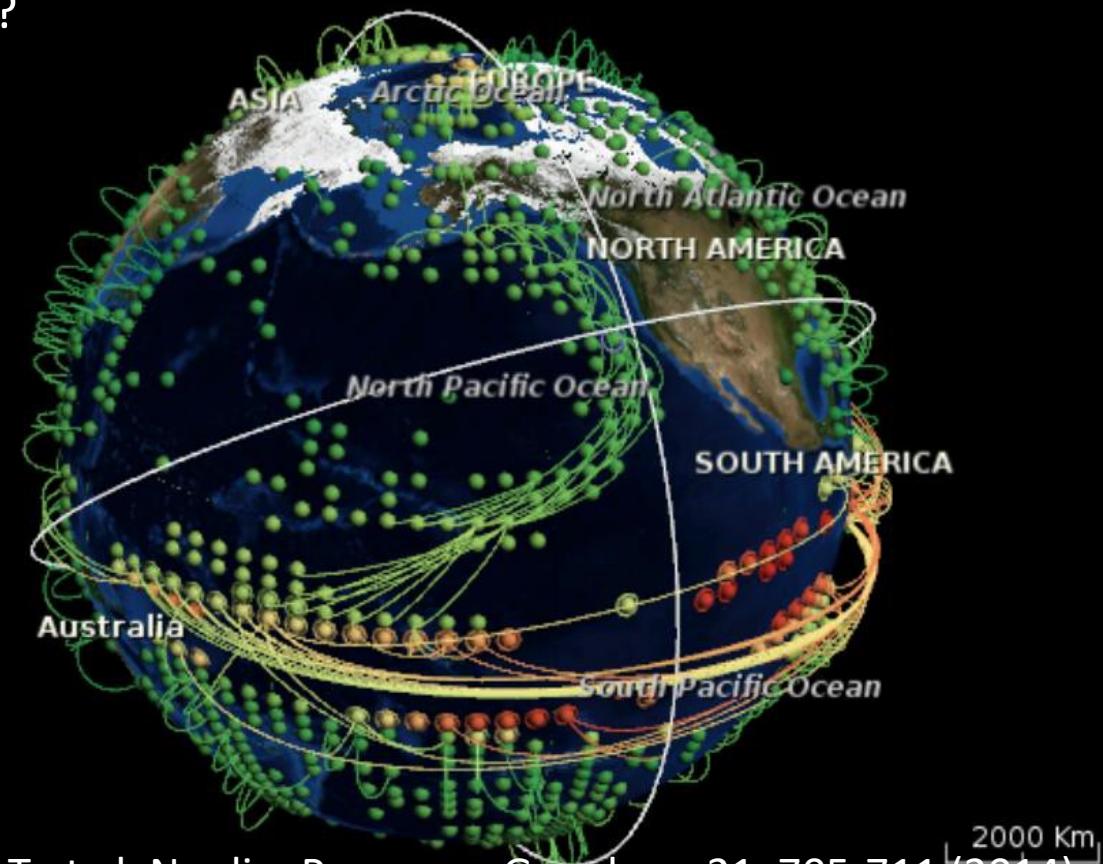
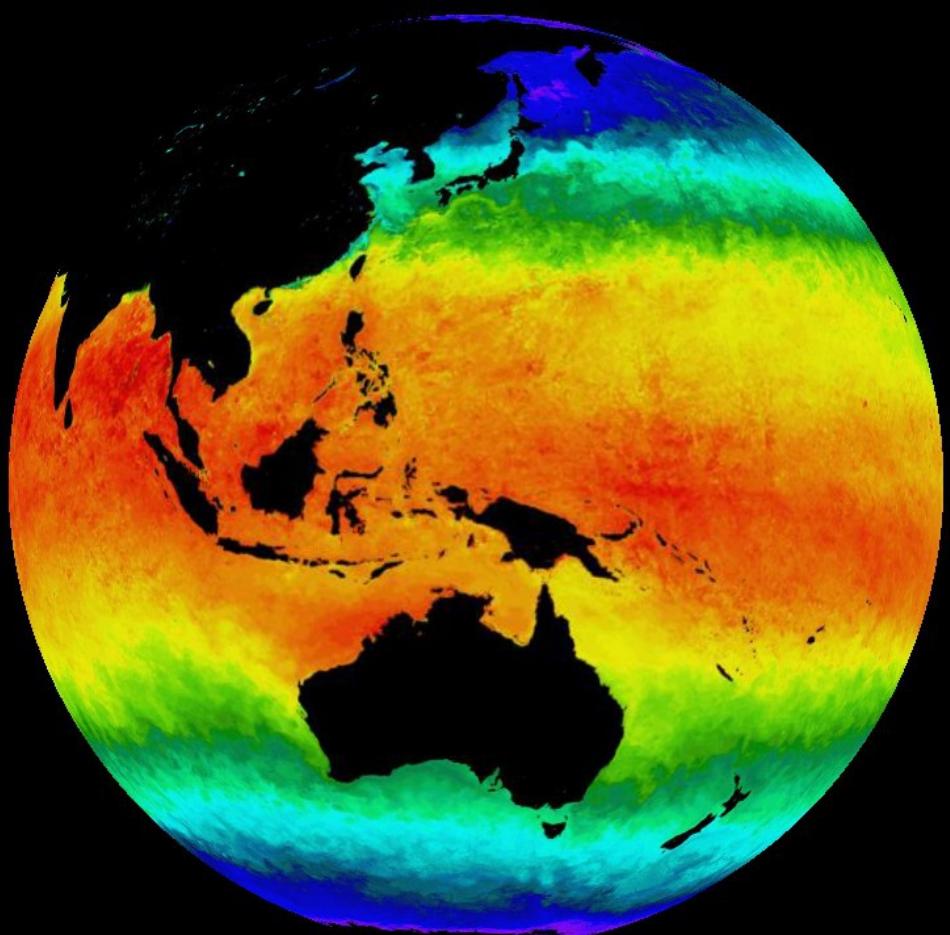
# Network visualisations platforms

<http://networkrepository.com/graph-vis.php>



Questions from physics and climatology:

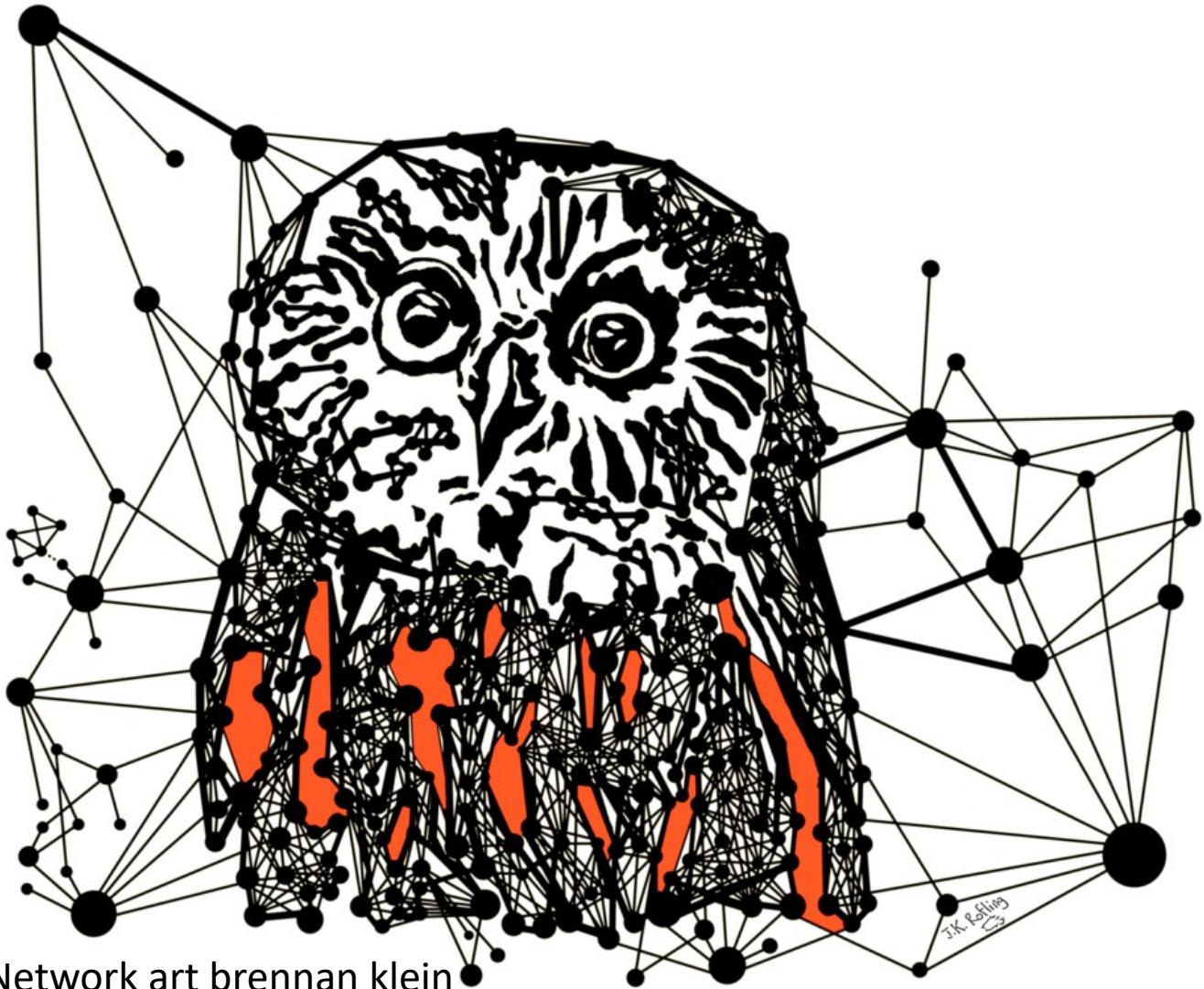
What is the meaning of correlations patterns in data structures?

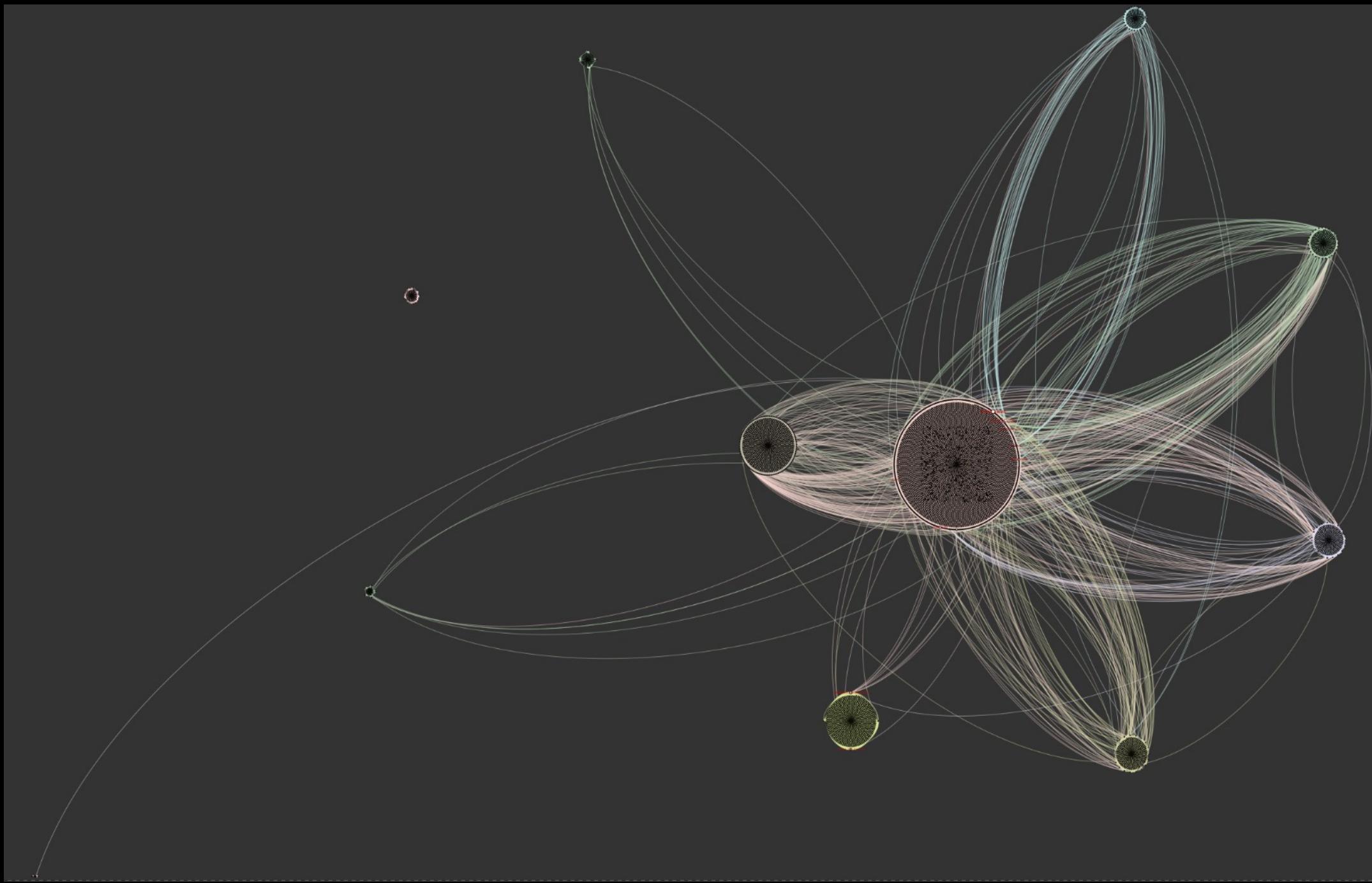


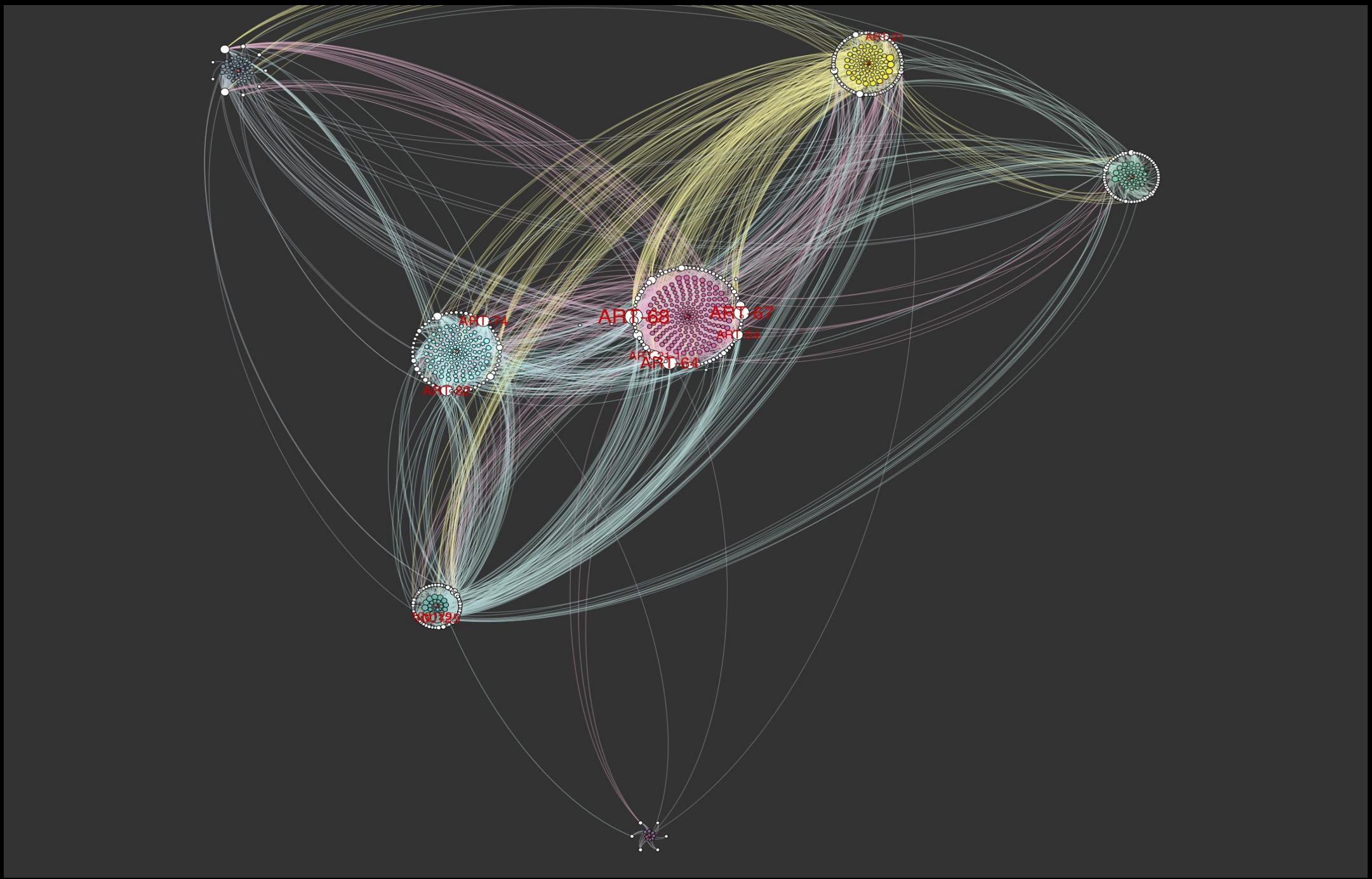
LT et al. Nonlin. Processes Geophys., 21, 705-711 (2014)

J.F. Donges et al. Chaos 25, 113101-1-25 (2015)

<http://www.pik-potsdam.de/~donges/pyunicorn/>



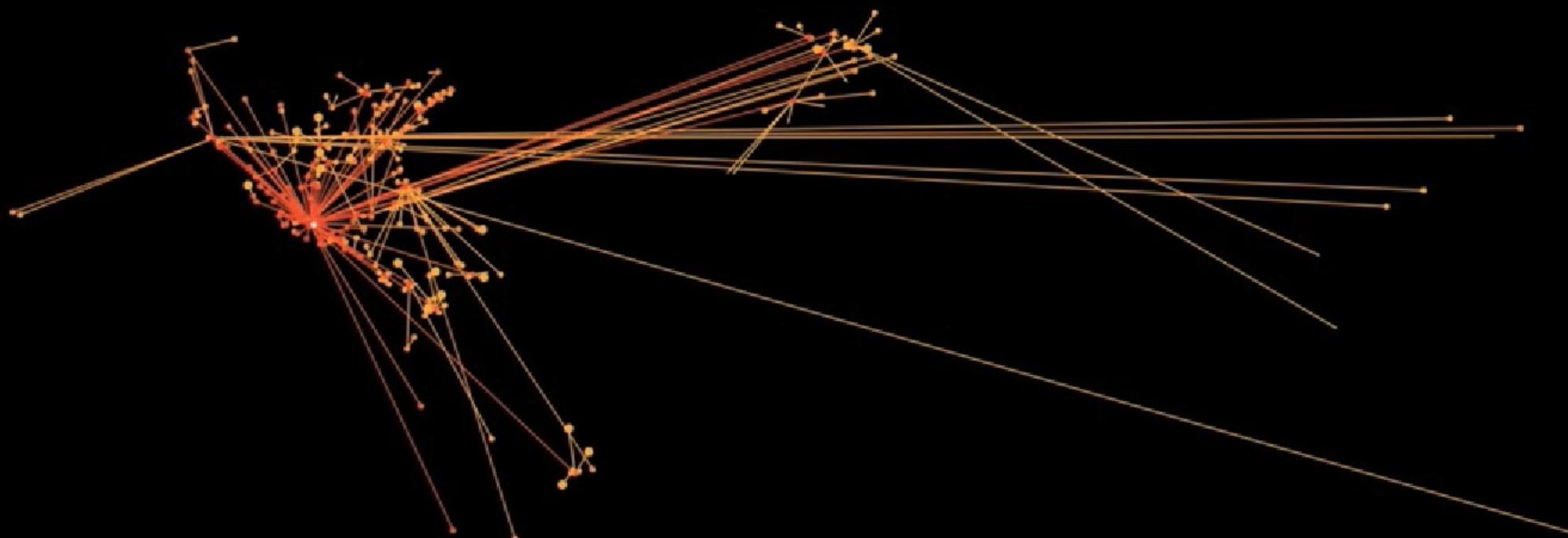




# Network visualisations platforms

<http://www.bleamviz.org> Vespignani GLEAM group

Jun 10 2009



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Frankfurt  
Amsterdam  
Rome  
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Moscow  
Dublin

Hong Kong  
Tokyo Narita  
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Manila

Sydney  
Brisbane  
Auckland  
Perth

# Network visualisations platforms

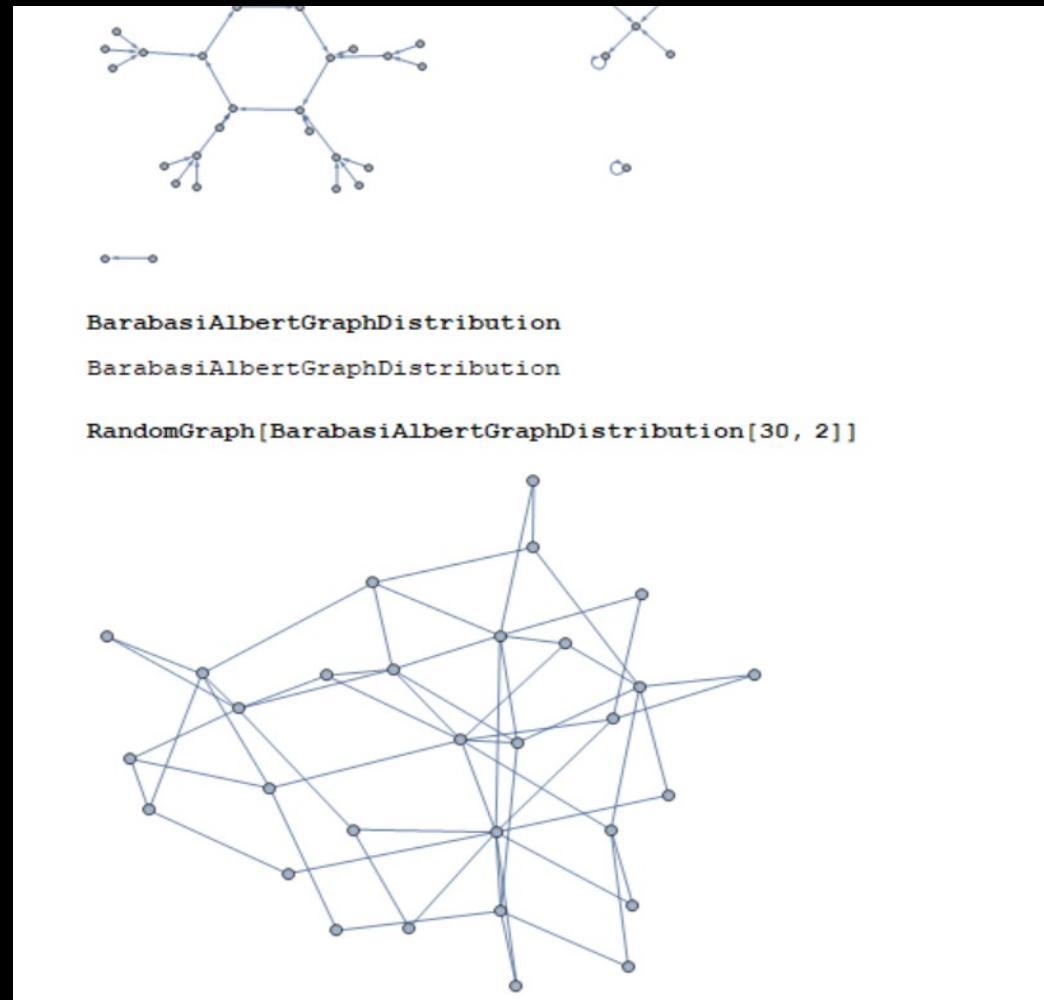
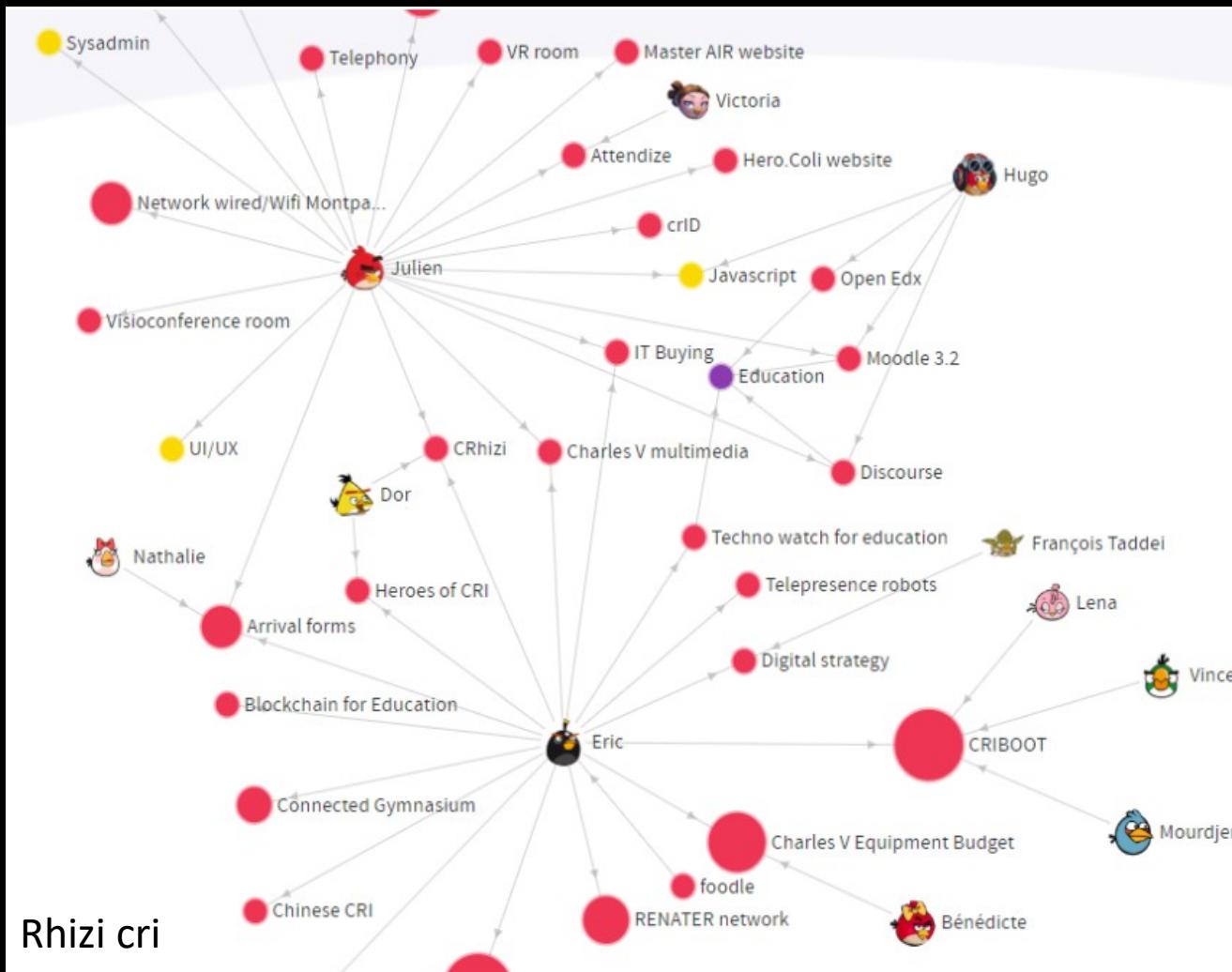
<http://www.gleamviz.org>

Aug 08 2009

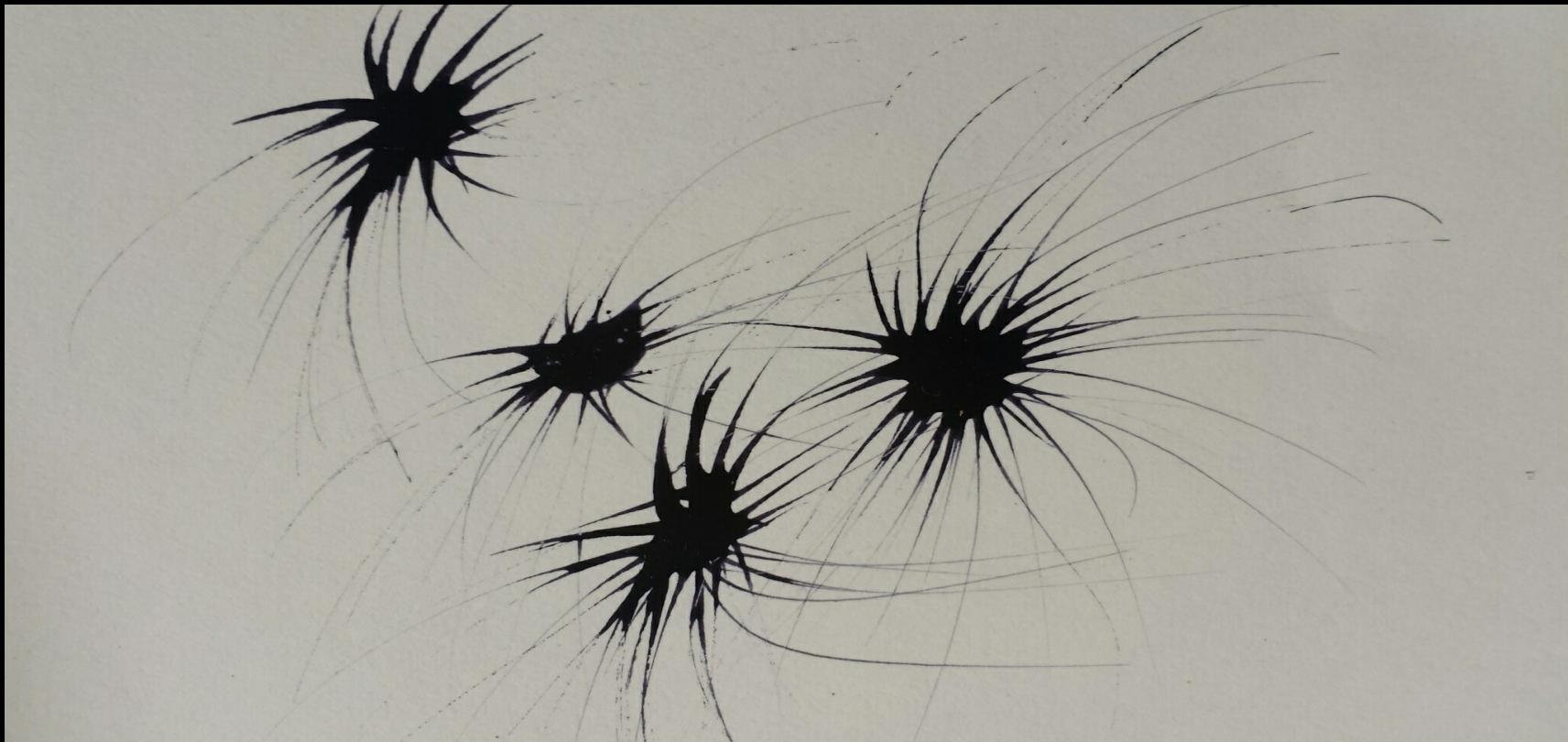


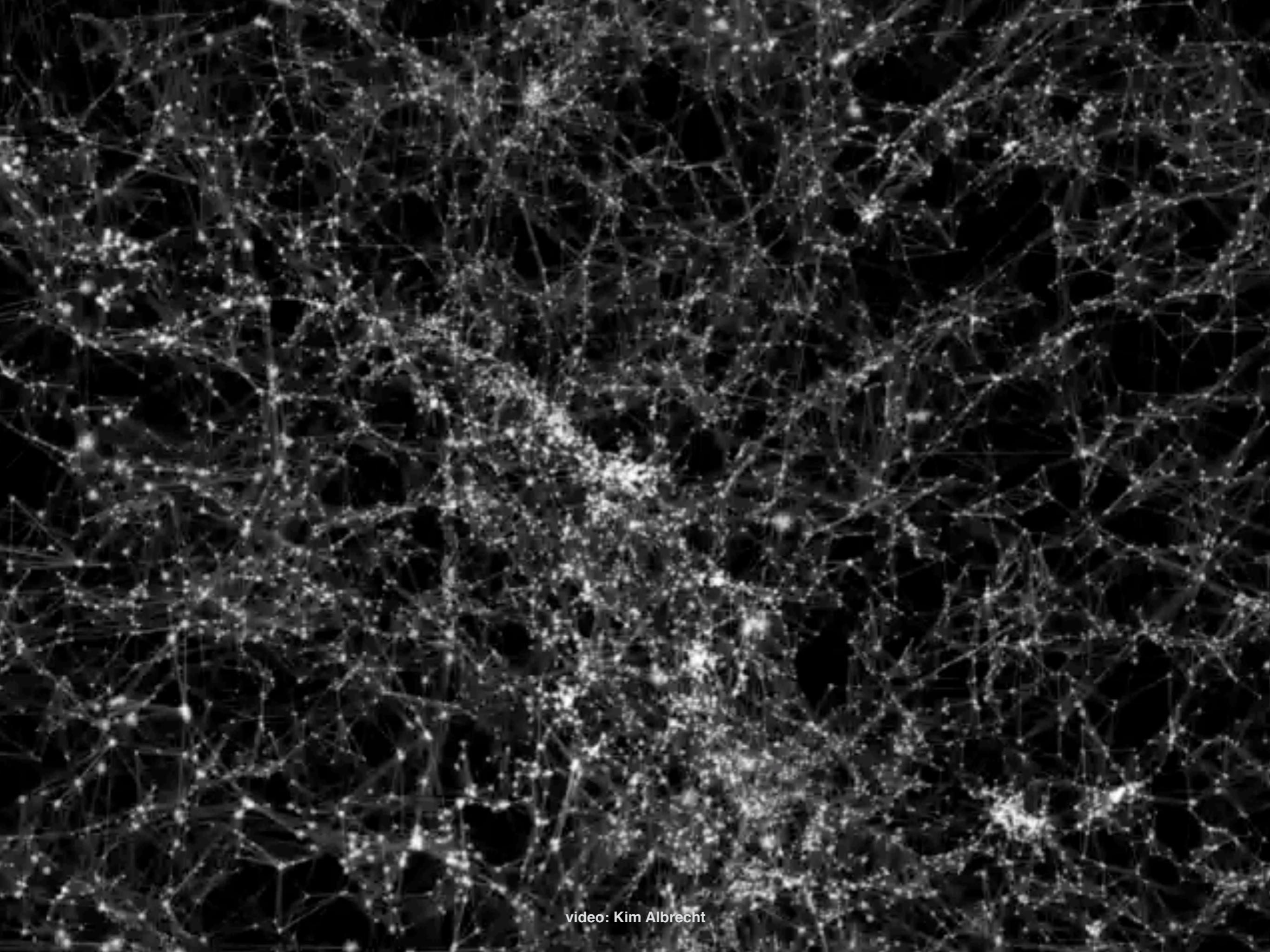
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Hong Kong  
Tokyo Narita  
Bangkok  
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Beijing  
Manila  
  
Sydney  
Brisbane  
Auckland  
Perth



Try it yourself



A dense network graph with many nodes and connections.

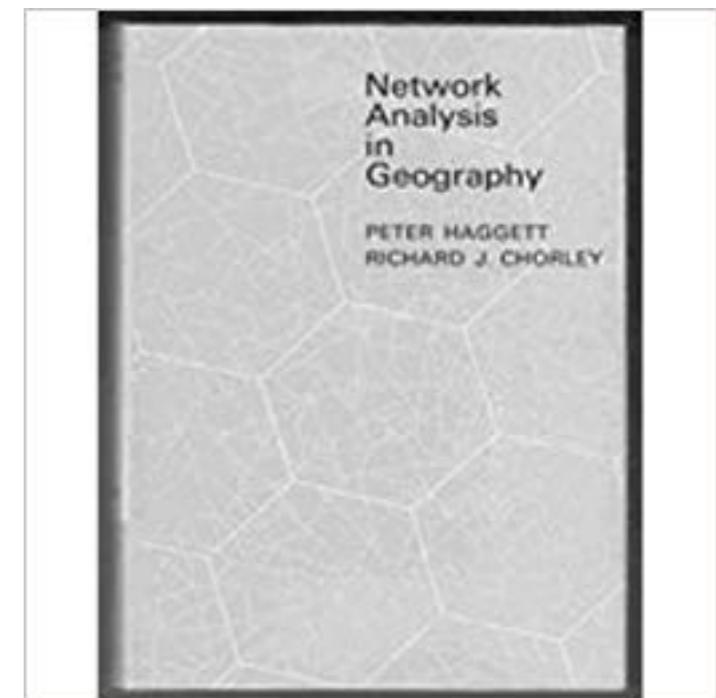
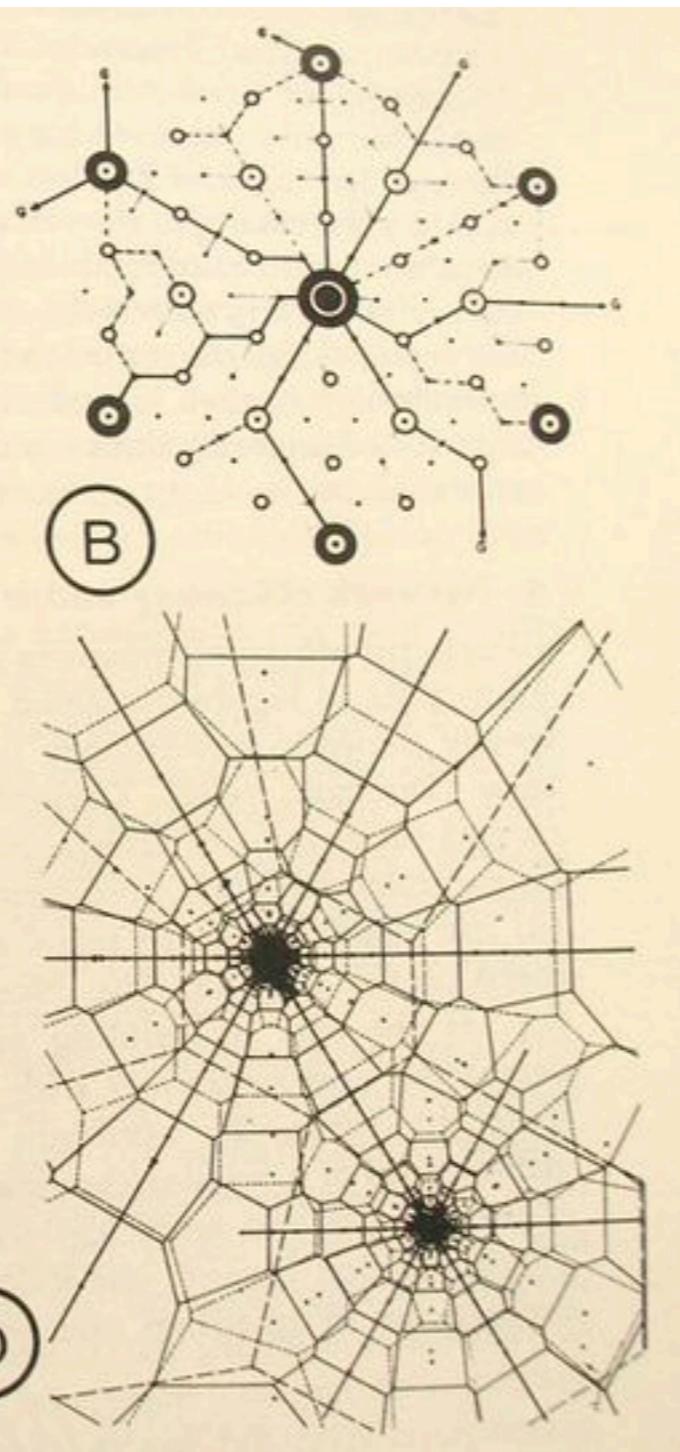
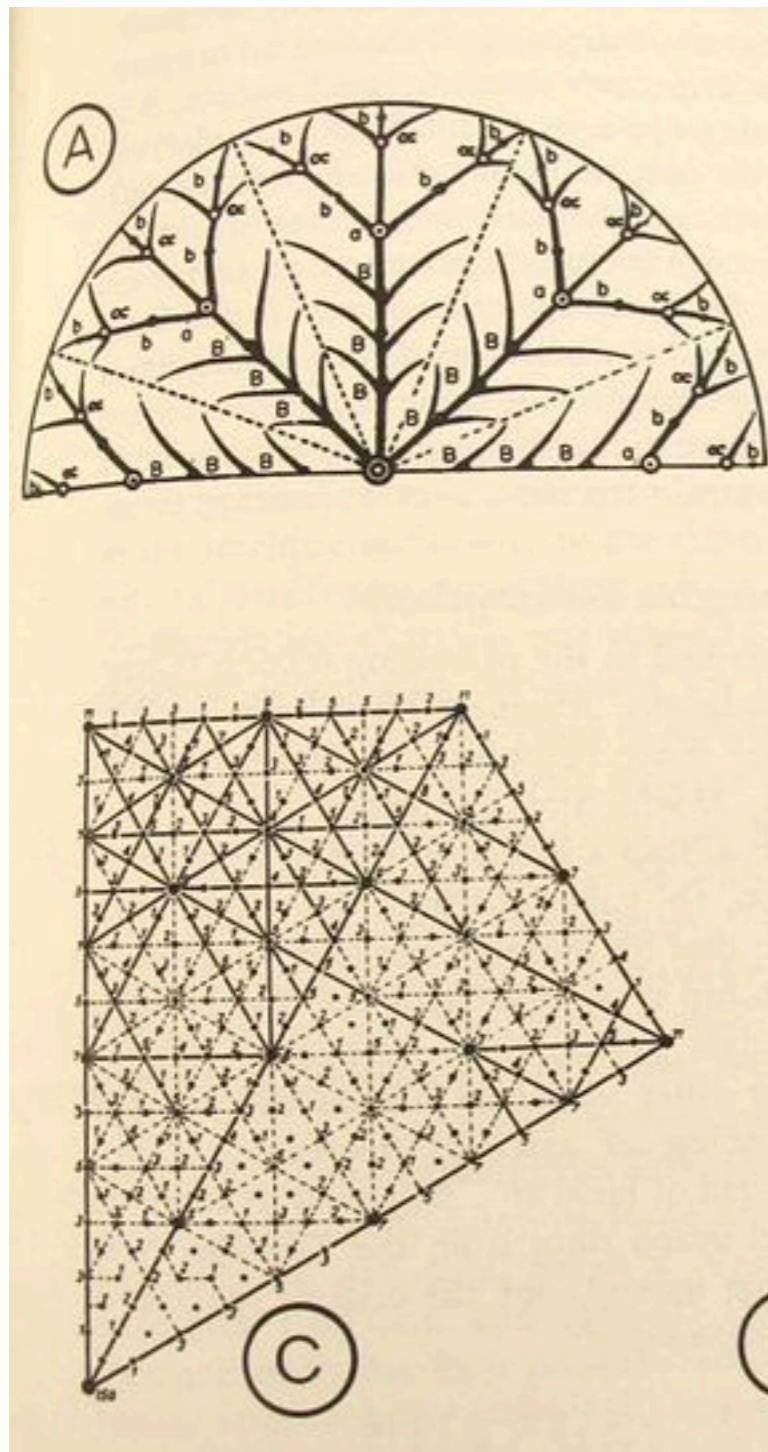
video: Kim Albrecht



**Camillo Golgi 1875**  
"diffuse nervous network"

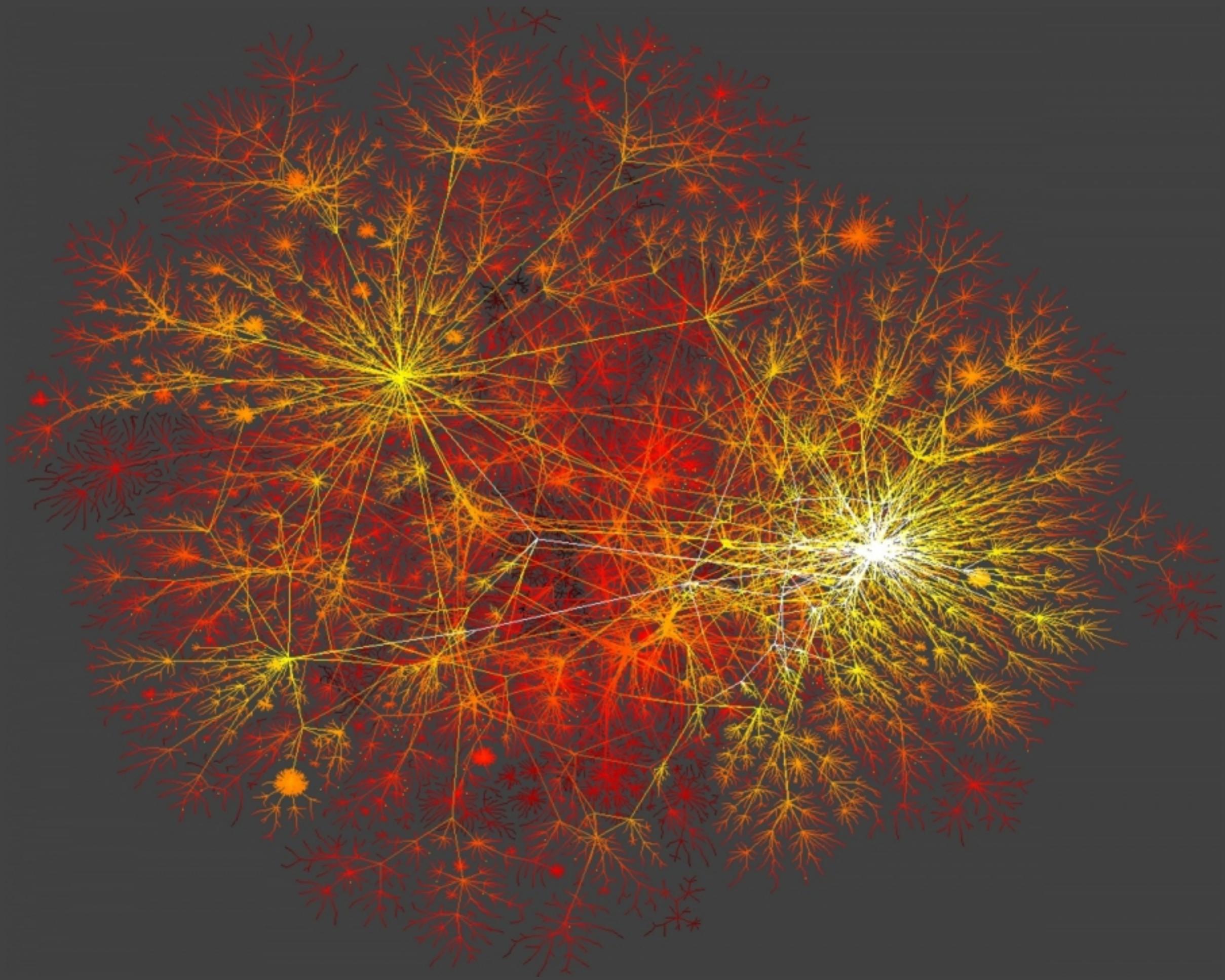


**Santiago Ramon y Cajal 1887**  
"cable theory"



**Network Analysis in Geography,  
1969, Haggett & Chorley**

**Transport networks for theoretical  
settlements** (A) Kohl, 1850 (B) Christaller, 1933  
(C) Losch, 1954 (D) Isard, 1960.



# Human Disease Network

Supporting Information Figure S9

Kwang-Il Goh, Michael E. Cusick, David Valle, Barton Childs, Marc Vidal, Albert-László Barabási

## Disorder Class

- Bone
- Cancer
- Cardiovascular
- Connective tissue disorder
- Dermatological
- Developmental
- Ear, Nose, Throat
- Endocrine
- Gastrointestinal
- Hematological
- Immunological
- Metabolic
- Muscular
- Neurological
- Nutritional
- Ophthalmological
- Psychiatric
- Renal
- Respiratory
- Skeletal
- multiple
- Unclassified

## Disorder Name

- 18 Acampegnic campodeal dysplasia  
 269 Adrenoleukodystrophy, very long chain fatty acids, type II  
 77 Adrenal hyperplasia, congenital  
 87 Alpha-1 antitrypsin deficiency  
 92 Alpha-thalassemia, mental retardation syndrome  
 93 Alpha-thalassemia, mental retardation  
 107 Analgesia from kappa-opioid receptor agonist, female-specific  
 117 Anterior segment anomalies and cataract  
 126 Anterior segment anomalies and cataract  
 137 Apparent mineralocorticoid excess, hypertension due to  
 144 Arrhythmogenic right ventricular dysplasia  
 163 Atypical hemolytic uremic syndrome  
 171 Attention deficit hyperactivity disorder  
 192 Bear-Sauvage cuts gyrata syndrome  
 198 Beta-2-adrenergic receptor, reduced response to  
 210 Beta-thalassemia, epiphyses, joints, and platelets  
 217 Bone mineral density variability  
 275 Cavernous malformations of CNS and retina  
 297 Cerebral hypoplasia  
 294 Cerebrovascular disease, occlusive  
 313 Chondrocalcinosis  
 320 Choracanthosis, hypothyroidism, and respiratory distress  
 347 Colonic aganglionosis, total with small bowel involvement  
 357 Cranial anomalies, empty sella turcica, corneal endothelial changes  
 378 Craniofacial dysmorphia  
 379 Craniofacial-skeletal-dermatologic dysplasia  
 386 Cyclic ichthyosis with episodic hyperkeratosis  
 418 Dermatofibrosarcoma protuberans  
 422 Dermatofibrosarcoma protuberans  
 438 Disordered steroidogenesis, isolated  
 439 Dissection of cervical arteries  
 441 Disorders of glucose homeostasis  
 453 Disorders of glucose homeostasis, with chondral neovascularization  
 461 Dyssegmental dysplasia, Silverman-Hamaderk type  
 471 Dysembryoplastic perineuronal glioma  
 474 Enzyme deficiency muscular dystrophy  
 529 Familial hypothyroidism  
 535 Fibrocalculus pancreatic diabetes  
 539 Fibrocalculus pancreatic diabetes  
 544 Fluorouracil toxicity, sensitivity to  
 545 Focal cortical dysplasia, Taylor cell type  
 549 Glomerular hematuria, proteinuria, with choroidal neovascularization  
 558 Fuchs endothelial corneal dystrophy  
 594 Glomerulopathy kidney disease, hypoplastic  
 601 Glutaric aciduria, organic aciduria  
 640 Glycogen storage disease  
 646 Hearing loss, low frequency sensorineural  
 659 Hemochromatosis, iron overload, hypoproteinemia  
 679 High-molecular-weight kininogen deficiency  
 695 Homocystine methylmalonic aciduria, cbt E type  
 701 Human immunodeficiency virus syndrome  
 727 Hyperkeratotic ectatic syndrome  
 734 Hyperkeratotic cutaneous capillary venous malformations  
 789 Hypoplastic enamel pitting, localized  
 792 Hydrax-like ichthyosis with deafness  
 803 Infundibular hypoplasia and hypopituitarism  
 809 Infundibular hypoplasia and hypopituitarism  
 820 Juvenile polyposis/hereditary hemorrhagic telangiectasia syndrome  
 833 Keratitis-ichthyosis-deafness syndrome  
 845 Keratitis-ichthyosis-deafness syndrome  
 847 Keratots palmarplantaris stritra  
 868 Leber congenital amaurosis  
 891 Leukodystrophy with vanishing white matter  
 912 Lower motor neuron disease, progressive, without sensory symptoms  
 930 Malignant hypertension susceptibility  
 945 Malignant hypertension, with hypotension  
 959 Mastocytosis with associated hematologic disorder  
 969 Maternal cytomegalovirus infection  
 982 Meckel-Gruber syndrome with osteopetrosis  
 1001 Methionine adenosyltransferase deficiency, autosomal recessive  
 1052 Mitochondrial DNA depletion  
 1016 Mitochondrial complex deficiency  
 1056 Myoglobinuria/hemolysis due to PFK deficiency  
 1057 Myopathy with necrotic epilepsy  
 1089 Nephritis, hematuria, proteinuria, hypertension  
 1090 Neural tube defects, material risk of  
 1098 Non-Hodgkin lymphoma  
 1104 Nevus, epidermal, epidermolytic hyperkeratotic type  
 1110 Newfoundland rod-cone dystrophy  
 1111 Norwalk virus infection, resistance to  
 1132 Ocular coloboma, epiphyses, and skeletal ligaments  
 1140 Oligodendroglial-cerebral cancer syndrome  
 1153 Optic nerve atrophy, progressive, and adult forms  
 1164 Osteopetrosis, pseudogliomas syndrome  
 1174 Full-blown leptinopathy  
 1183 Primary hypothyroidism, hypopituitarism, periorbital edema  
 1227 Pigmentation of hair, skin, and eyes, variation in  
 1232 Pituitary ACTH-secreting adenoma  
 1238 Pneumonitis, desquamative interstitial  
 1239 Pseudogliomas syndrome  
 1263 Prion disease with protracted course  
 1265 Prostaglandins, hyperthyroidism, with mitochondrial DNA deletions  
 1267 Pyruvate dehydrogenase deficiency  
 1323 Robinow syndrome, with epiphyses  
 1335 Robinow syndrome, autosomal recessive  
 1342 Rhabdomyopathy, progressive, and adult forms  
 1361 Schwartz-Jampel syndrome, type I  
 1376 Sensory static neuropathy, dysarthria, and ophthalmoplegia  
 1383 Sjögren syndrome  
 1396 Silver spastic paraparesis syndrome  
 1401 Solitary fibrous tumor  
 1414 Solitary median maxillary central incisor  
 1424 Staphylococcal scalded skin syndrome  
 1438 Staphylococcal scalded skin syndrome  
 1446 Stevens-Johnson syndrome, carbamazepine induced  
 1456 T-cell lymphoma, primary  
 1472 T-cell lymphoma, primary  
 1476 Tissue pathology and respiratory failure  
 1490 Thiamine pyrophosphate dysesthesias types I and II  
 1513 Transient hemiparesis  
 1519 Transposition of great arteries, dextro-looped  
 1520 Transposition of great arteries, levo-looped  
 1528 Tricuspid-pseudocomplicated syndrome  
 1542 Ultrasound-assisted microneurolytic  
 1543 Ultrasound-assisted microdissection  
 3037 Multiple cutaneous and uterine leiomyomatosis  
 3144 Uterine leiomyomatosis, with endometriosis  
 3212 Persistent insulinsulinemic hypoglycemia of infancy  
 3260 Premature chromosome condensation, with microcephaly, mental retardation  
 3270 Total idioleptic organic disease  
 3282 Venous thromboembolism, idiopathic  
 4291 Cerebral cavernous malformations  
 5233 Ovarian steroid sulfatase deficiency

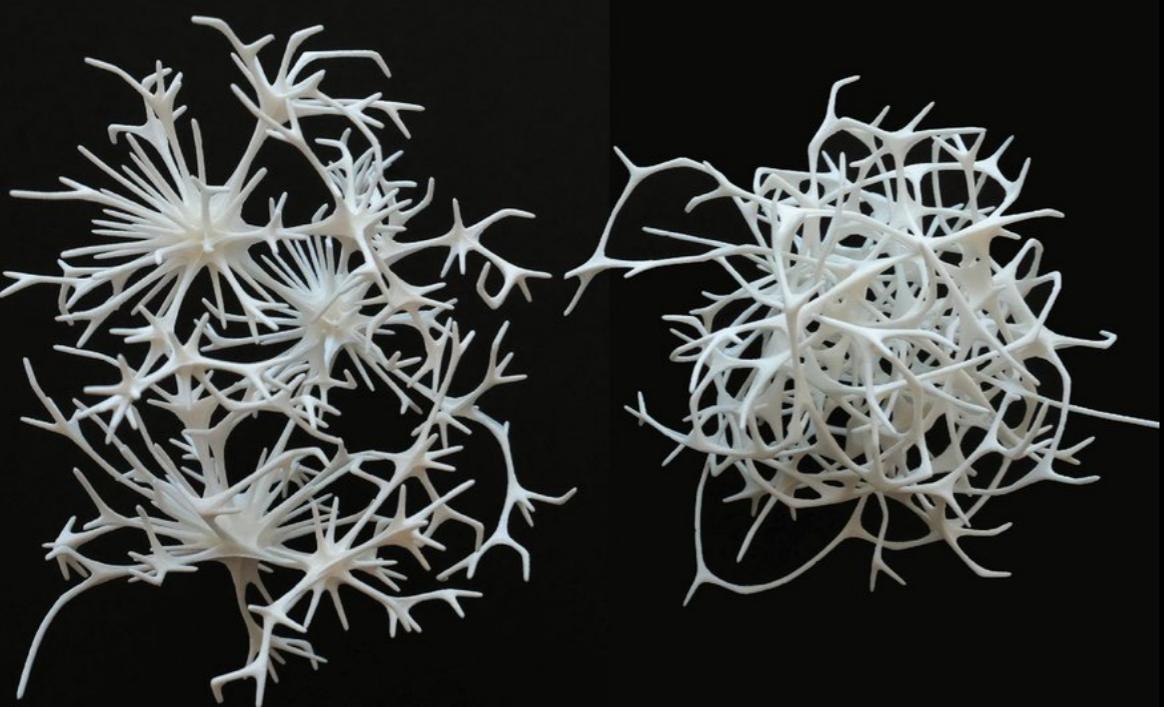
Supporting Information Figure S9 | Bipartite-graph representation of the diseaseome. A disorder (circle) and a gene (rectangle) are connected if the gene is implicated in the disorder. The size of the circle represents the number of distinct genes associated with the disorder. Isolated disorders (disorders having no links to other disorders) are not shown. Also, only genes connecting disorders are shown.

# 3D printing networks

OUTLOOK  
Digital revolution

# nature

THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE



**CLEAR CONNECTIONS**

Architecture of physical networks rendered in 3D **PAGE 676**

**RESEARCH**

**BULLYING IN SCIENCE**  
Are universities and funding agencies doing enough?  
**PAGE 616**

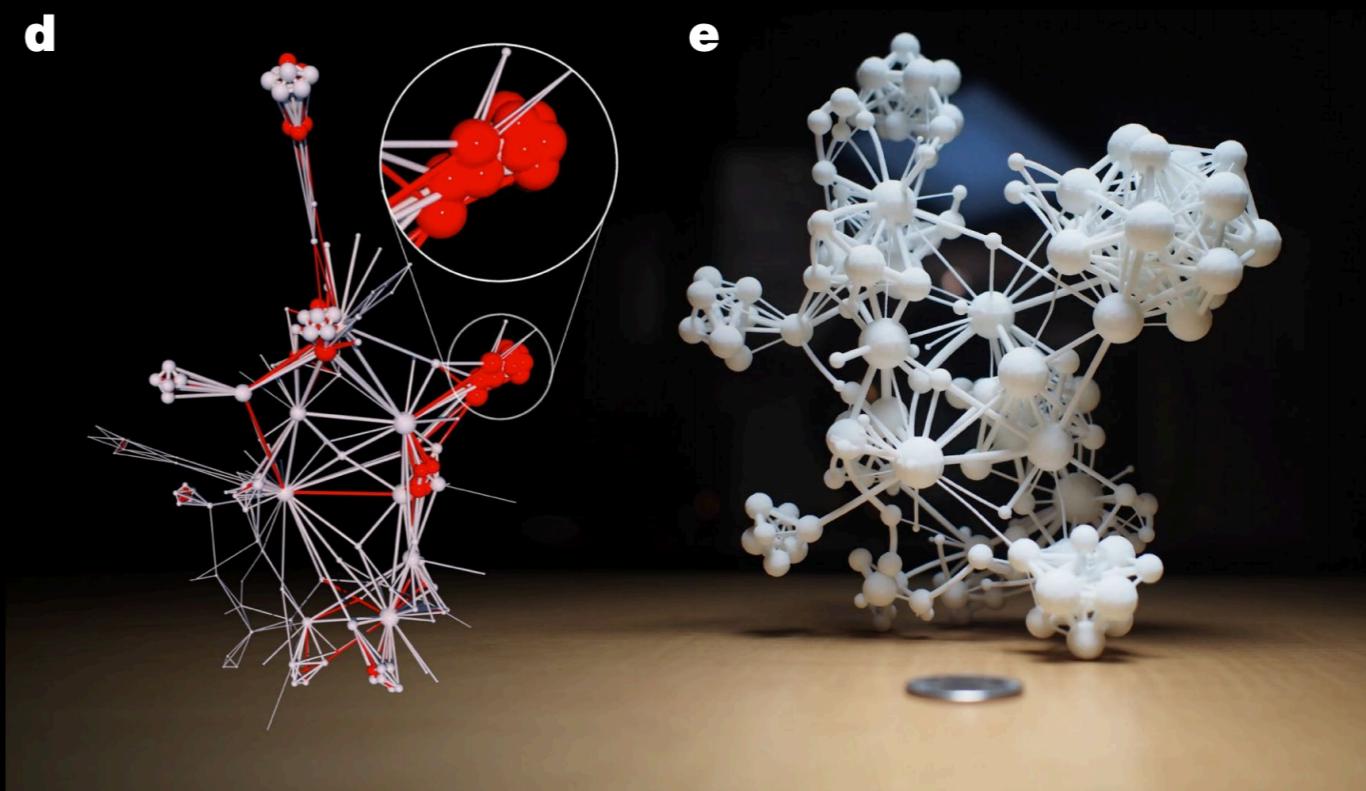
**MICROBIOLOGY**

**A ROUTE TO RESISTANCE**  
Virus helps *Staphylococcus* evade the immune system  
**PAGES 637 & 705**

**PALAEONTHROPOLOGY**

**NEANDERTHAL VIOLENCE**  
Skulls reveal hominins' bad reputation is unwarranted  
**PAGES 634 & 686**

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Dehmamy et al, Nature (2018)

