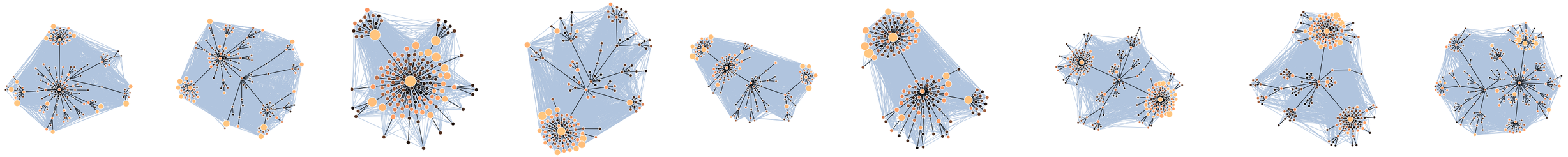
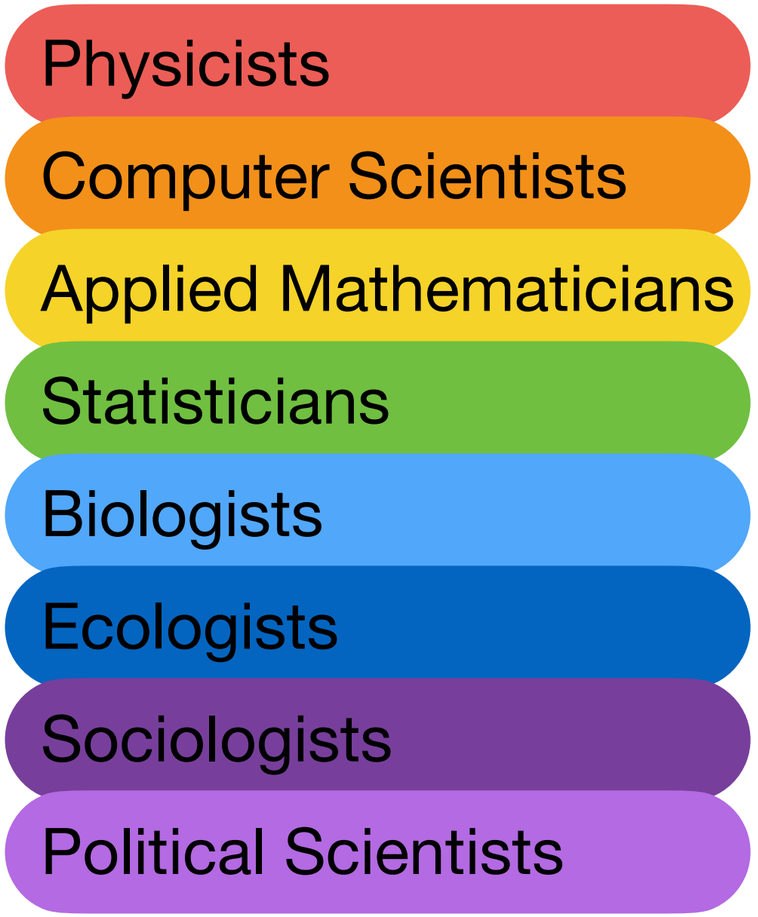


Network Analysis & Modeling

lecture 0: what are networks and how do we talk about them?

Prof. Aaron Clauset
Computer Science & BioFrontiers Institute
@aaronclauset
aaron.clauset@colorado.edu

who are network scientists?

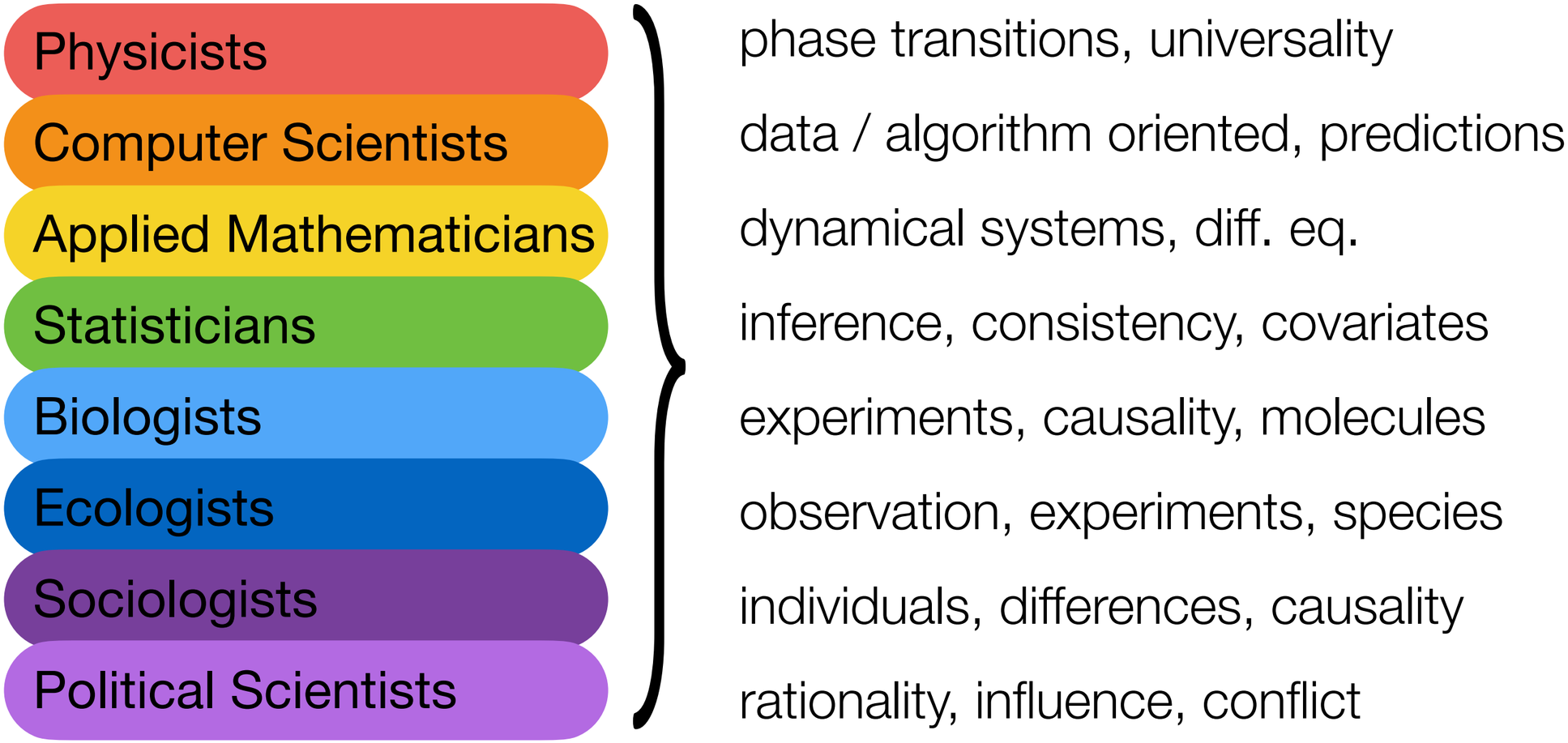


it's a big community!

- different *traditions*
- different *tools*
- different *questions*

increasingly, not ONE community,
but MANY, only loosely interacting communities

who are network scientists?

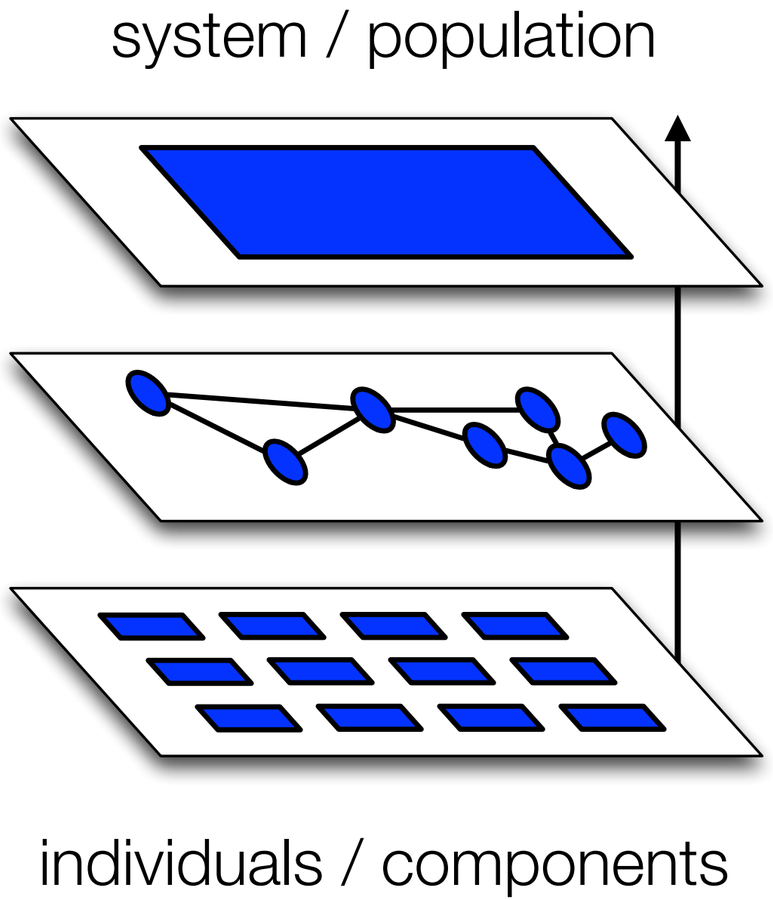


what are networks?

an approach.
a mathematical representation
provide structure to complexity.

structure that exists *above*
individuals / components

or: structure that exists *below*
system / population



tools and resources

Software

R
Python
Matlab

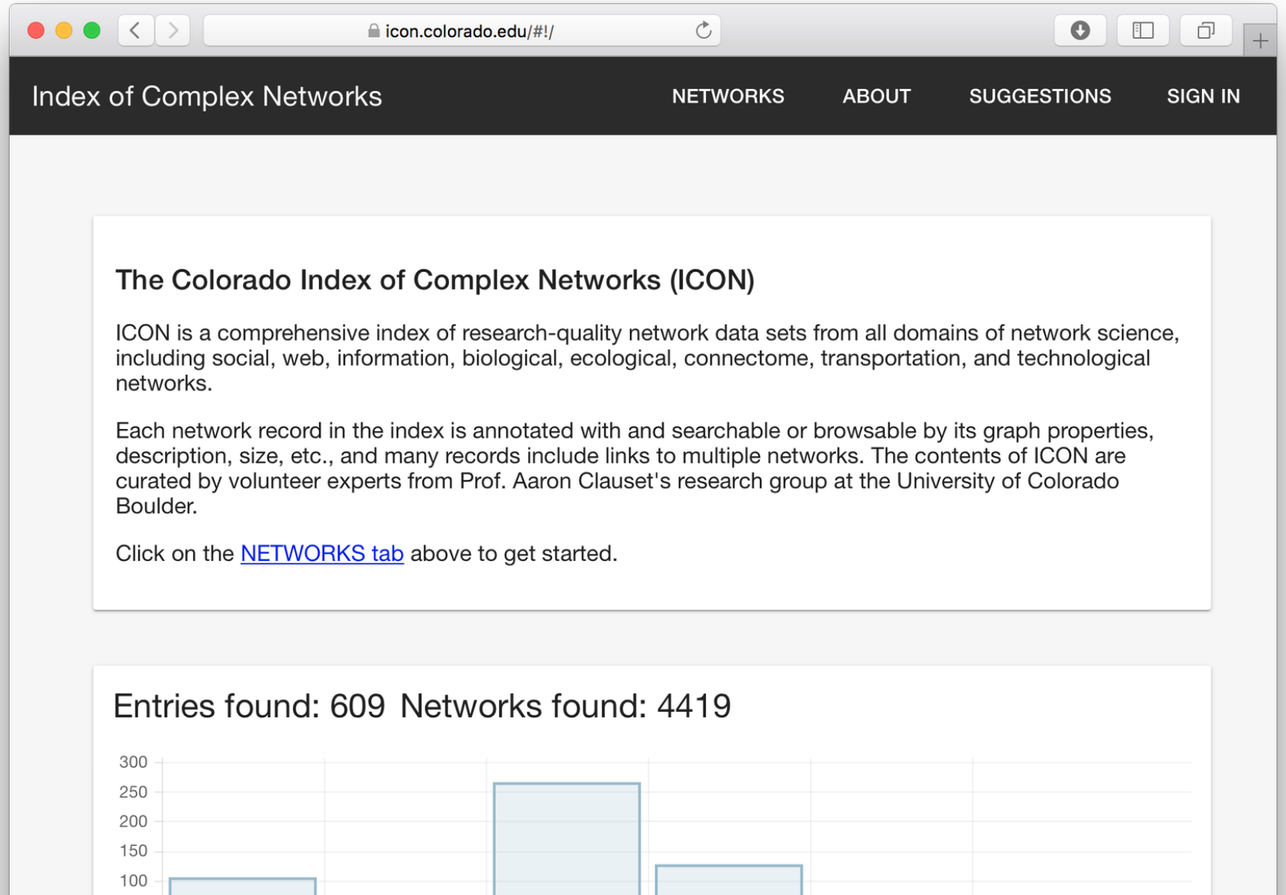
⭐ NetworkX [python]
⭐ igraph [python, R, c++]
graph-tool [python, c++]
graspologic [python]

Standalone editors

UCI-Net
NodeXL
Gephi
Pajek
Network Workbench
Cytoscape
yEd graph editor
Graphviz

Network data sets

⭐ Colorado Index of Complex Networks



learning goals

1. develop a **network intuition** for reasoning about network phenomena
2. understand **network representations**, **basic terminology**, and **concepts**.
3. learn principles and methods for **describing and clustering network data**
4. learn to **predict missing network information**
5. understand how to **conduct and interpret** numerical network experiments, to **explore and test hypotheses** about networks
6. analyze and model **real-world network data**, using math and computation

course format

- course meets in-person in ECES 1B14 & on Zoom
- lectures 2 times a week, some guest lectures and some class discussions
- deliverables:
  - biweekly problem sets (6 total)
  - class project: proposal, presentation, final report
- all content via class Canvas (lecture notes, recordings, problem sets, submissions)
- **see syllabus** for all course policies

course schedule

week by week

1. fundamentals of networks
2. representations and summary statistics
3. simple random graphs
4. better random graphs
5. predicting missing node attributes
6. predicting missing links
7. community structure and mixing patterns
8. community structure models
9. spreading processes and cascades
10. spreading processes with structure (epidemics)
11. data incompleteness and sampling
12. ranking in networks
13. ethics and networks
14. student project presentations

- building intuition
- basic concepts, tools
- practical tools
- advanced tools

lessons learned

what's difficult

1. students need to know many different things:

some probability	Erdos-Renyi, configuration, calculations
some mathematics	physics-style calculations, phase transitions
some statistics	basic data analysis, correlations, distributions
some machine learning	prediction, likelihoods, features, estimation algorithms
some programming	data wrangling, coding up measures and algorithms

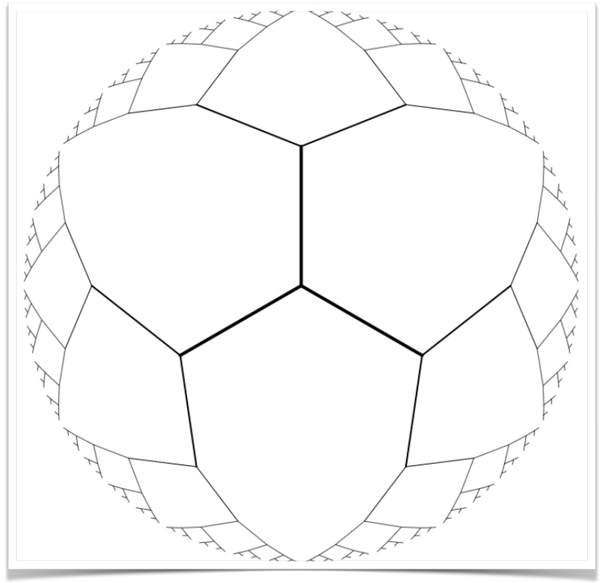
2. can't teach all of these things to all types of students!

- vast amounts of advanced material in each of these directions
- students have little experience / intuition of what makes *good* science

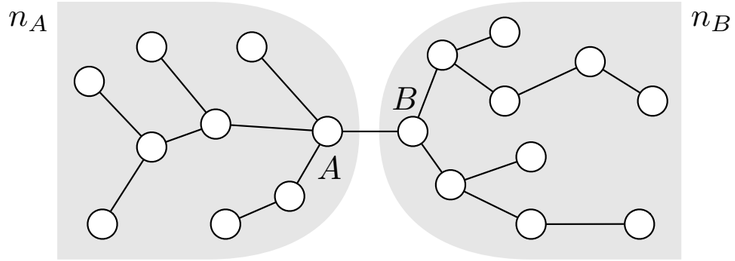
lessons learned

what works well

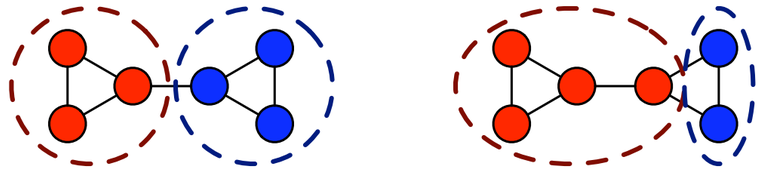
1. simple mathematical problems—build intuition & practice with concepts



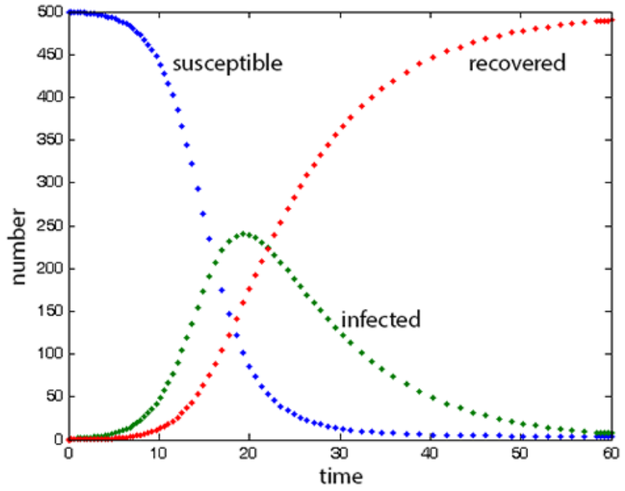
calculate summary statistics



derive mathematical relations



clustering highly-structured networks

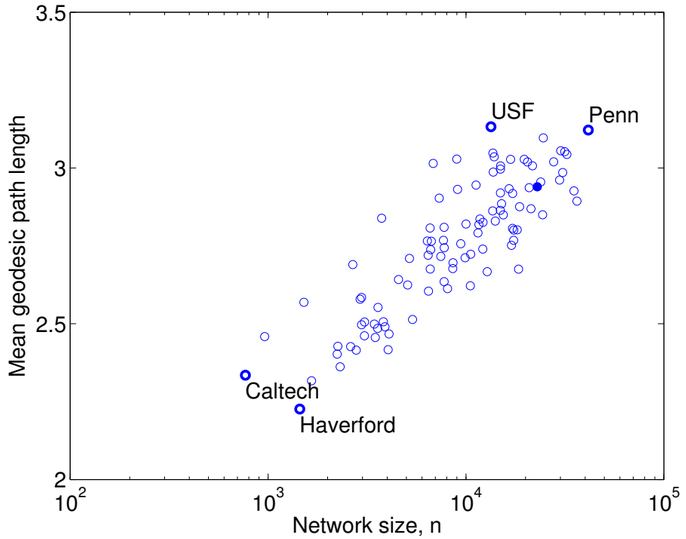


spreading process on networks

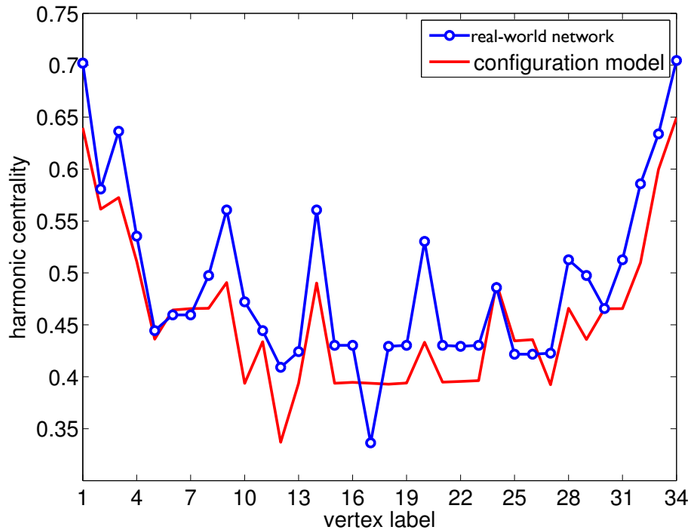
lessons learned

what works well

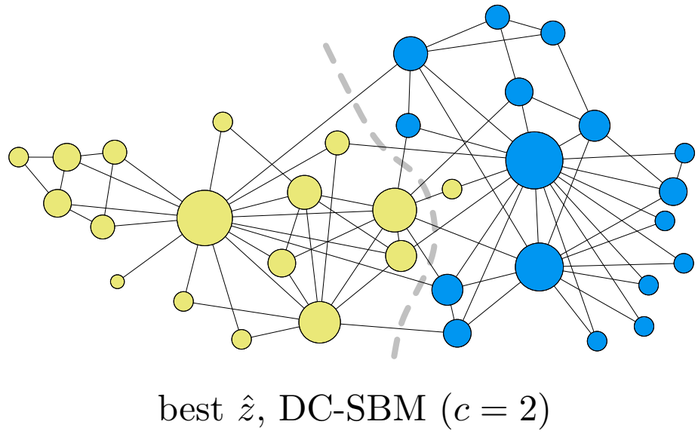
2. analyze *real* networks—test understanding & practice with *implementing* methods



what patterns really occur?



how much does randomness explain?
(when is a pattern *interesting*?)

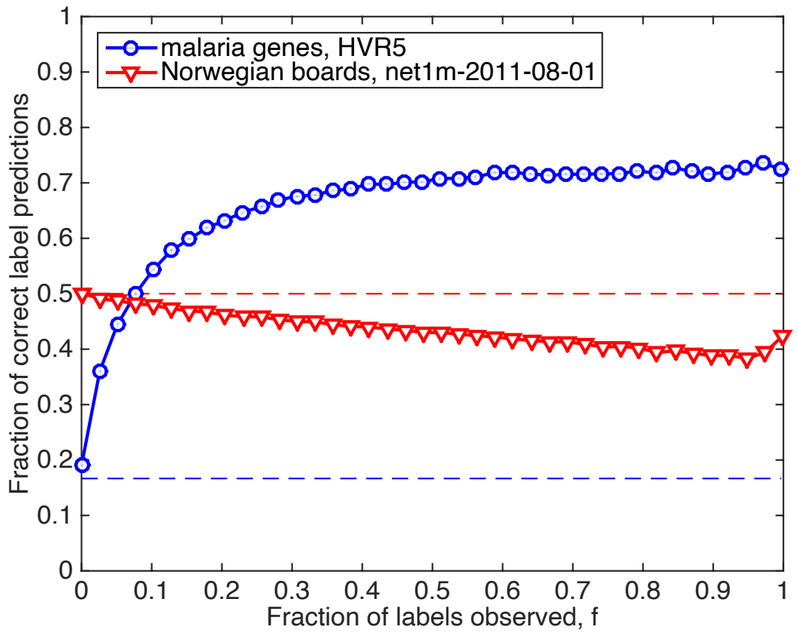


stochastic block models

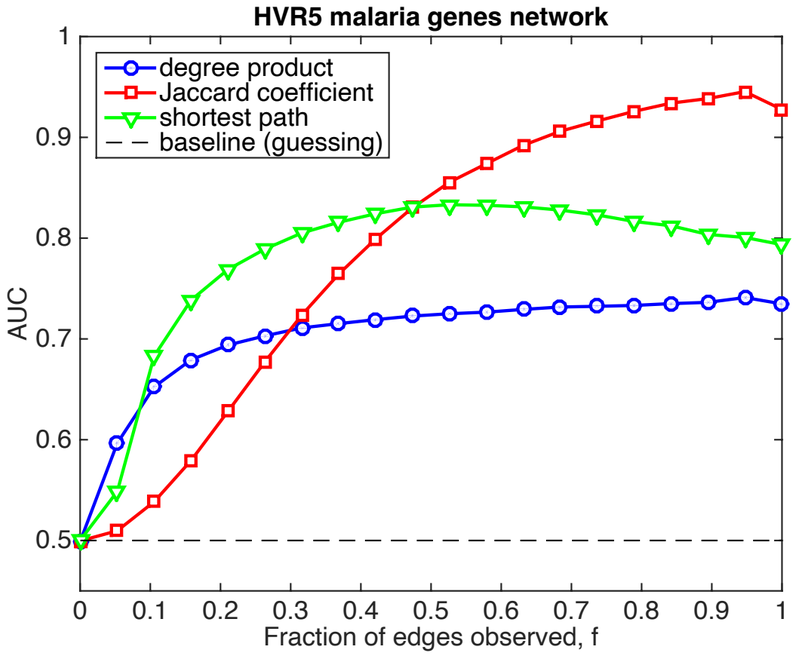
lessons learned

what works well

3. simple prediction tasks—test intuition & run numerical experiments



label prediction via homophily

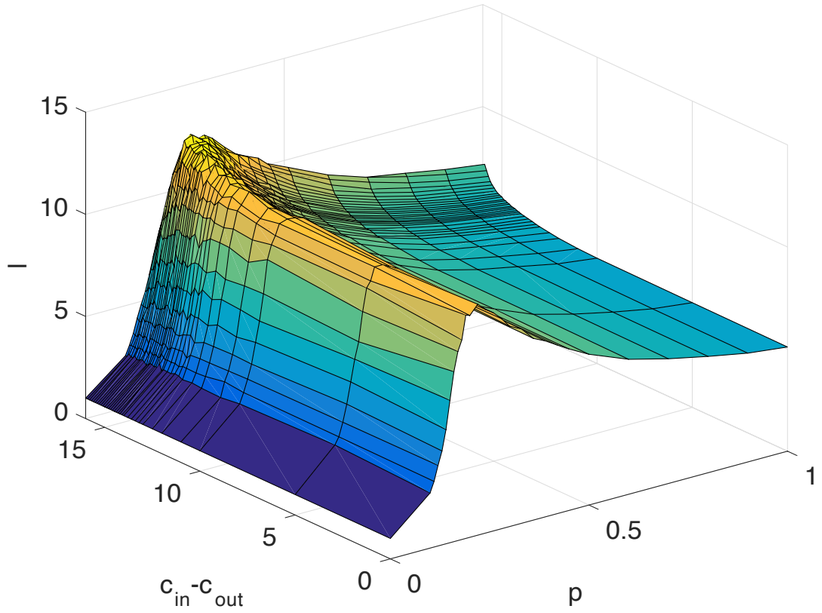


link prediction via heuristic

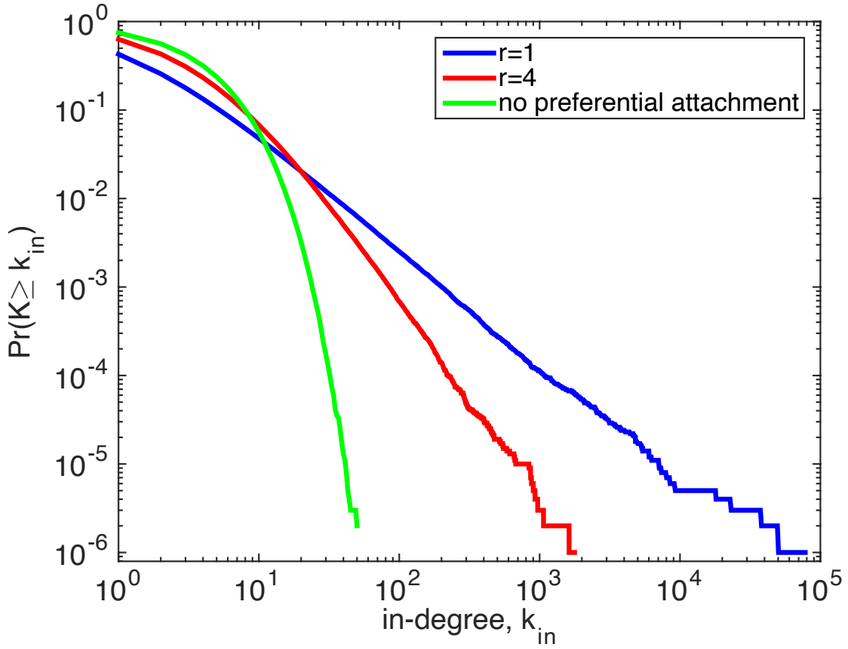
lessons learned

what works well

4. simple simulations—explore dynamics vs structure & numerical experiments



simulate epidemics (SIR) on planted partitions

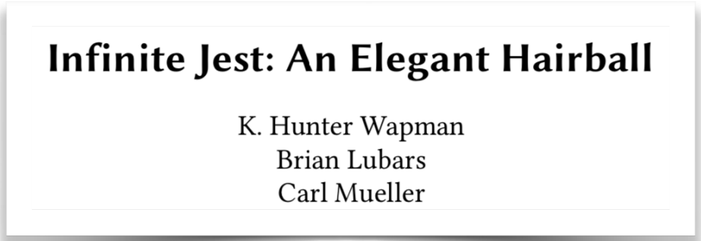


simulate Price's model

lessons learned

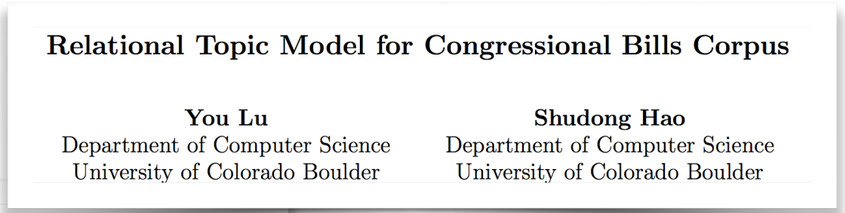
what works well

4. team projects—teamwork & exploring their (your!) own ideas



Infinite Jest: An Elegant Hairball

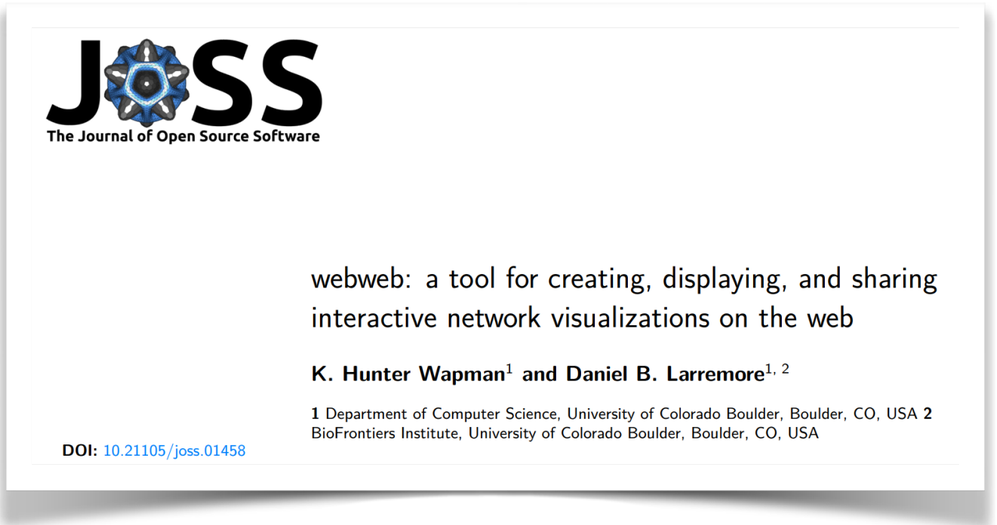
K. Hunter Wapman
Brian Lubars
Carl Mueller



Relational Topic Model for Congressional Bills Corpus

You Lu
Department of Computer Science
University of Colorado Boulder

Shudong Hao
Department of Computer Science
University of Colorado Boulder



JOSS
The Journal of Open Source Software

webweb: a tool for creating, displaying, and sharing interactive network visualizations on the web

K. Hunter Wapman[1] **and Daniel B. Larremore**[1, 2]

1 Department of Computer Science, University of Colorado Boulder, Boulder, CO, USA **2** BioFrontiers Institute, University of Colorado Boulder, Boulder, CO, USA

DOI: 10.21105/joss.01458

Morgan et al. *EPJ Data Science* (2018) 7:40
https://doi.org/10.1140/epjds/s13688-018-0166-4

EPJ Data Science
a SpringerOpen Journal

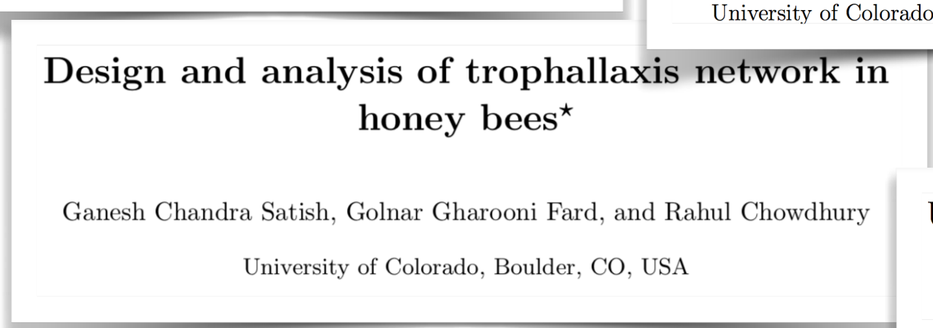
EPJ.org

REGULAR ARTICLE Open Access

CrossMark

Prestige drives epistemic inequality in the diffusion of scientific ideas

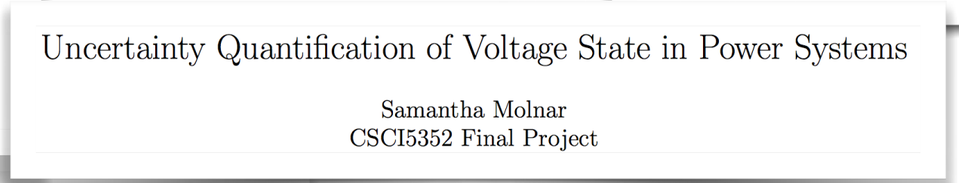
Allison C. Morgan[1*], Dimitrios J. Economou[1], Samuel F. Way[1] and Aaron Clauset[1,2,3]



Design and analysis of trophallaxis network in honey bees*

Ganesh Chandra Satish, Golnar Gharooni Fard, and Rahul Chowdhury

University of Colorado, Boulder, CO, USA



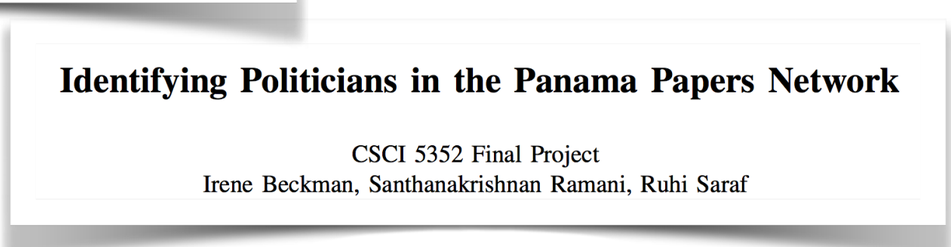
Uncertainty Quantification of Voltage State in Power Systems

Samantha Molnar
CSCI5352 Final Project

Communities across U.S. Congress cosponsorship networks

Alexander Ray,[1,*] David Crosswy,[1,†] and Aaron Aaeng[1,‡]

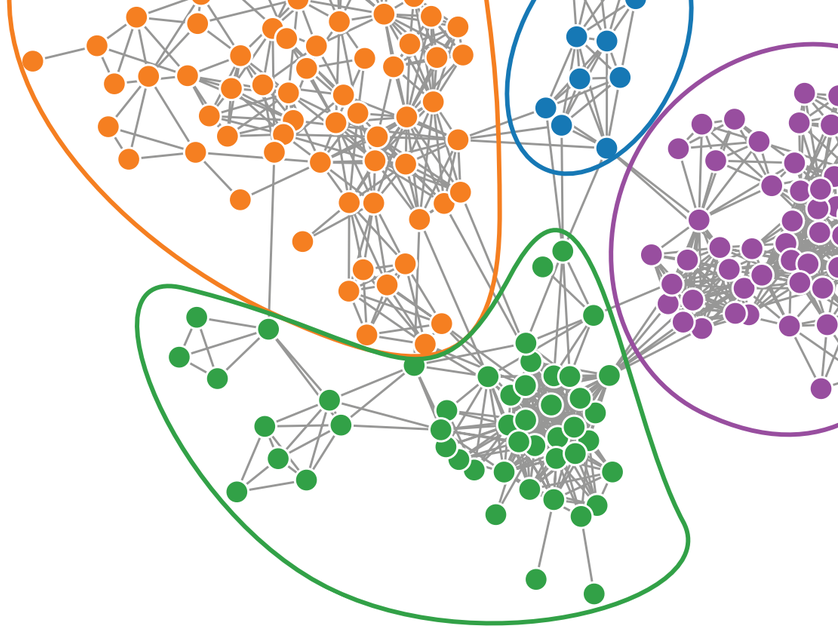
[1] *Department of Computer Science, University of Colorado, Boulder, CO, USA*



Identifying Politicians in the Panama Papers Network

CSCI 5352 Final Project
Irene Beckman, Santhanakrishnan Ramani, Ruhi Saraf

key takeaways



- **network intuition is hard to develop!**
  good intuition draws on many skills
  (probability, statistics, computation, causal dynamics, etc.)

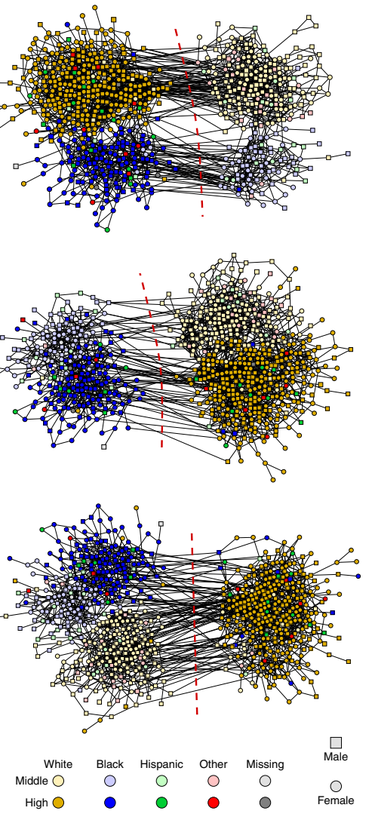
- best results come from
  1. exercises to get practice with calculations
  2. practice analyzing diverse real-world networks
  3. conducting out numerical experiments & simulations

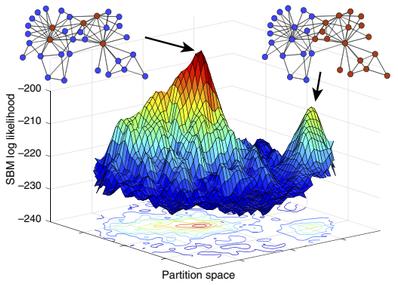
- practical tasks are a pedagogical tool (e.g., link and label prediction)
- interpreting the results requires a good *intuition* and to *think like a scientist*
- null models are key concept: is a pattern interesting? what could explain it?
- networks are fun!

about me

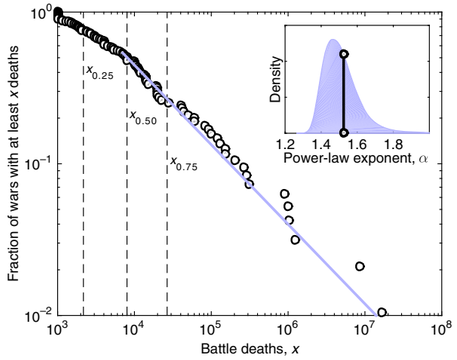
Aaron Clauset
Professor
Computer Science + BioFrontiers Institute
aaronclauset.github.io

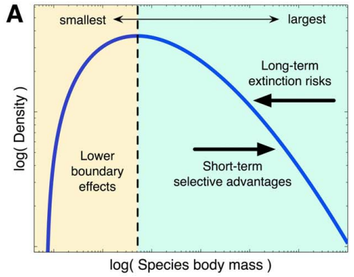
computational methods for network analysis

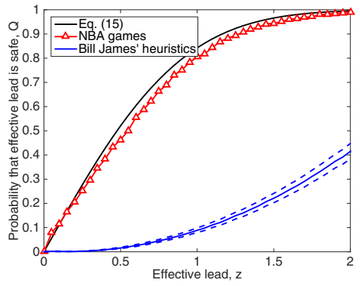




complex social and biological systems







inequality and the spread of ideas in science