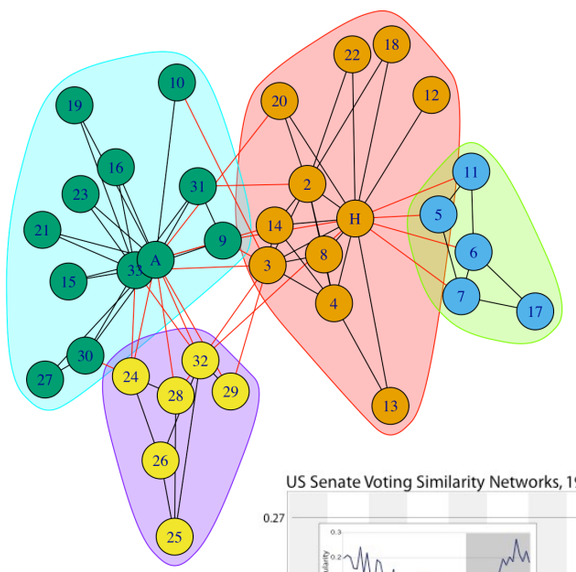
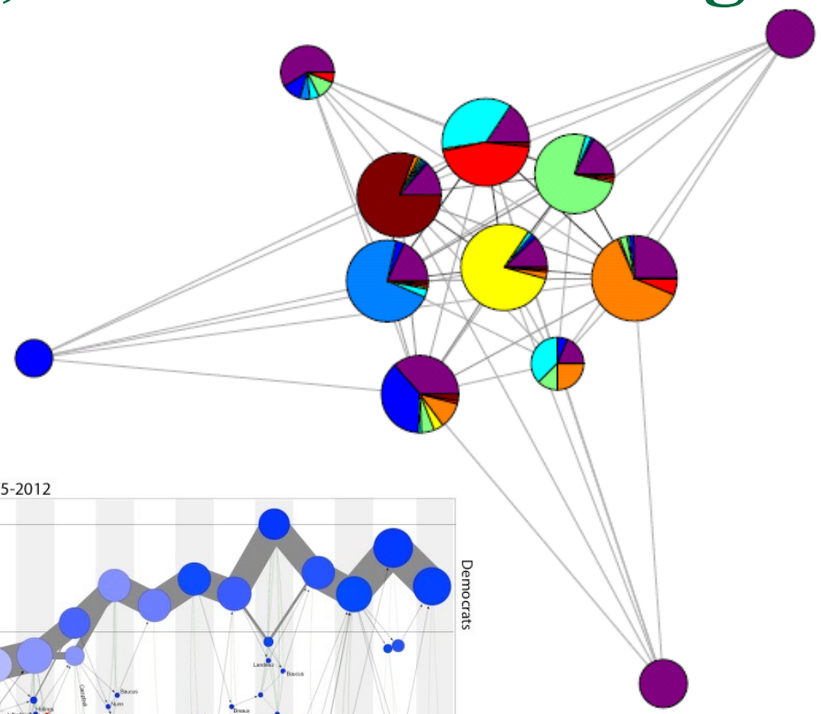
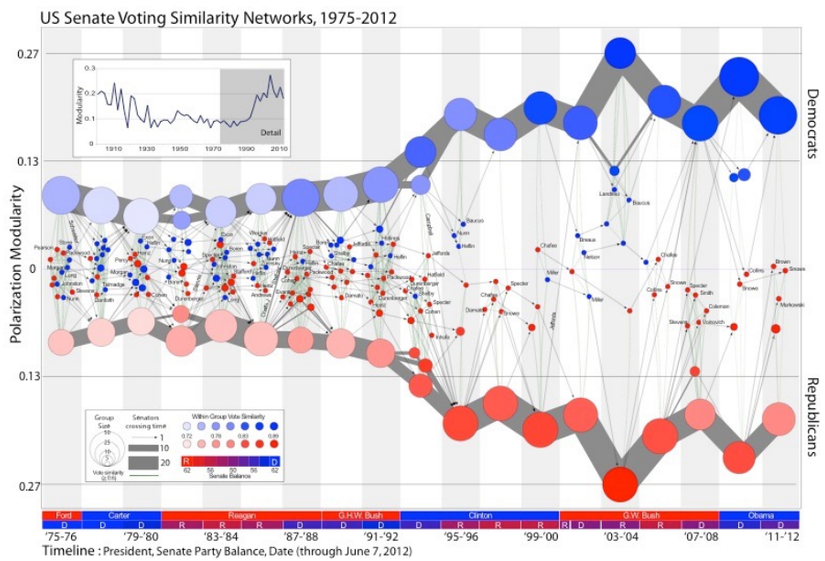
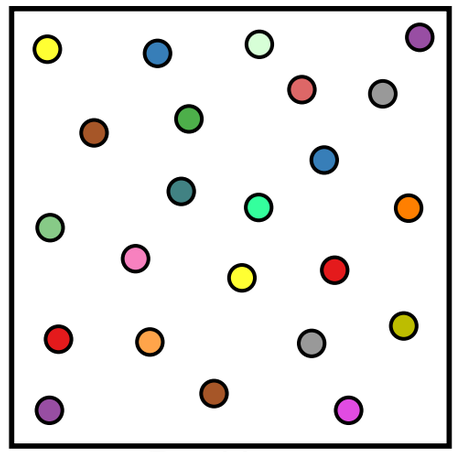
Community Detection in R at SNH 2023

Peter J. Mucha, Dartmouth College

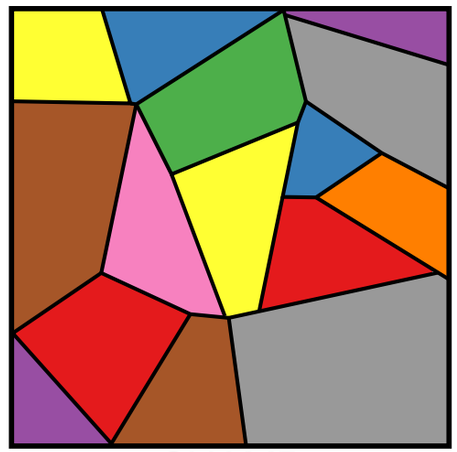




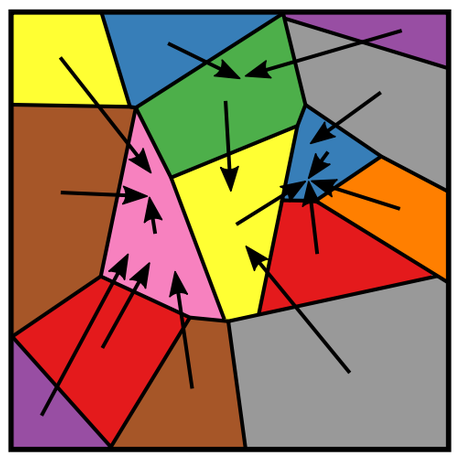




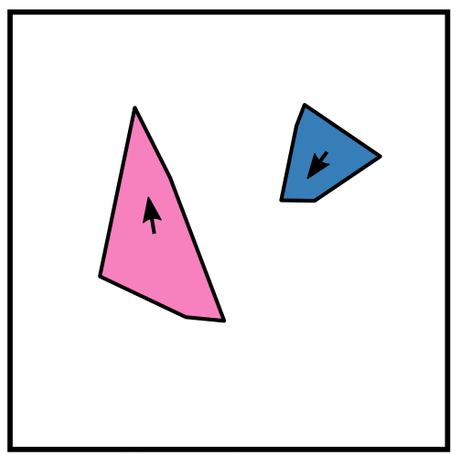
Partitions



CHAMP



Map Parameters

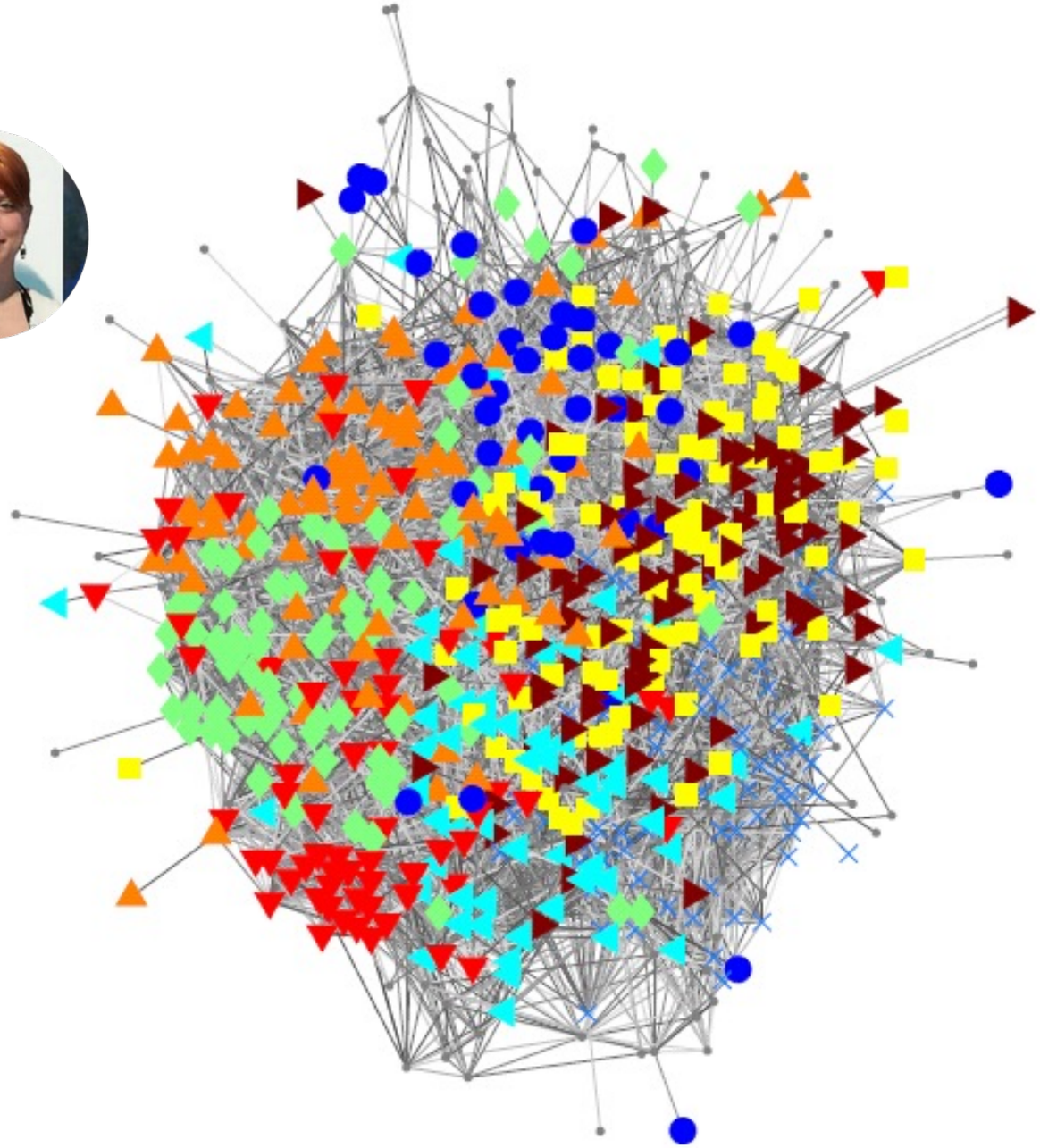


Fixed Points

Facebook

Traud *et al.*, “Comparing community structure to characteristics in online collegiate social networks” (2011)
Traud *et al.*, “Social structure of Facebook networks” (2012)

Caltech 2005:
Colors indicate residential “House” affiliations



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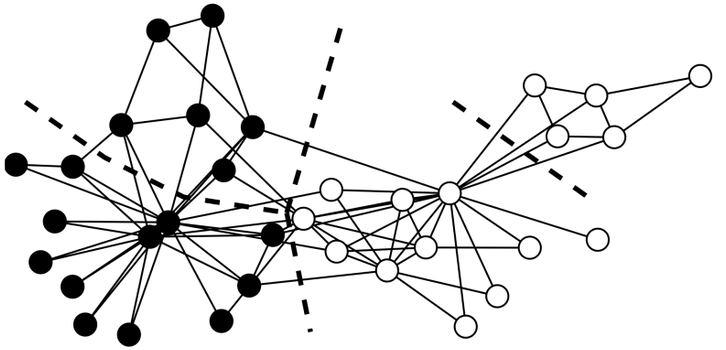
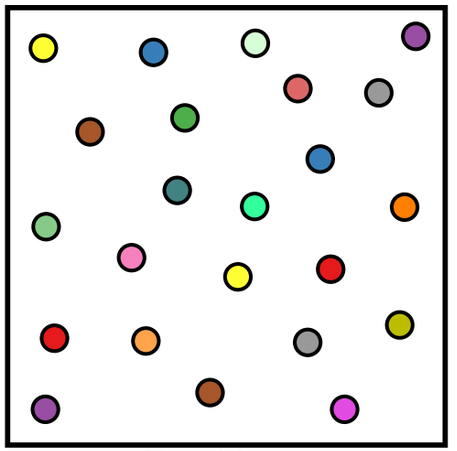
Purple = Not provided

Takeaway Messages

1. CommunitiesSNH2023.Rmd file designed to highlight upcoming IDEANet capabilities
2. Community detection is "just" unsupervised clustering of nodes in the network:
   - NFL: No single "right" way to cluster (different tools, knobs)
   - "Meaning" of identified groups depends on your application
3. CHAMP and Iterative Parameter Maps in R:
   - Multilayer modularity capabilities "coming soon"
     github.com/wweir827/CHAMP
     github.com/ragibson/ModularityPruning





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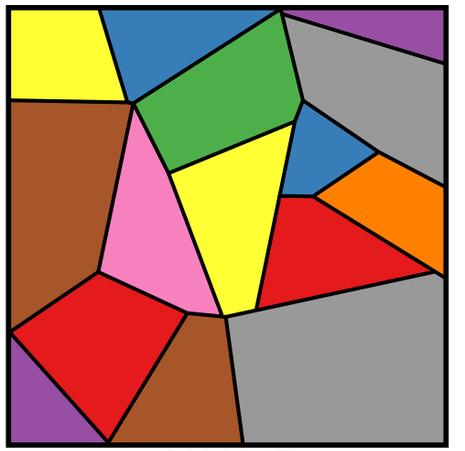

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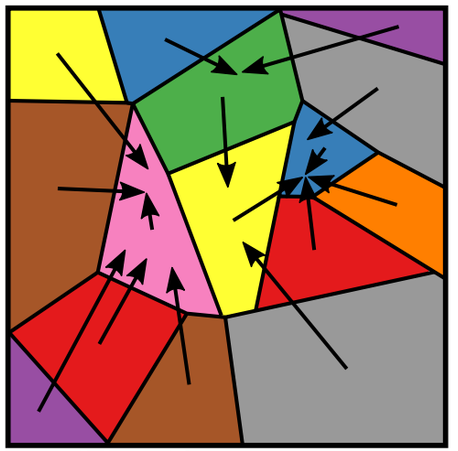

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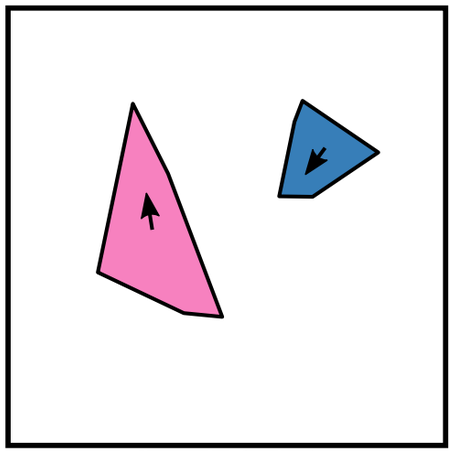
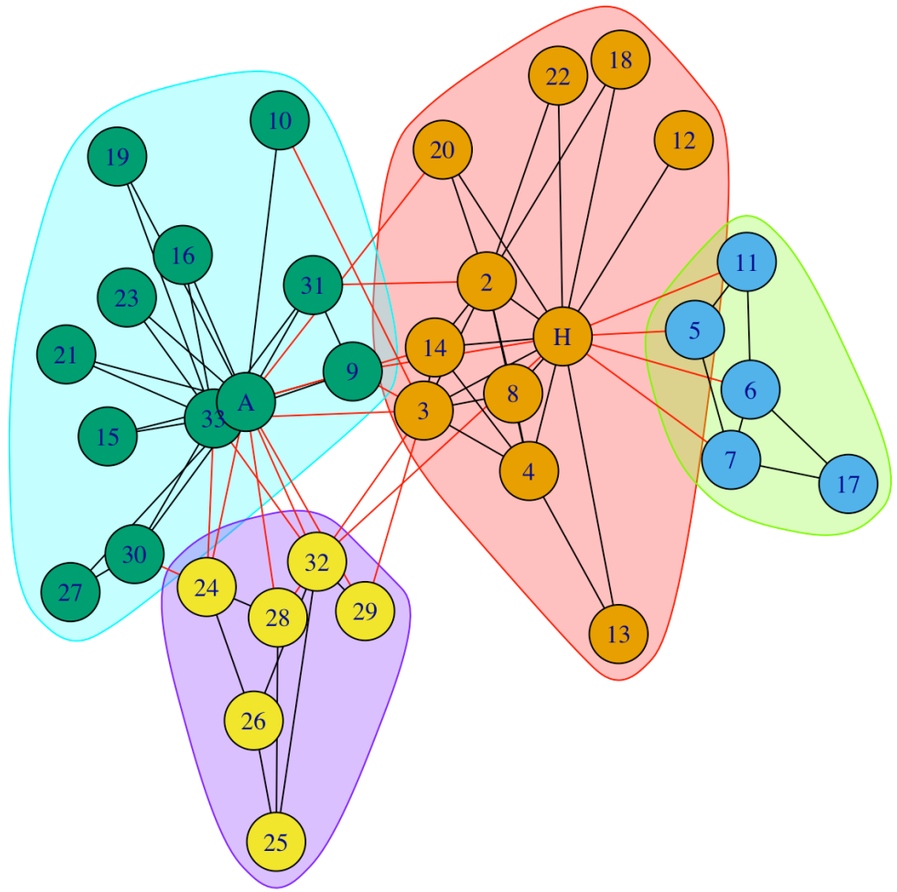


Fixed Points

This is the typical user:

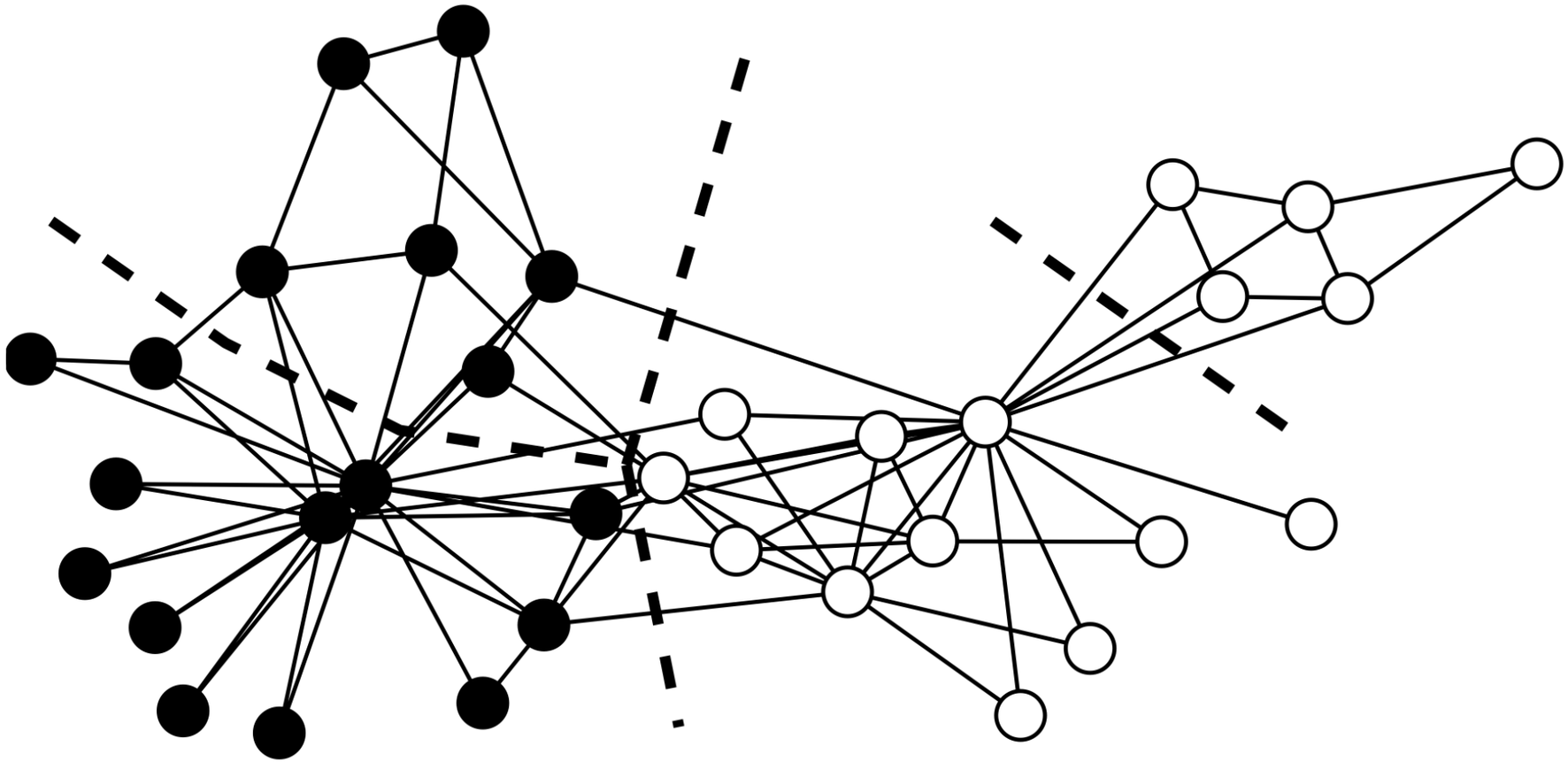
```
> library(igraphdata)
> data(karate)
> partition1 <- cluster_louvain(karate)
> partition1
IGRAPH clustering multi level, groups: 4, mod: 0.44
+ groups:
  $`1`
   [1] "Mr Hi"    "Actor 2"  "Actor 3"  "Actor 4"  "Acto
   [8] "Actor 14" "Actor 18" "Actor 20" "Actor 22"

  $`2`
  [1] "Actor 5"  "Actor 6"  "Actor 7"  "Actor 11" "Actor

  $`3`
   [1] "Actor 9"  "Actor 10" "Actor 15" "Actor 16" "Acto
   [8] "Actor 27" "Actor 30" "Actor 31" "Actor 33" "John
  + ... omitted several groups/vertices
> plot(partition1,karate)
>
```



Network Scientists with Karate Trophies

http://networkkarate.tumblr.com/

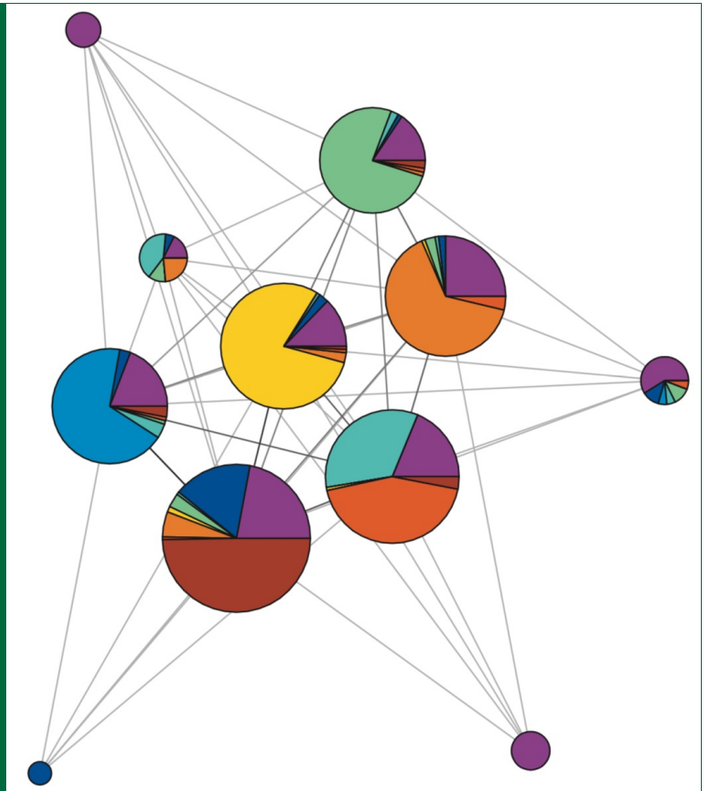
Zachary Karate Club

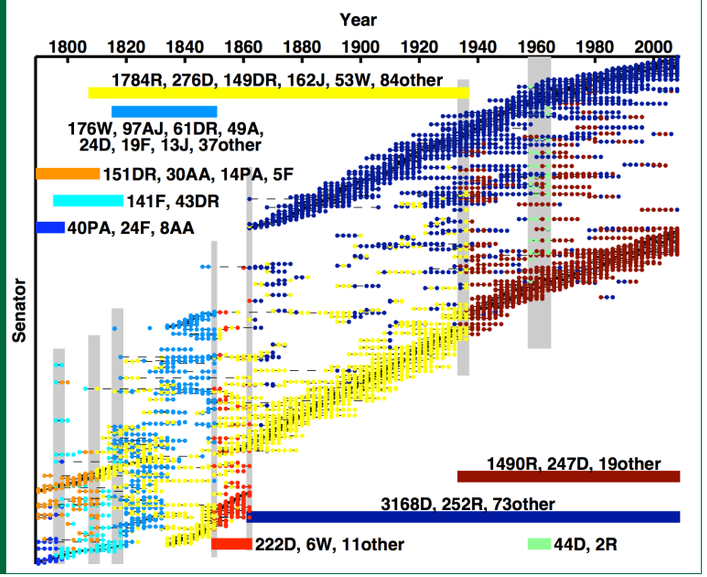


This partition optimizes ***modularity*** (at default resolution) which measures the number of intra-community ties (relative to a random model)

"If your method doesn't work on this network, then go home."

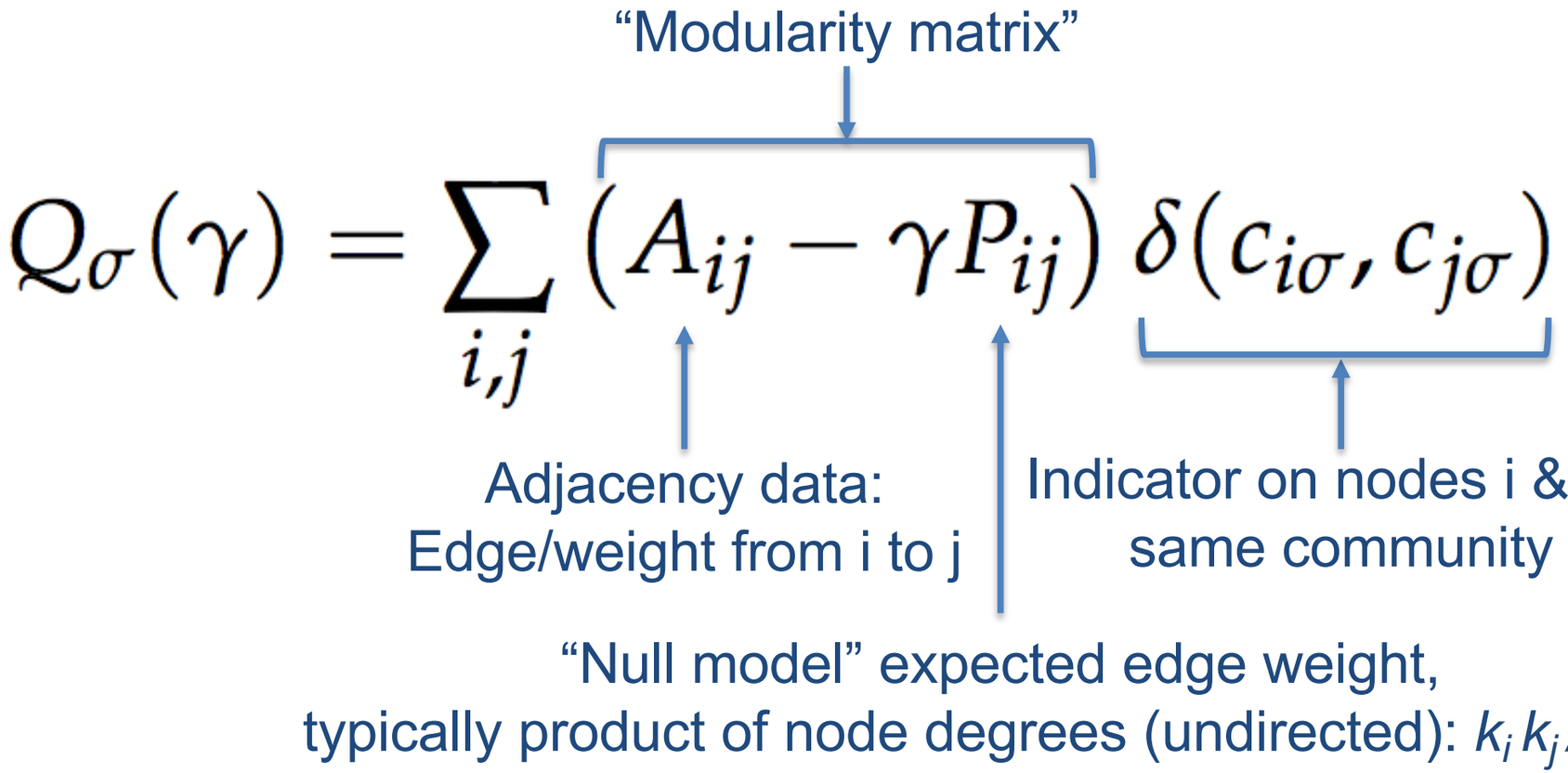
- Modularity is problematic
- Modularity maximization remains most used method of community detection
- **Frequently misused**
  - Heuristics → Stochastic
  - Pick resolution γ & coupling ω
- *If you're going to use modularity, we want to help you use it right*





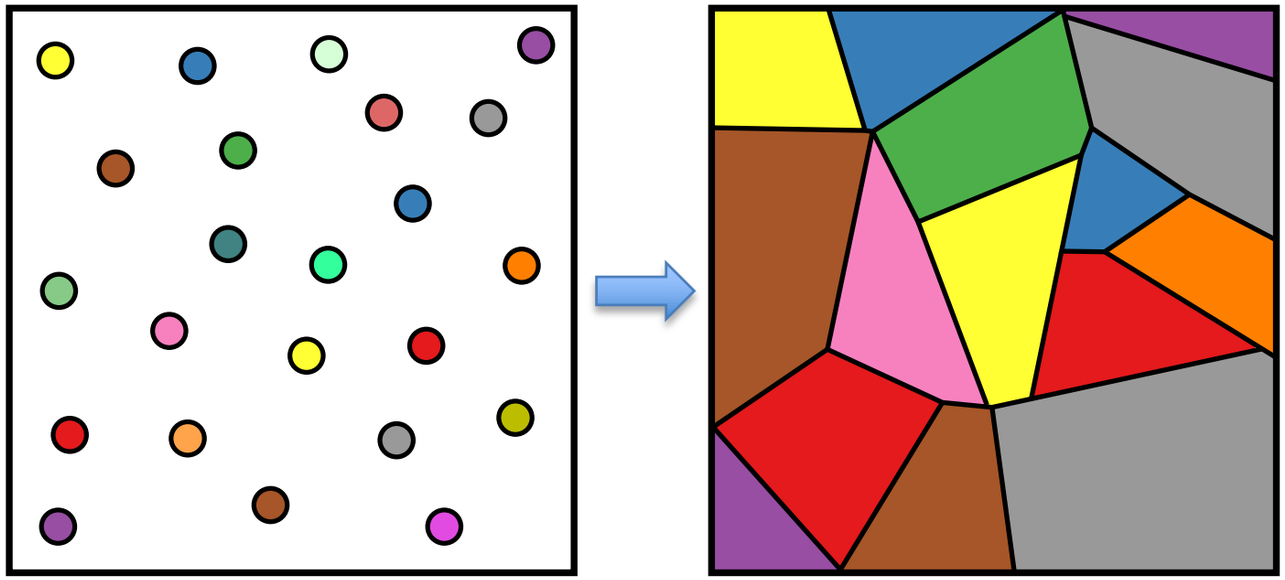
Modularity with resolution parameter γ

(Newman & Girvan, 2004; Reichardt & Bornholdt, 2006)



Optimization: Find partition σ of nodes in communities to maximize *Q*
Resolution parameter γ indirectly controls number/sizes of communities

Convex Hull of Admissible Modularity Partitions



github.com/wweir827/champ

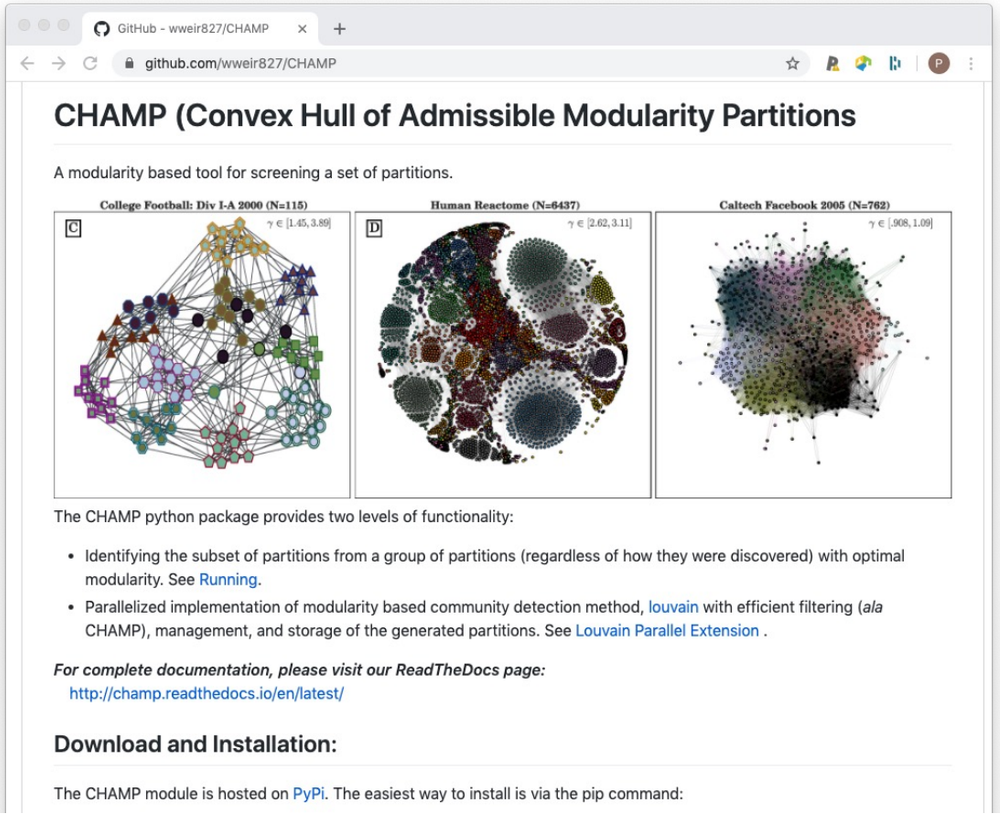
algorithms

MDPI

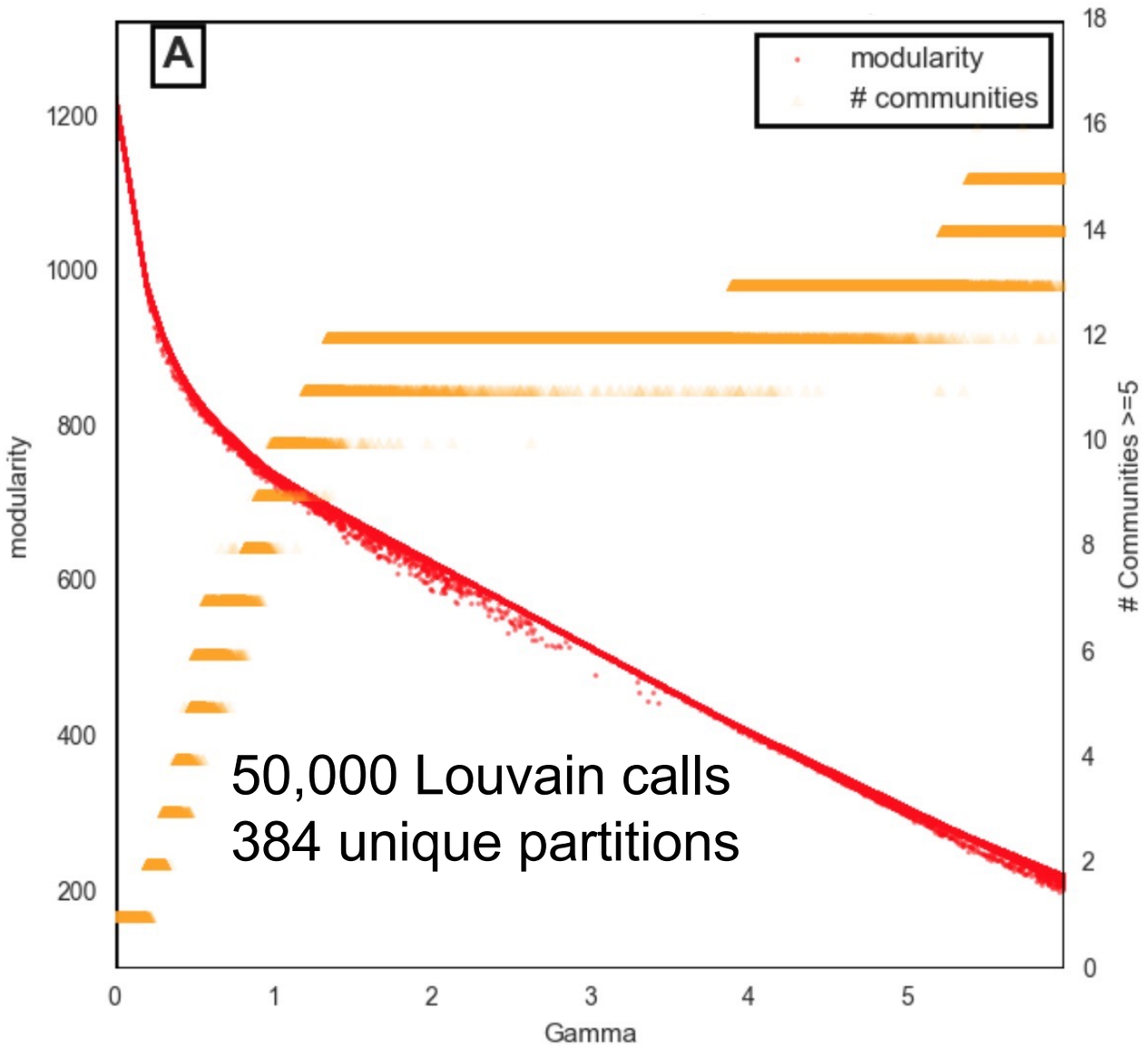
Article

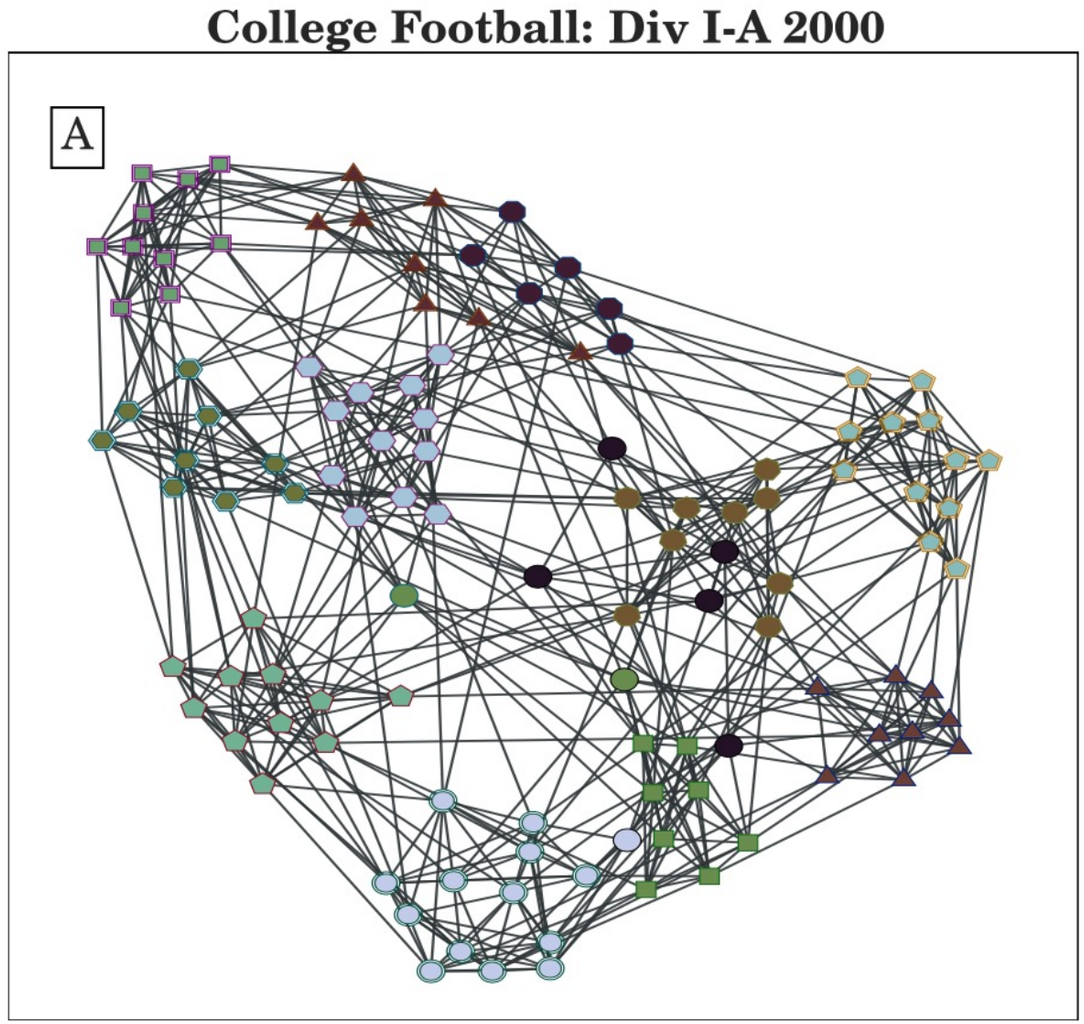
Post-Processing Partitions to Identify Domains of Modularity Optimization

William H. Weir [1,2,*], Scott Emmons [1], Ryan Gibson [1], Dane Taylor [1] and Peter J. Mucha [1,2]

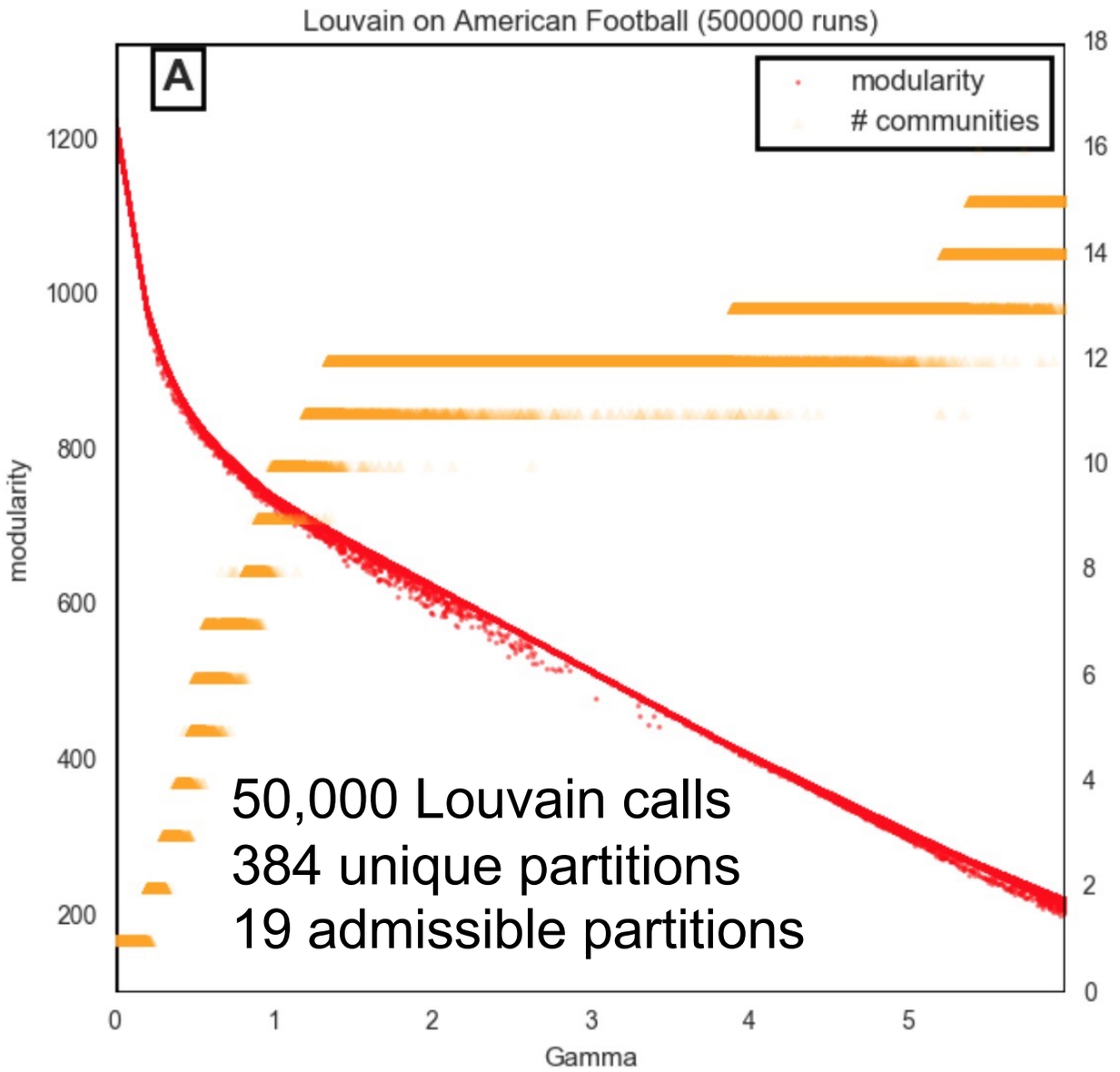


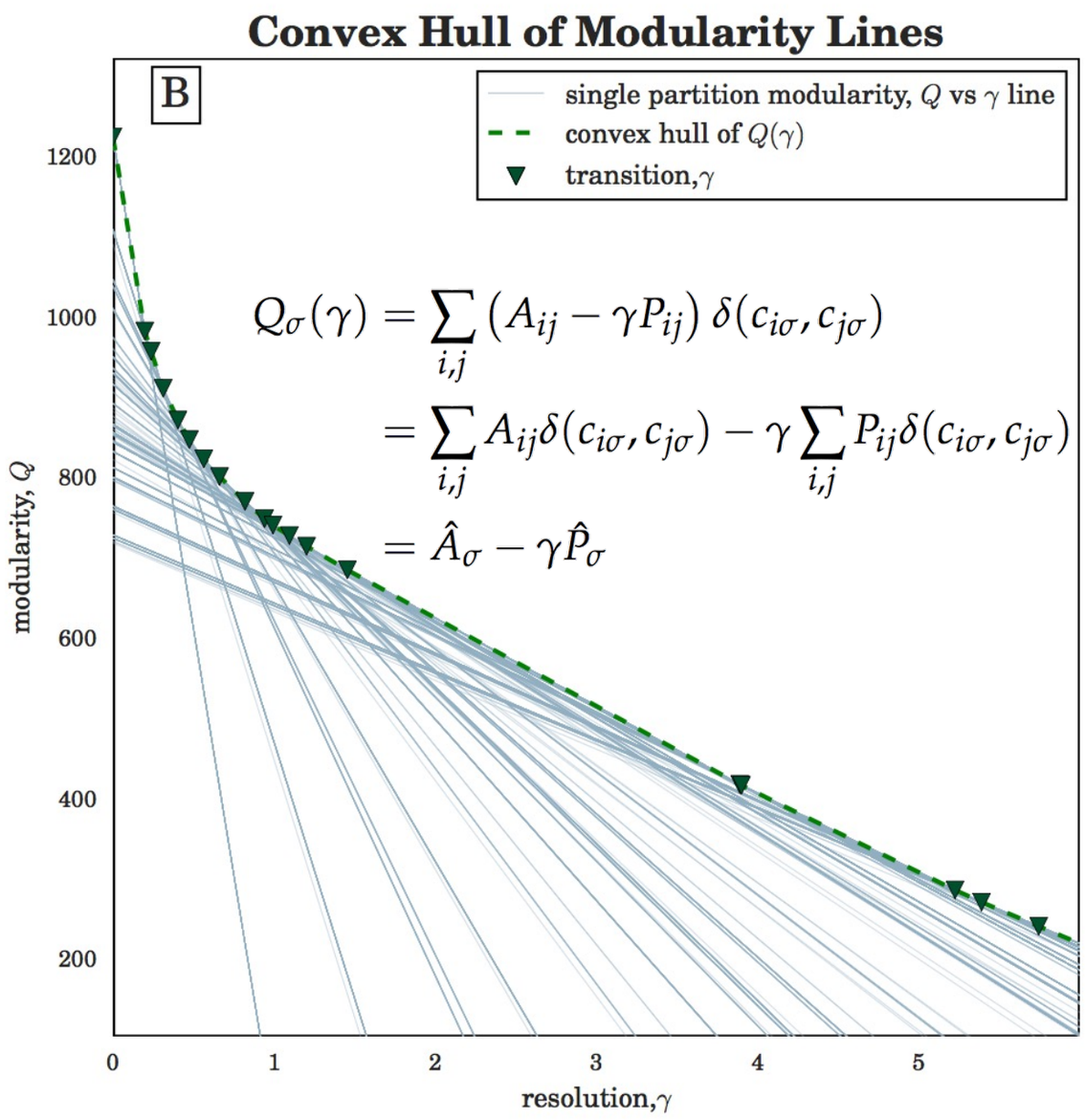
How to pick γ? (1) CHAMP





$Q_\sigma(\gamma)$ isn't a point. Each partition σ defines a line.





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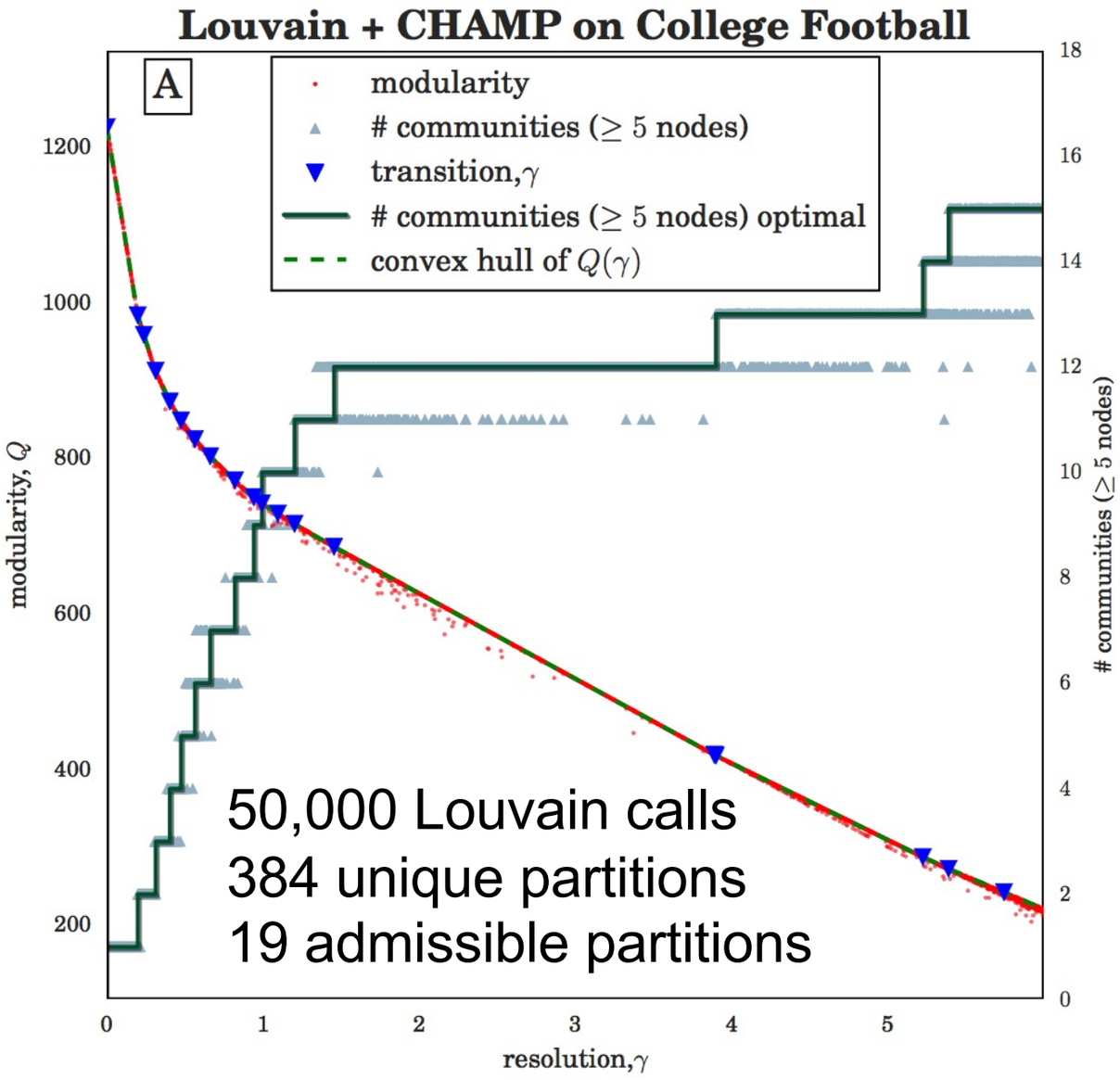
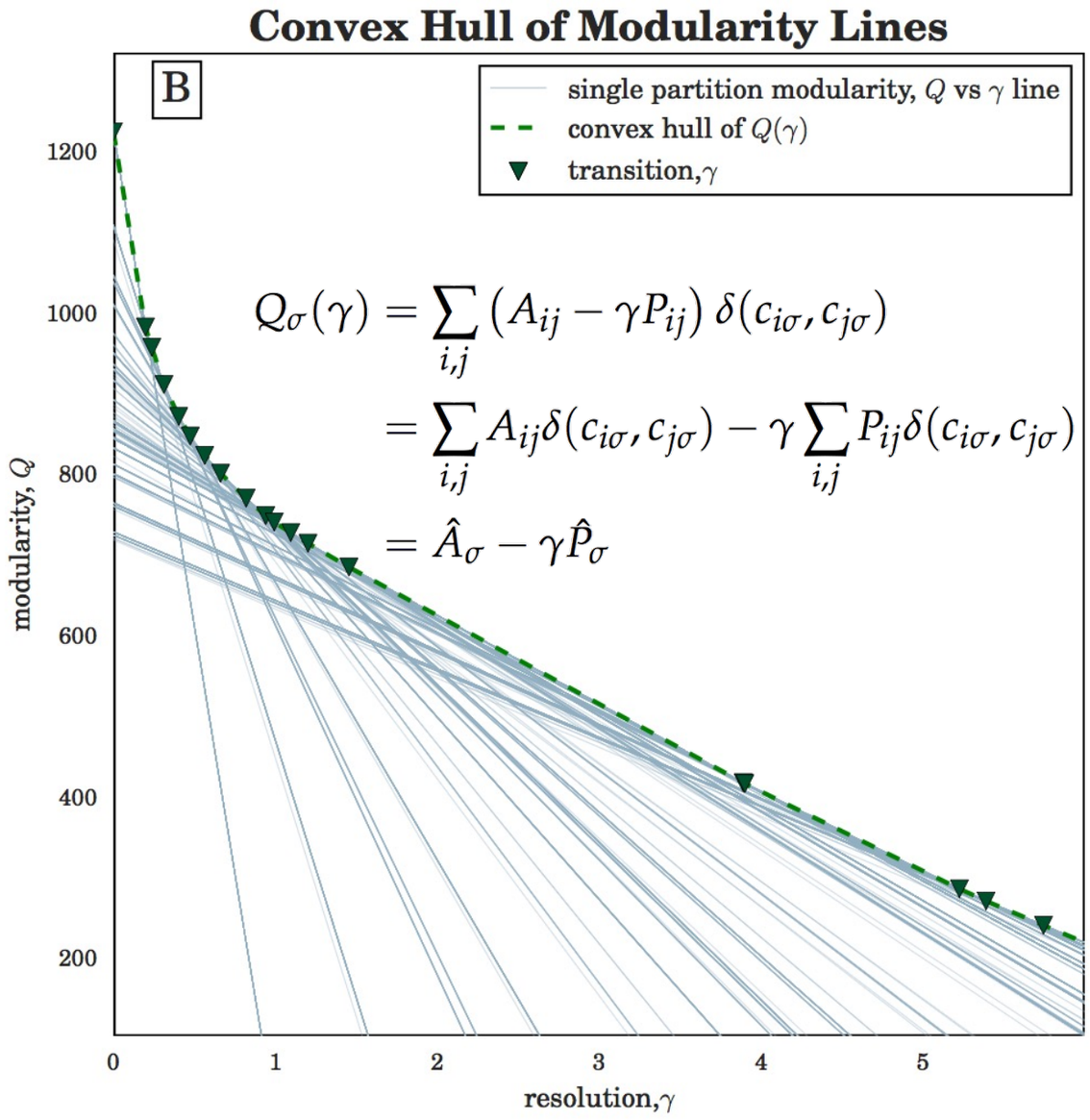




Modularity-SBM Equivalence (Newman, 2016)

- Degree-corrected "planted partition" SBM with *K* blocks, θ_{in}, θ_{out}

$$\ln P(\mathbf{A} \mid \theta_{\text{in}}, \theta_{\text{out}}, \mathbf{g}) = \sum_{i,j} \left[A_{ij} - \frac{k_i k_j}{2m} \cdot \frac{\theta_{\text{in}} - \theta_{\text{out}}}{\ln \theta_{\text{in}} - \ln \theta_{\text{out}}} \right] \delta(g_i, g_j)$$

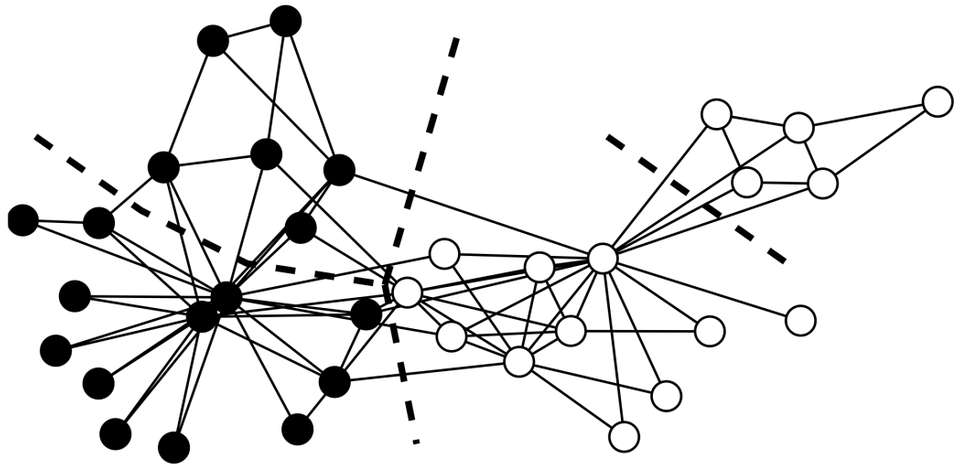
$$\gamma = \frac{\theta_{\text{in}} - \theta_{\text{out}}}{\ln \theta_{\text{in}} - \ln \theta_{\text{out}}}$$

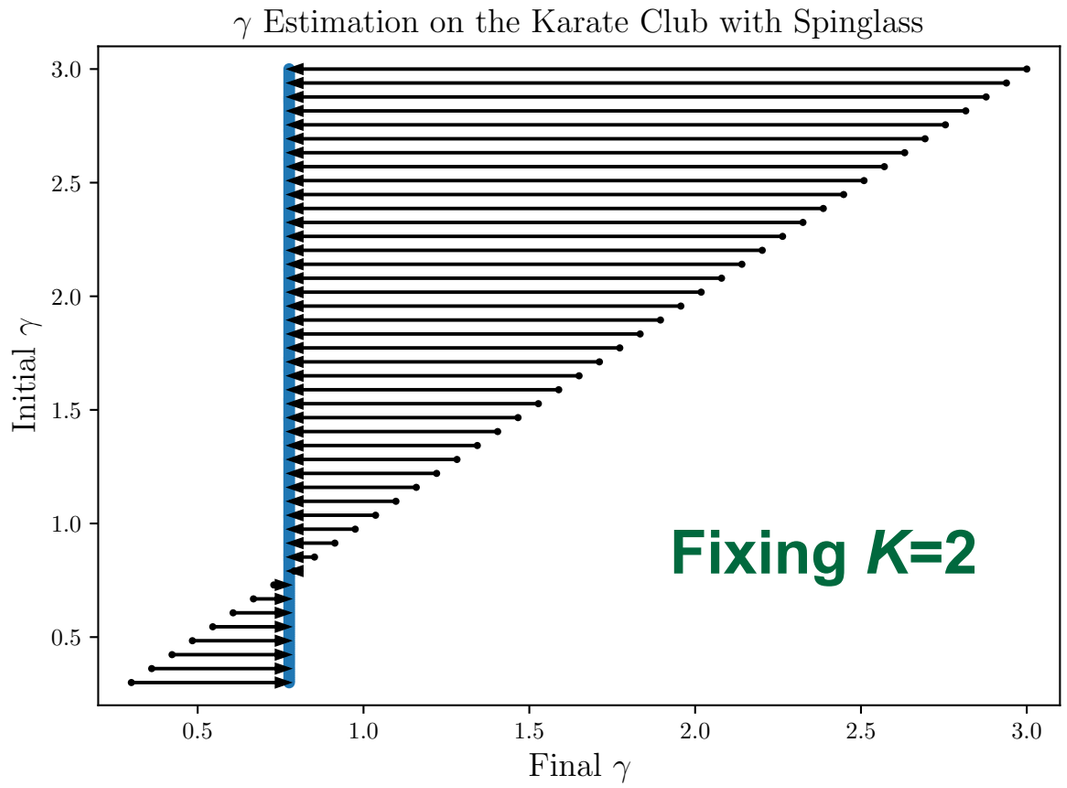
$$\theta_{\text{in}} = \frac{2m_{\text{in}}}{\sum_r \kappa_r^2 / (2m)}, \quad \kappa_r = \sum_i k_i \delta(g_i, r)$$

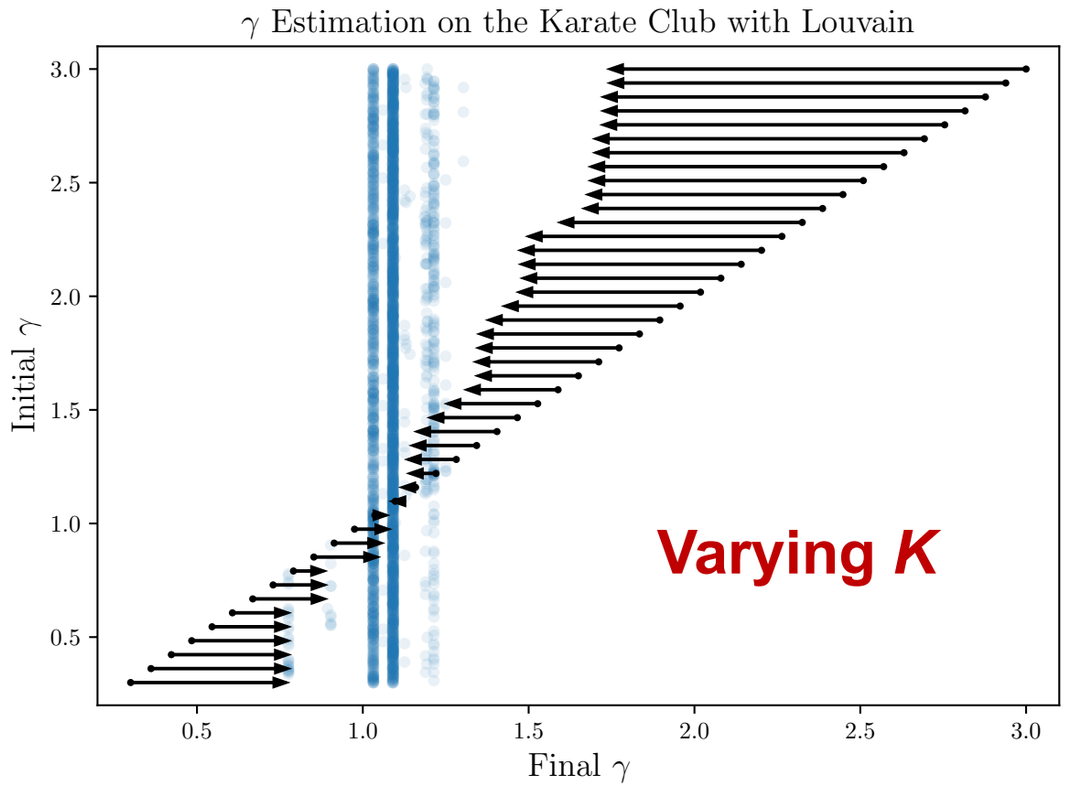
$$\theta_{\text{out}} = \frac{2m - 2m_{\text{in}}}{2m - \sum_r \kappa_r^2 / (2m)}$$

Network	n	m	K	γ
Karate club	34	78	2	0.78
Dolphin social network	62	159	2	0.59
Political blogs	1225	16780	2	0.67
Books about politics	105	441	2	0.59
Characters from *Les Miserables*	77	254	6	1.36
American college football	115	614	11	2.27
Jazz collaborations	198	2742	16	1.19
Email messages	1133	5451	26	3.63

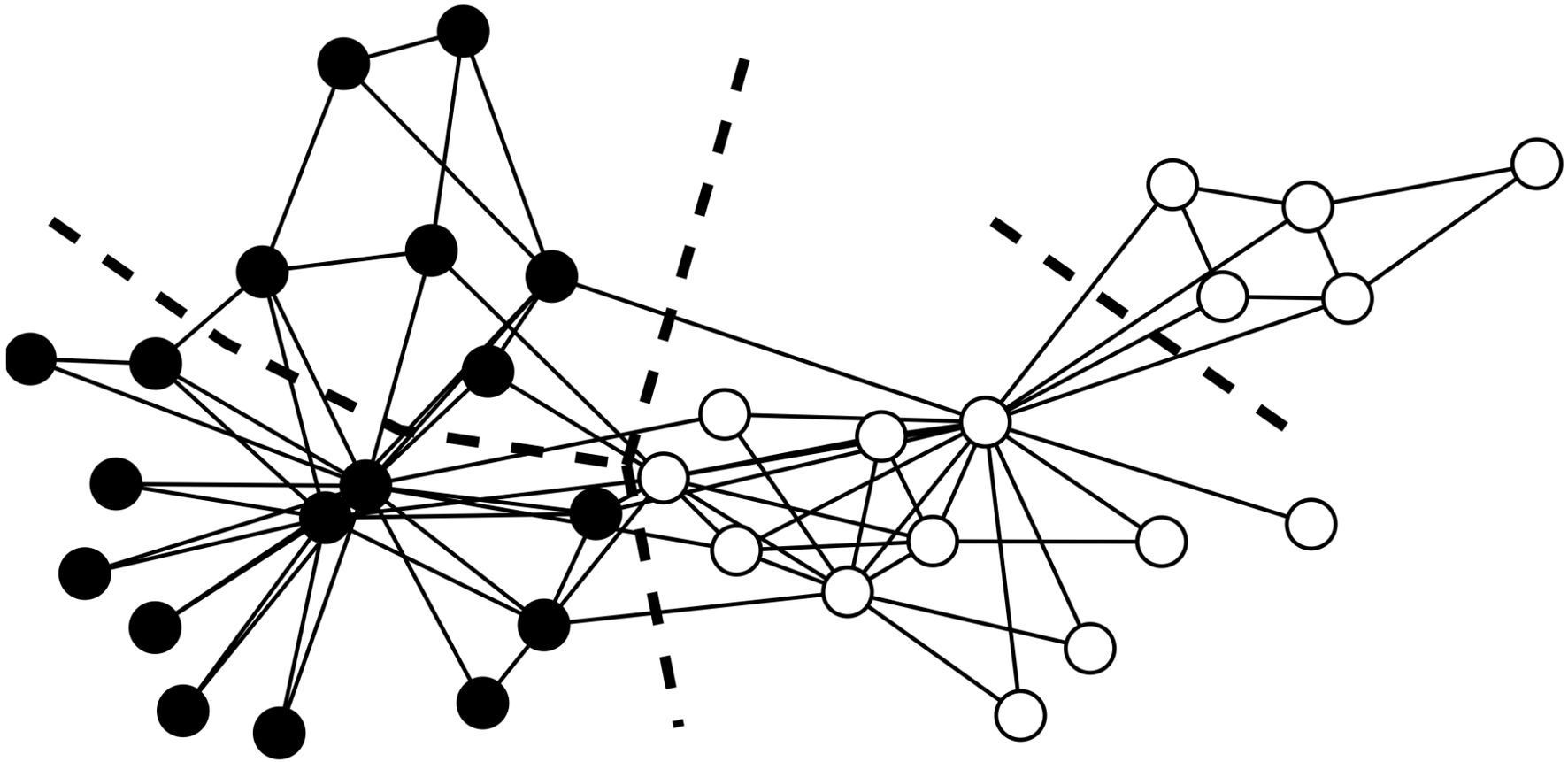
Fixing v. Varying K for Zachary's Karate Club







Zachary Karate Club



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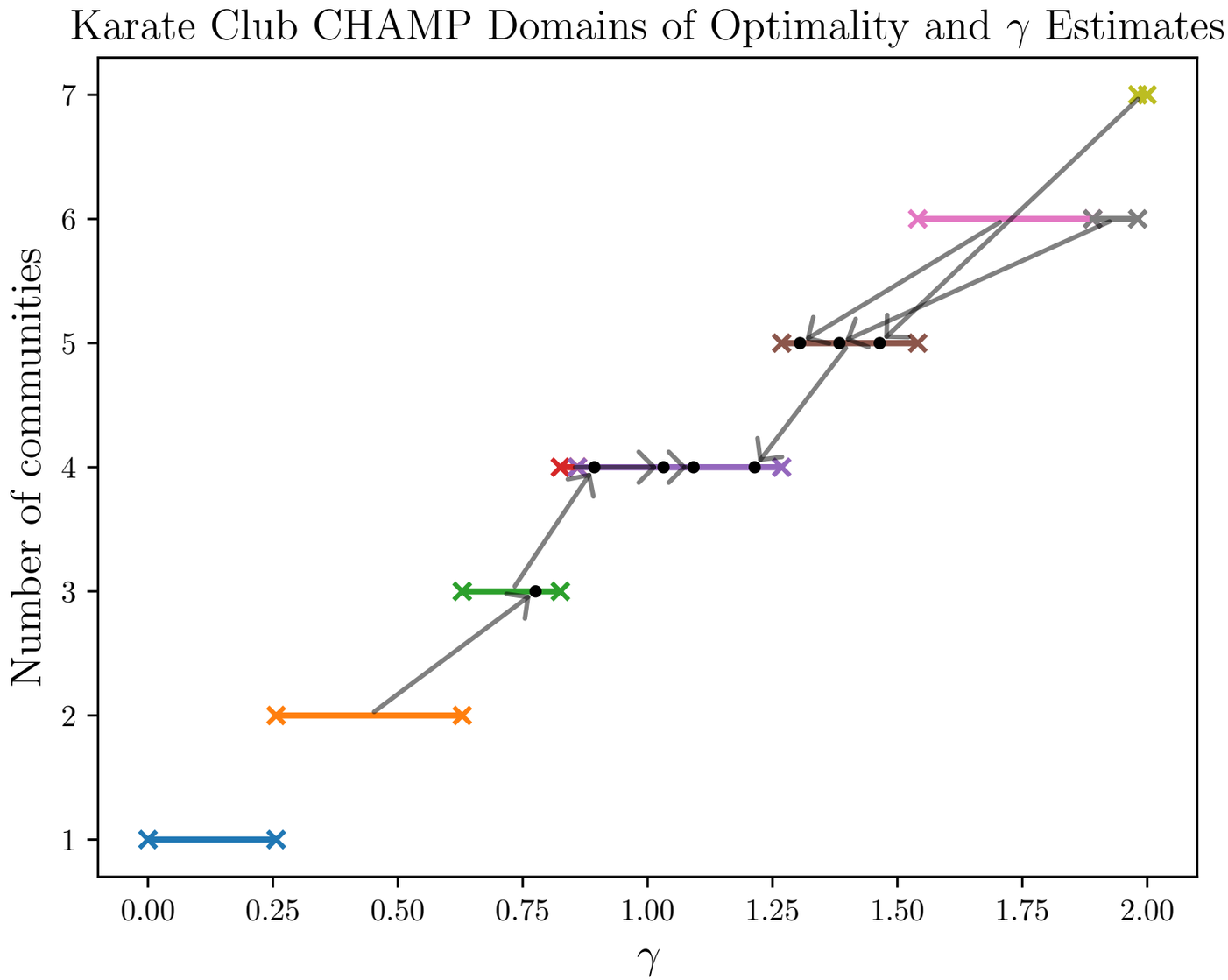
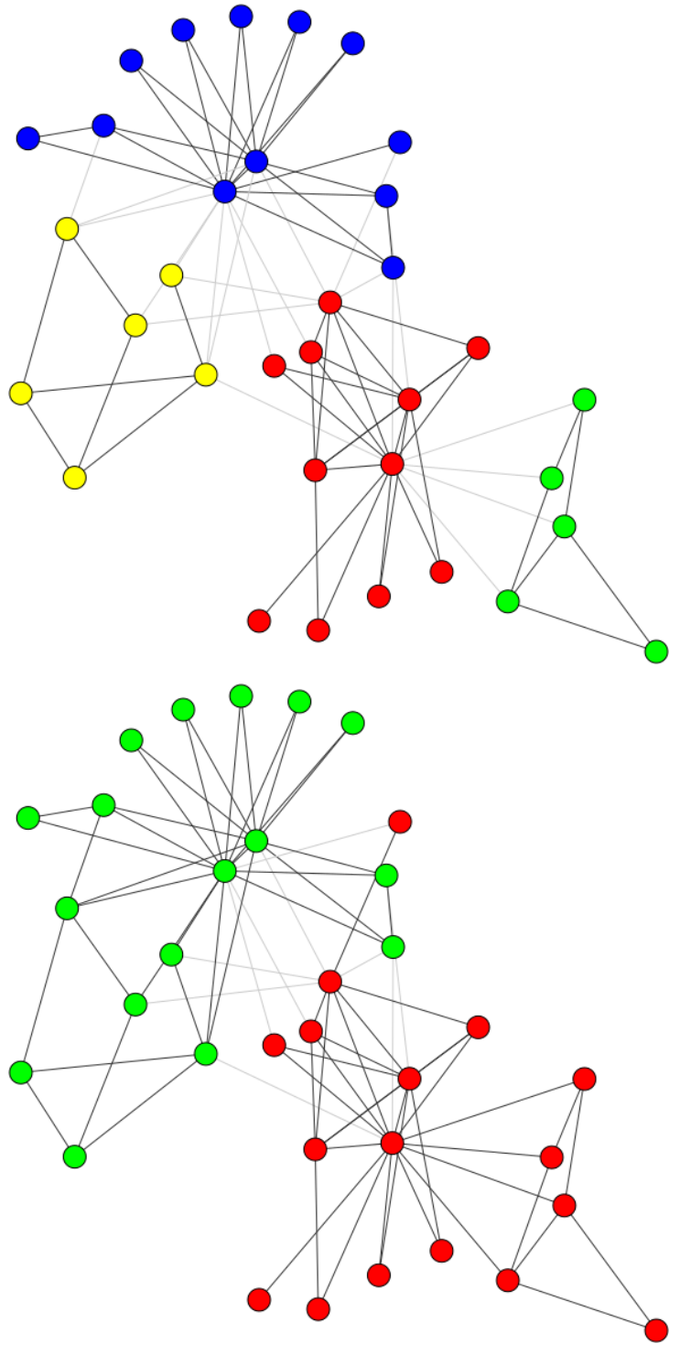
Karate Club: “ModularityPruning” Iterative Map on Parameter Space





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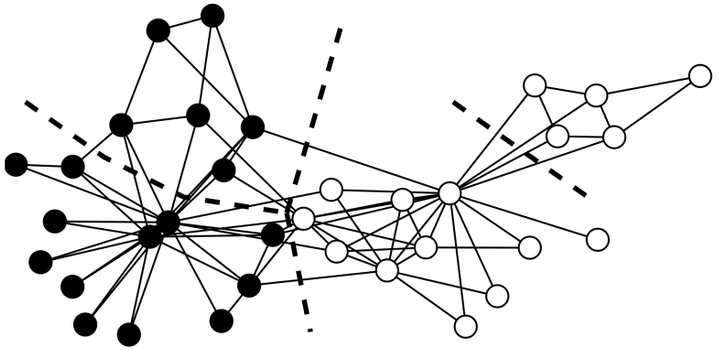

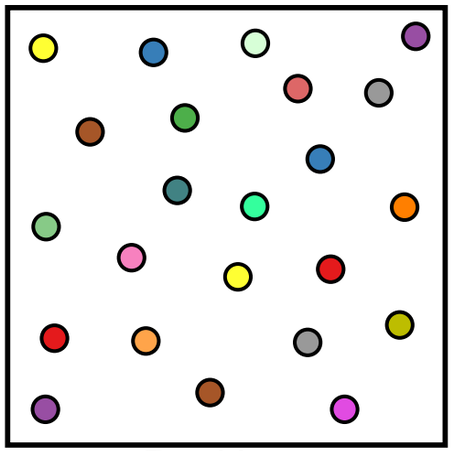

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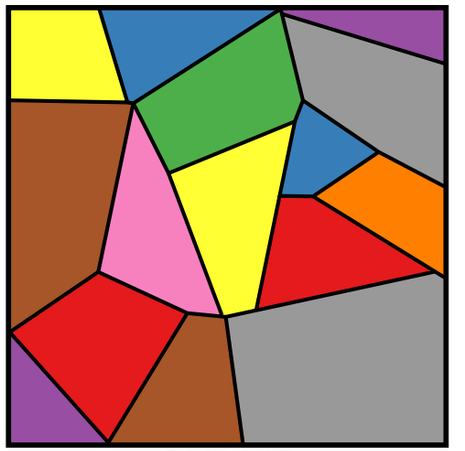

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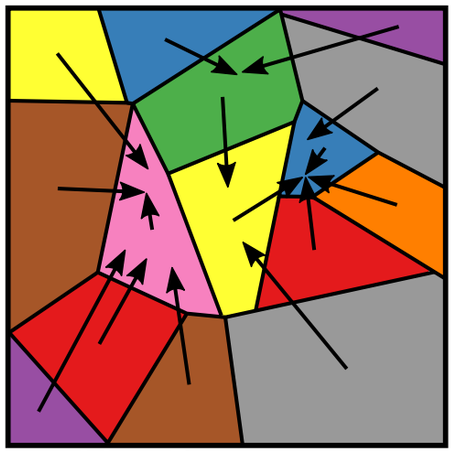

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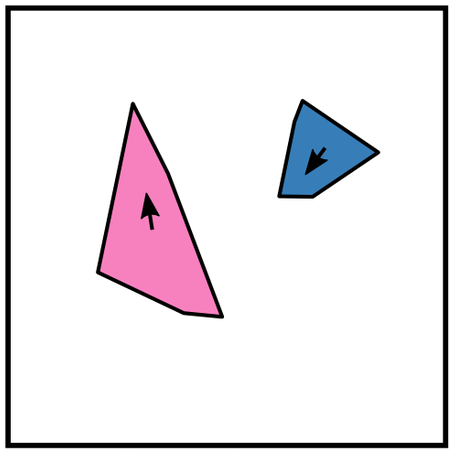

Fixed Points

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http://mucha.host.dartmouth.edu
peter.j.mucha@dartmouth.edu