Sex, Drugs and STIs:
Decomposing Network Contributions of Different Risk Behaviors

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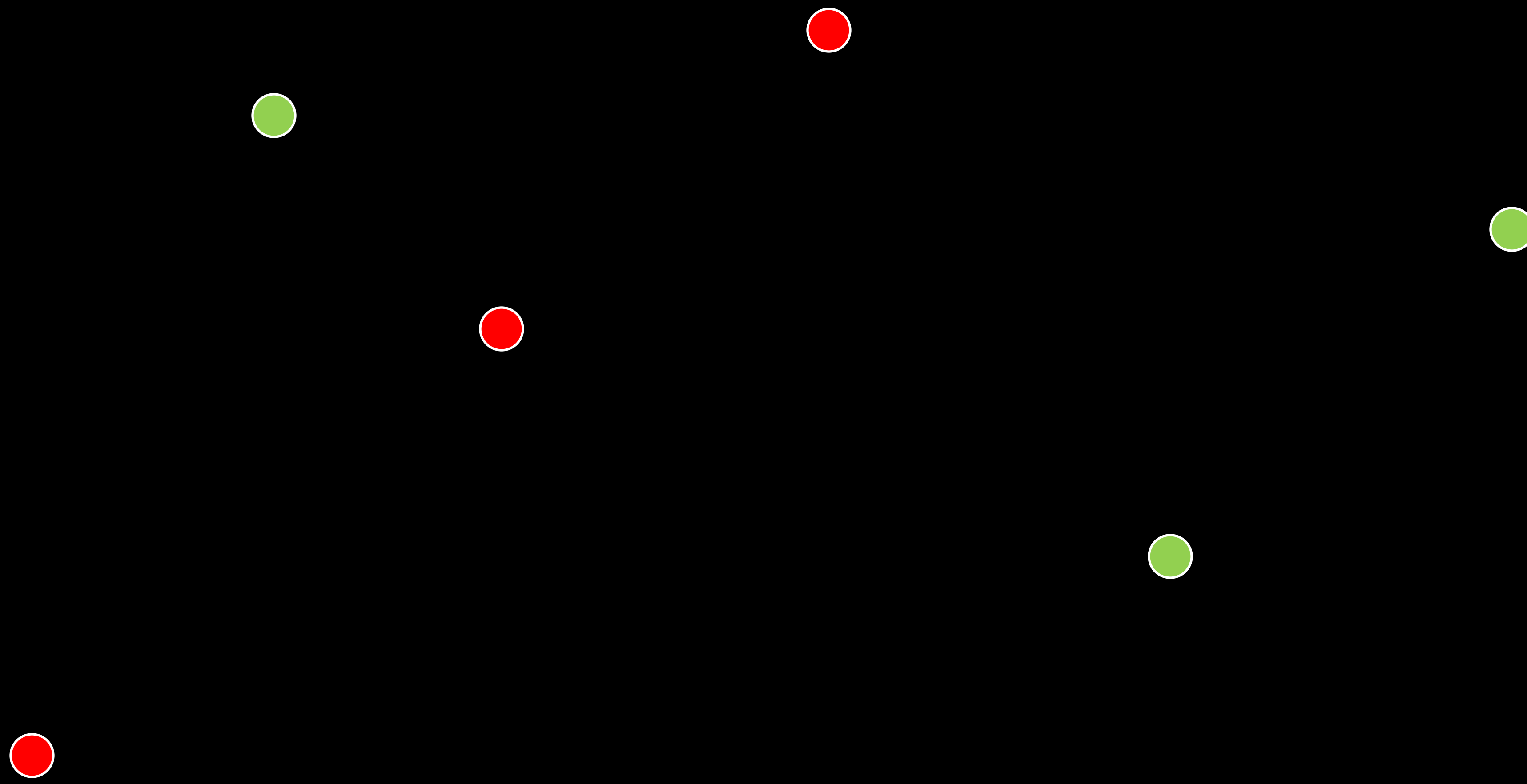
Today's Roadmap

- Background
  - My research
  - Networks & STIs
- The question(s)
  - How do different risk behaviors contribute to network predictors of STI?
  - Could those differences help understand racial differences in STI?
- Method
  - Simulation-based network counterfactual approach
- Results
  - Sex-ties fundamentally different
  - (& most likely to be cross-race)
- Discussion
  - Intervention implications

My primary projects

- IDEAS – Interdisciplinary Dynamics in Emerging Areas of Science Project
  - w/ Ryan Light, University of Oregon
  - Coauthorship, Cocitation & Topic Model networks in problem-based science (HIV & environmental science) examining catalysts and barriers to effective multi-disciplinary science
- "Capturing Context" – Integrating network and spatial analytic strategies
  - w/ Gina Lovasi, Columbia University
  - Forthcoming special issue of *Social Networks*, late 2011
- Modeling HIV/STI Epidemics
  - Simulation & empirical-based epidemic surveillance, modeling and decomposition
  - Partner-Based Interventions Modeling Project
    - w/ Georges Reniers, Princeton University

What predicts disease risk?



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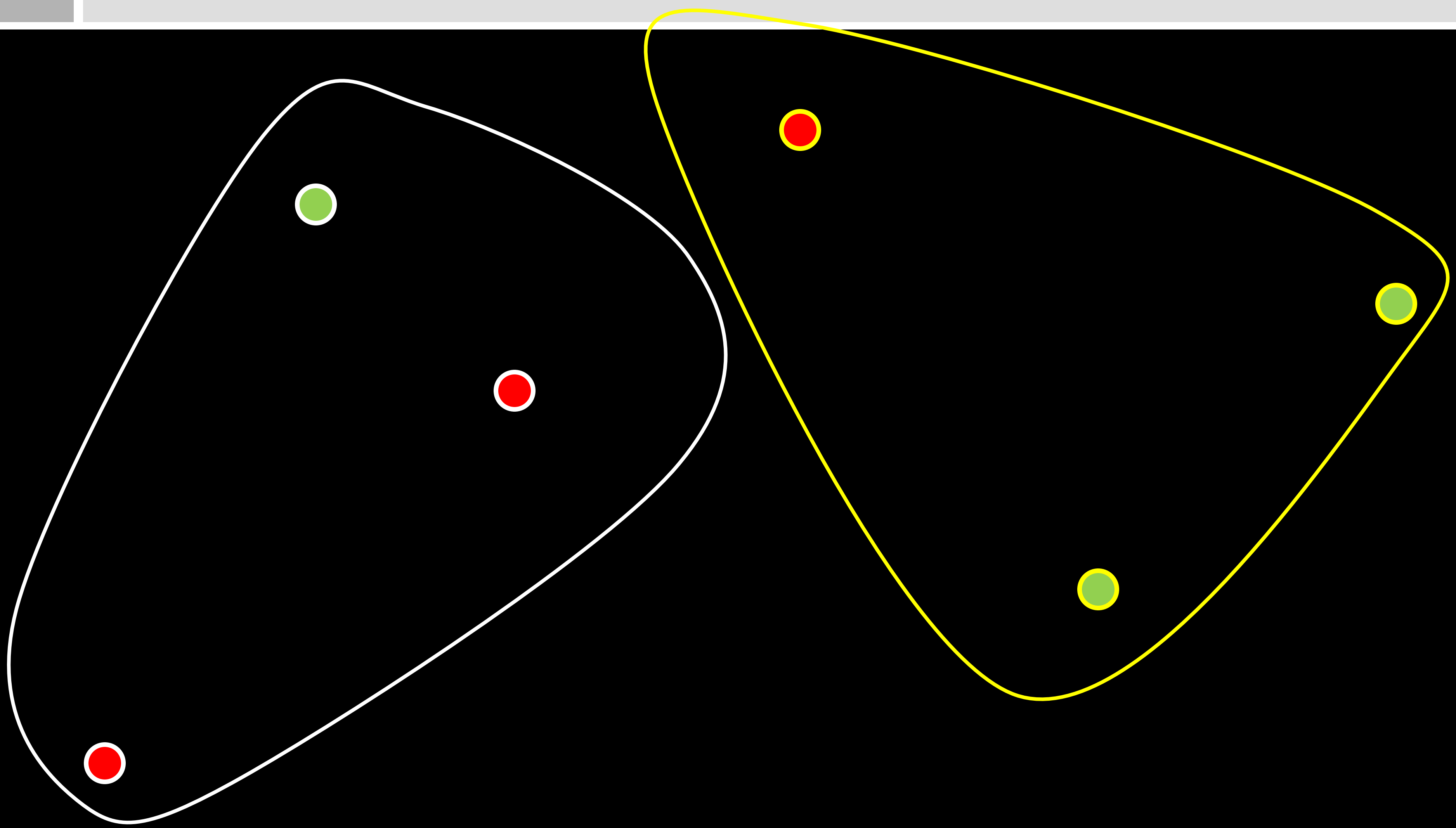

What predicts disease risk?

Resp	Gender	Age	Race	Village	Stat T_0	Risk F1	Risk F2	Risk F3	Risk F4
1	m	28	b	a	0	high	low	hi	zero
2	m	30	w	b	0	low	low	low	low
3	f	15	w	b	0	zero	zero	zero	low
4	m	16	o	b	0	low	low	low	low
5	f	18	b	a	0	zero	high	high	zero
6	f	25	b	a	1	low	high	high	high

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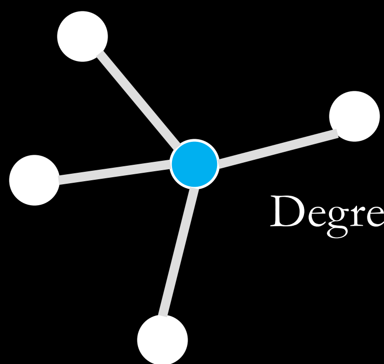
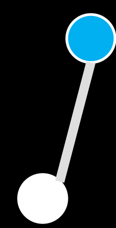
What predicts disease risk?

degree: number of partners for an individual (node)

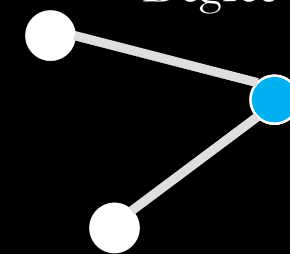


Degree = 4

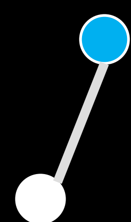


Degree = 1

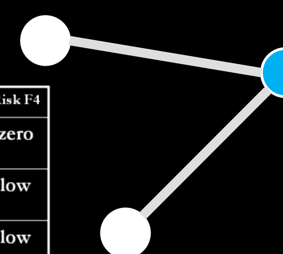
Degree = 2



Who is at greatest risk? Least?



Degree = 1



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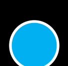
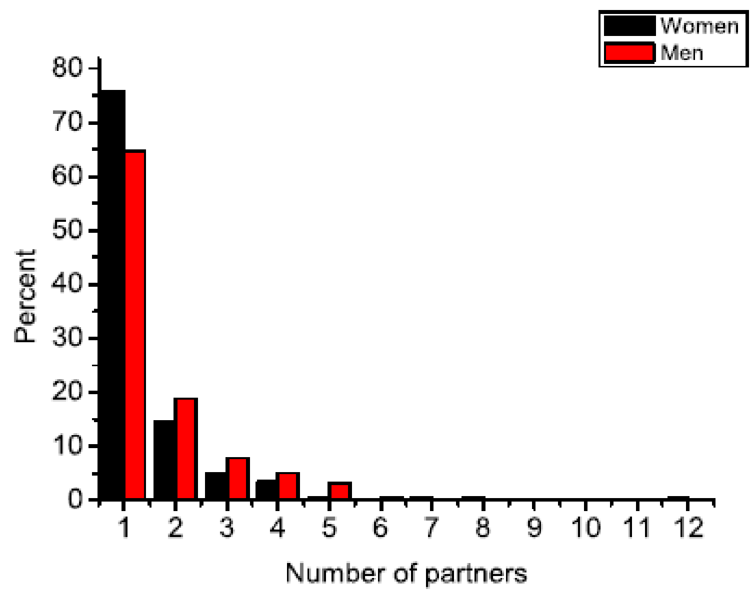


Degree = 0

Resp	Gender	Age	Race	Village	Stat T_0	Risk F1	Risk F2	Risk F3	Risk F4
1	m	28	b	a	0	high	low	hi	zero
2	m	30	w	b	0	low	low	low	low
3	f	15	w	b	0	zero	zero	zero	low
4	m	16	o	b	0	low	low	low	low
5	f	18	b	a	0	zero	high	high	zero
6	f	25	b	a	1	low	high	high	high

Why / how does “degree” matter?



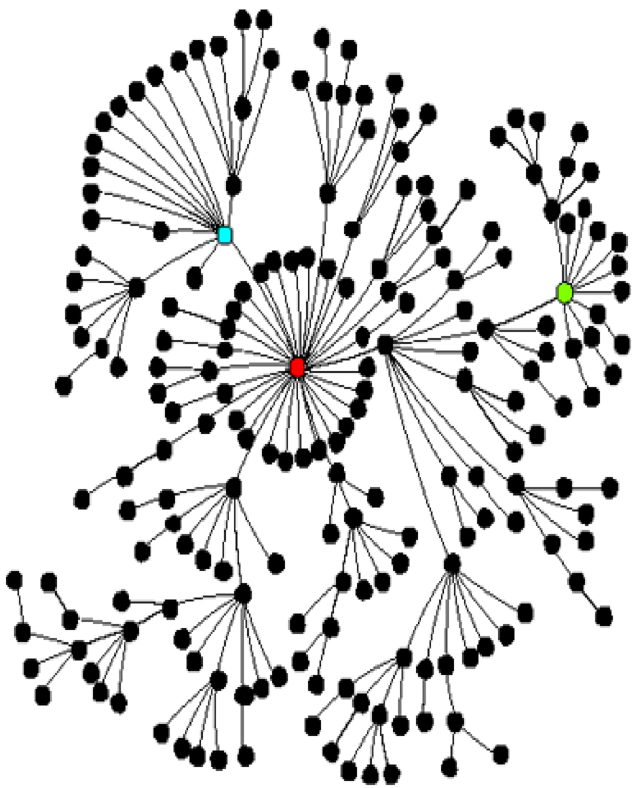


Figure 1: Distribution of the number of sex partners during one year men and women in the Gotland data.

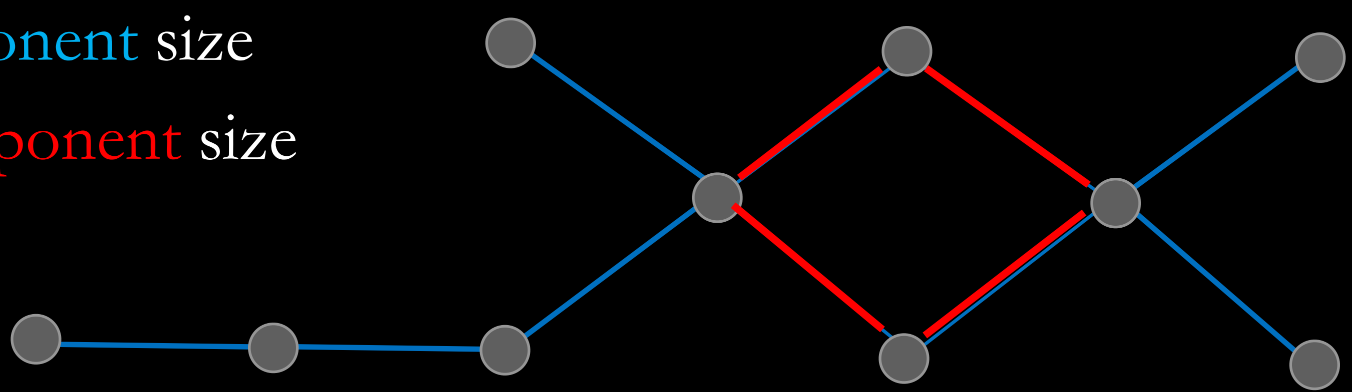
-“Epidemics arise and propagate much faster in scale free networks” (Liljeros et al 2001:907)

-“To stop AIDS, find hub, scientists say” (Bay Area Reporter 2001)

Is degree enough?

A Network Simulation of Epidemic Potential - Description

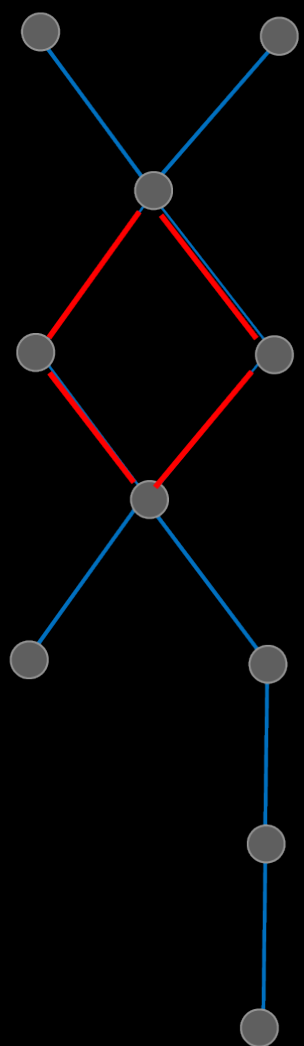
- Simulate networks
  - 10,000 nodes
- Same total # of partners - 2 degree distributions
  - "Scale free"
  - Low-degree ($1 < x < 3$)
- Compare measures of epidemic potential
  - Component size
  - Bicomponent size

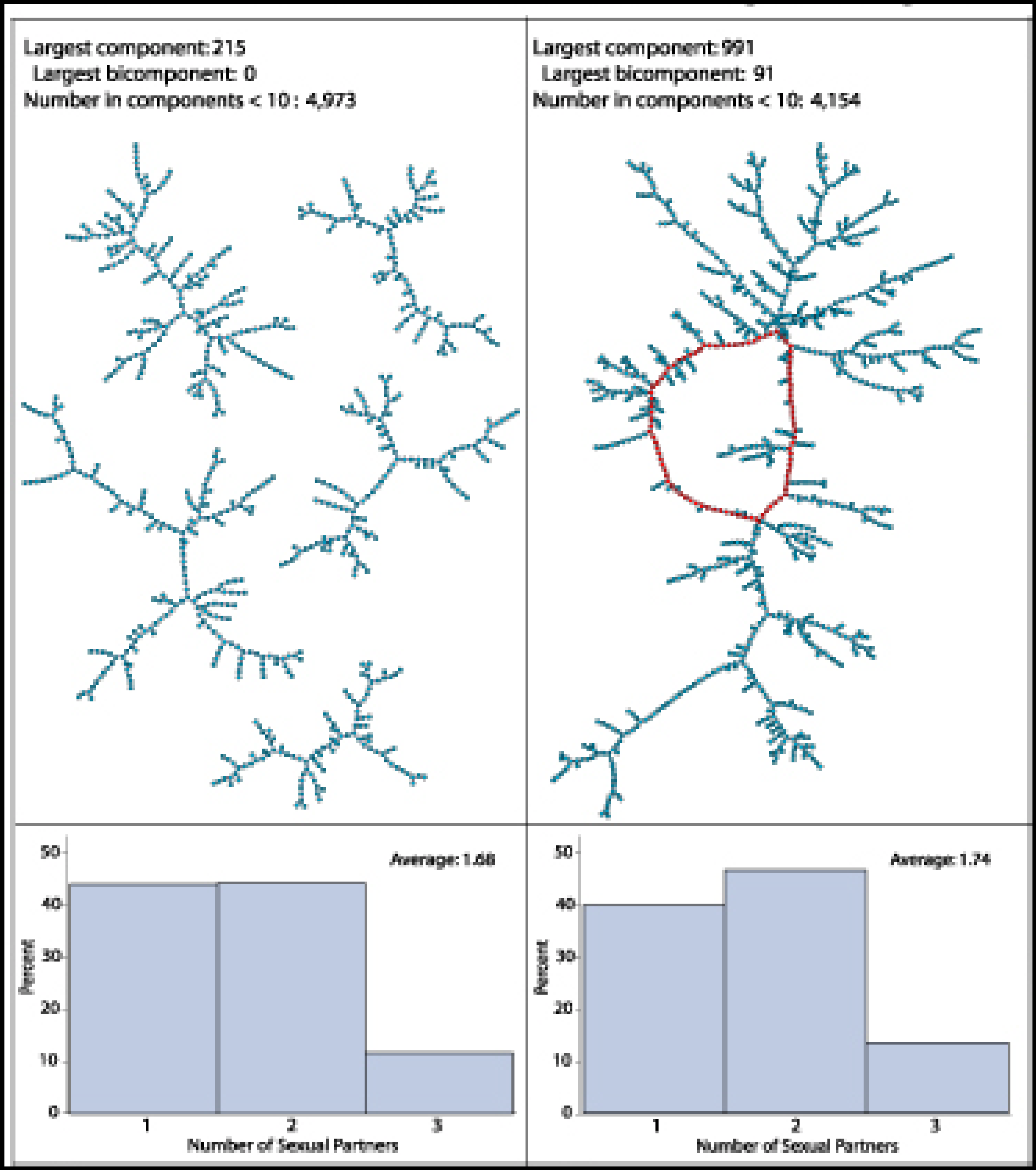


Is degree enough?

A Network Simulation of
Epidemic Potential

Simulated Low-Degree Networks





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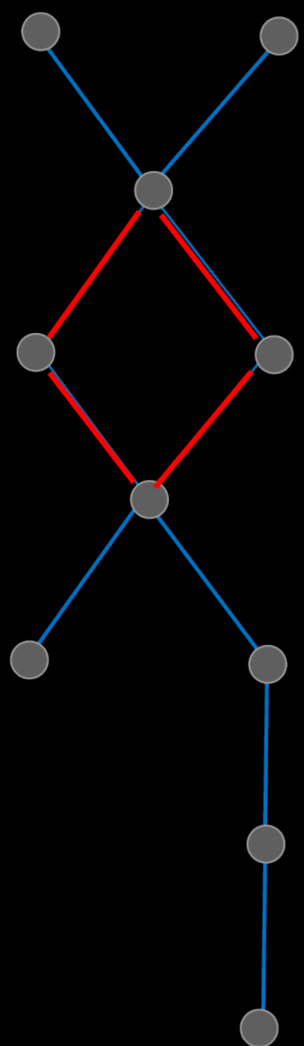
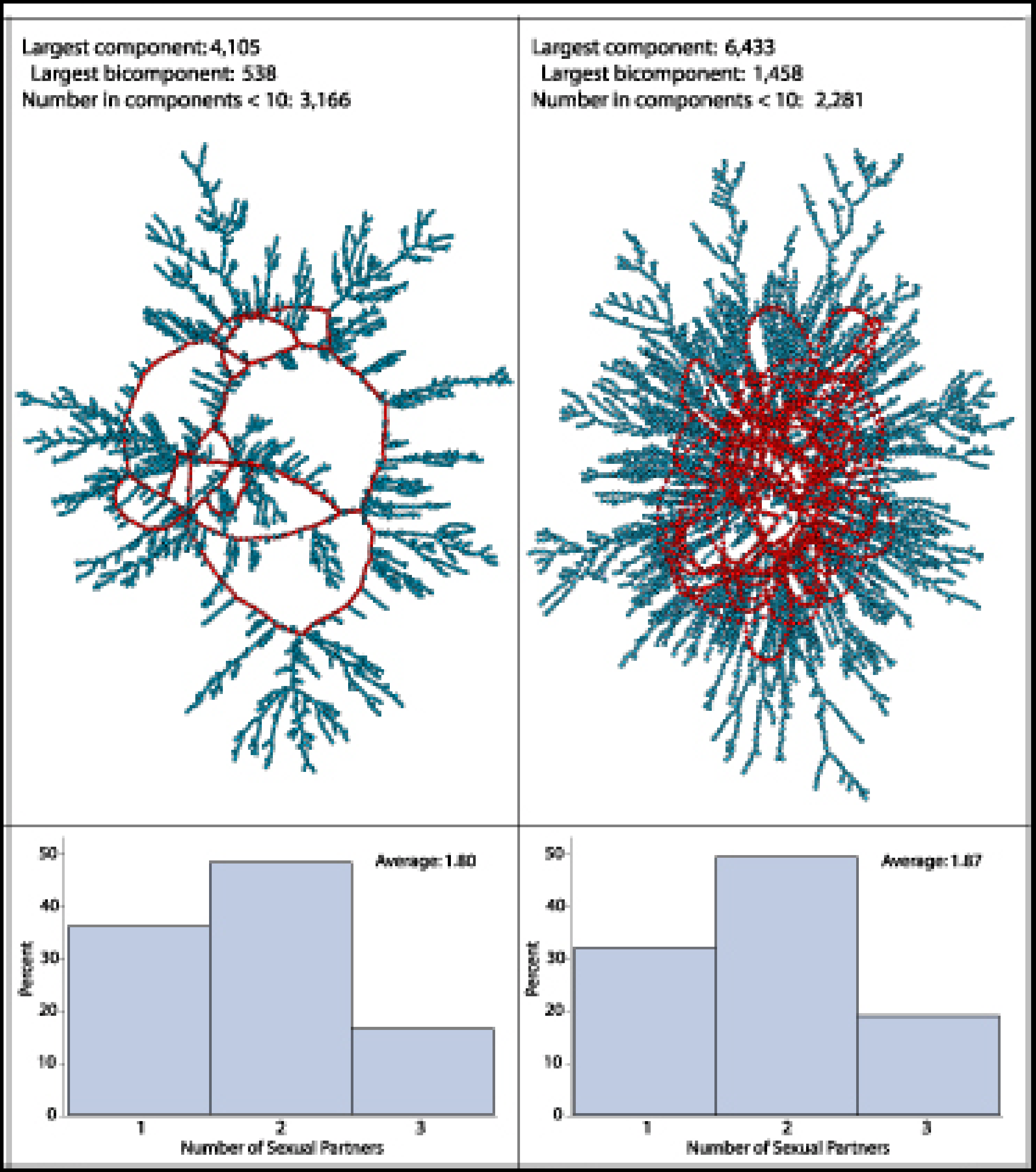
A Network Simulation of Epidemic Potential

Simulated Low-Degree Networks





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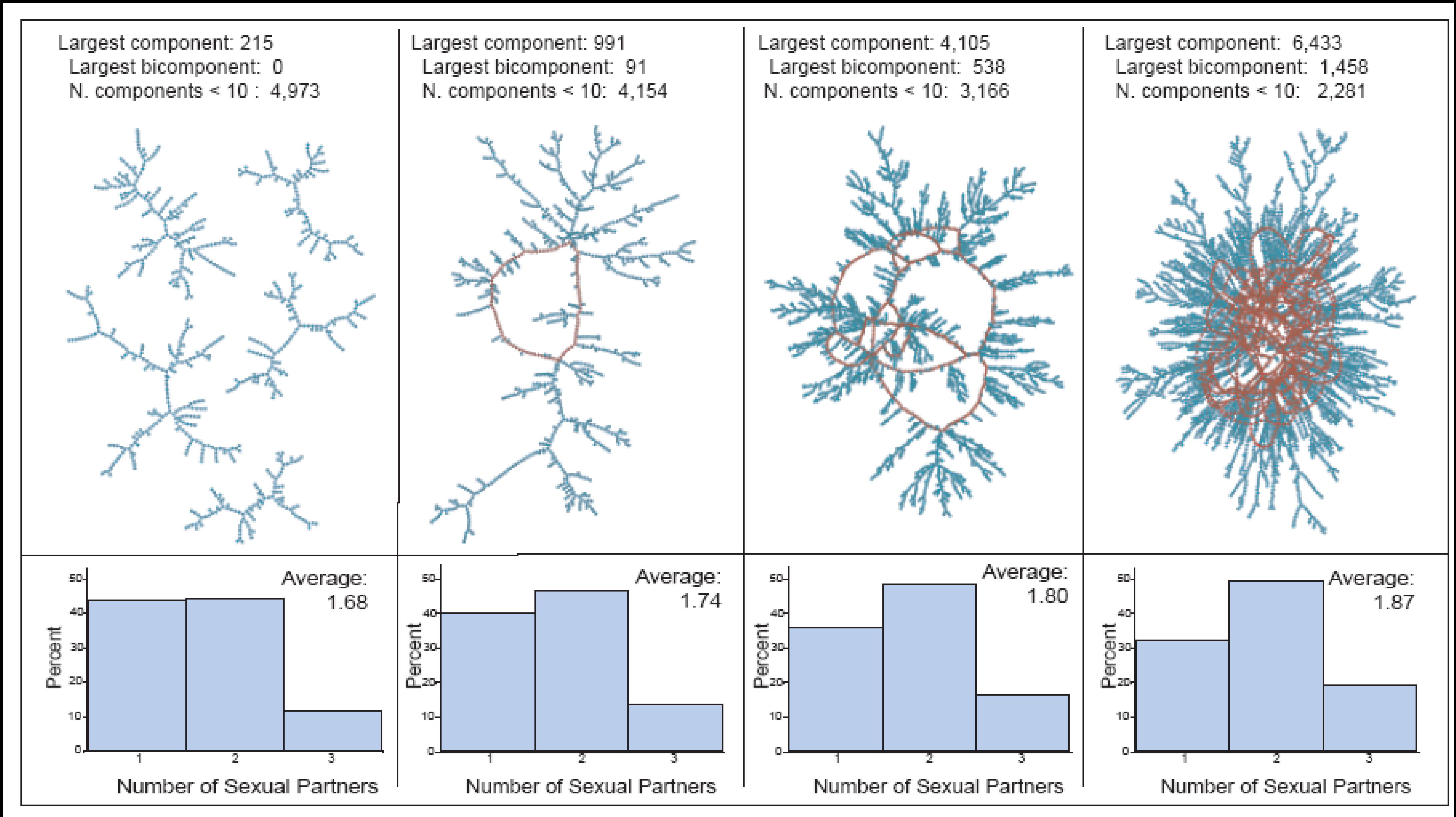
A Network Simulation of Epidemic Potential

Simulated Low-Degree Networks



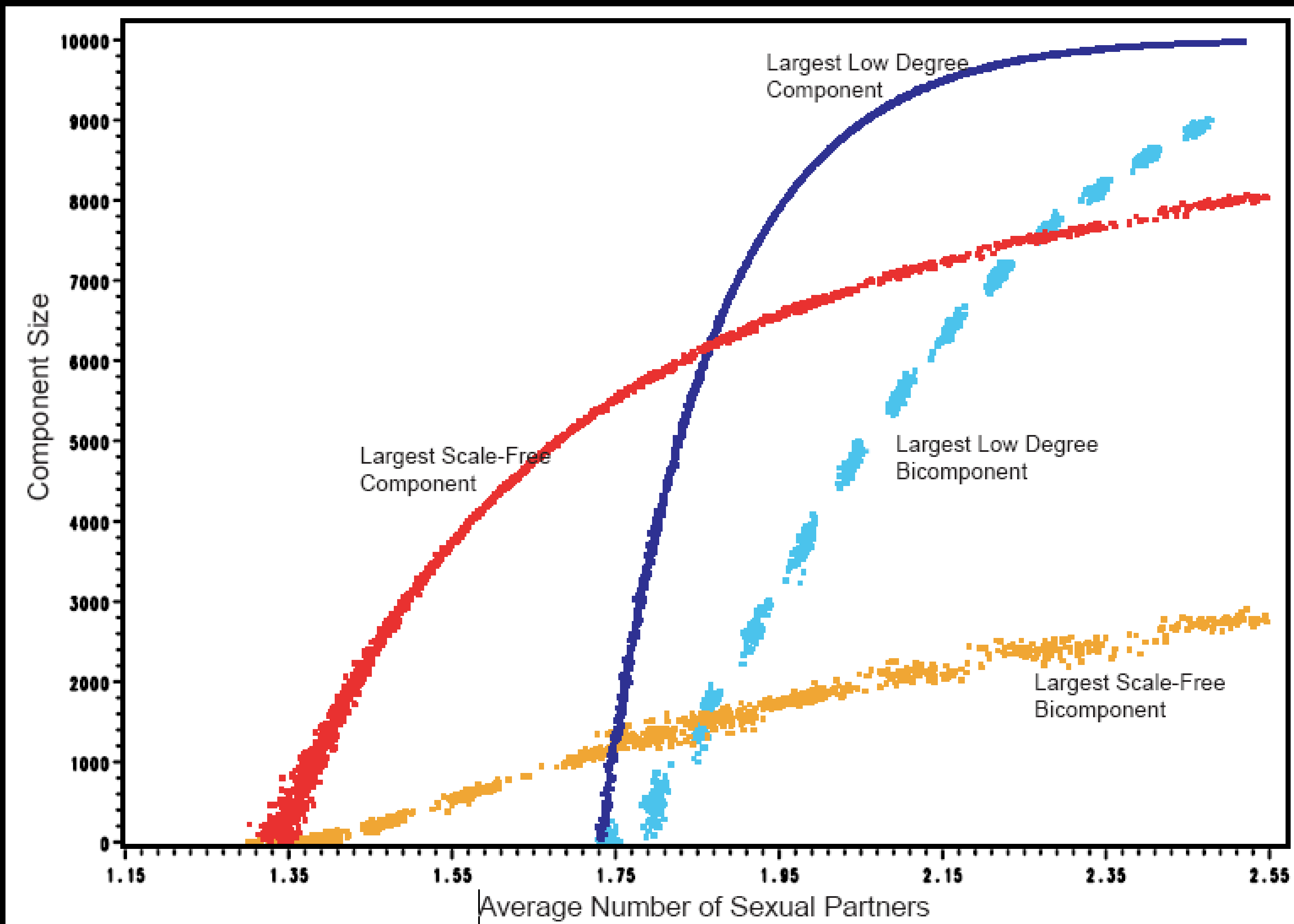
Is degree enough?

A Network Simulation of Epidemic Potential

“Epidemi… and prop… te much faster in … ale free … orks’

-(L… t al 2001:907)

Comparing Low-Degree and Scale-Free Networks



Is degree enough?

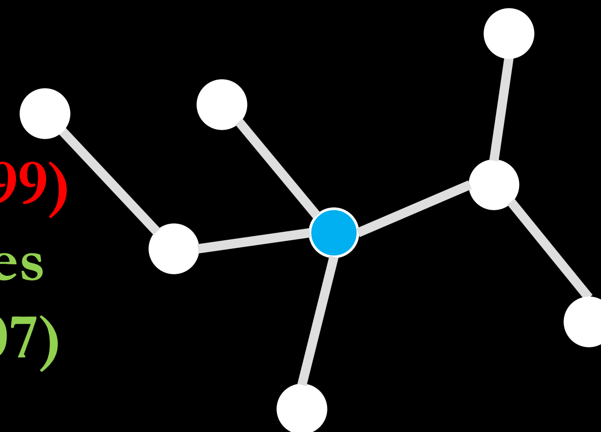
A Network Simulation of Epidemic Potential

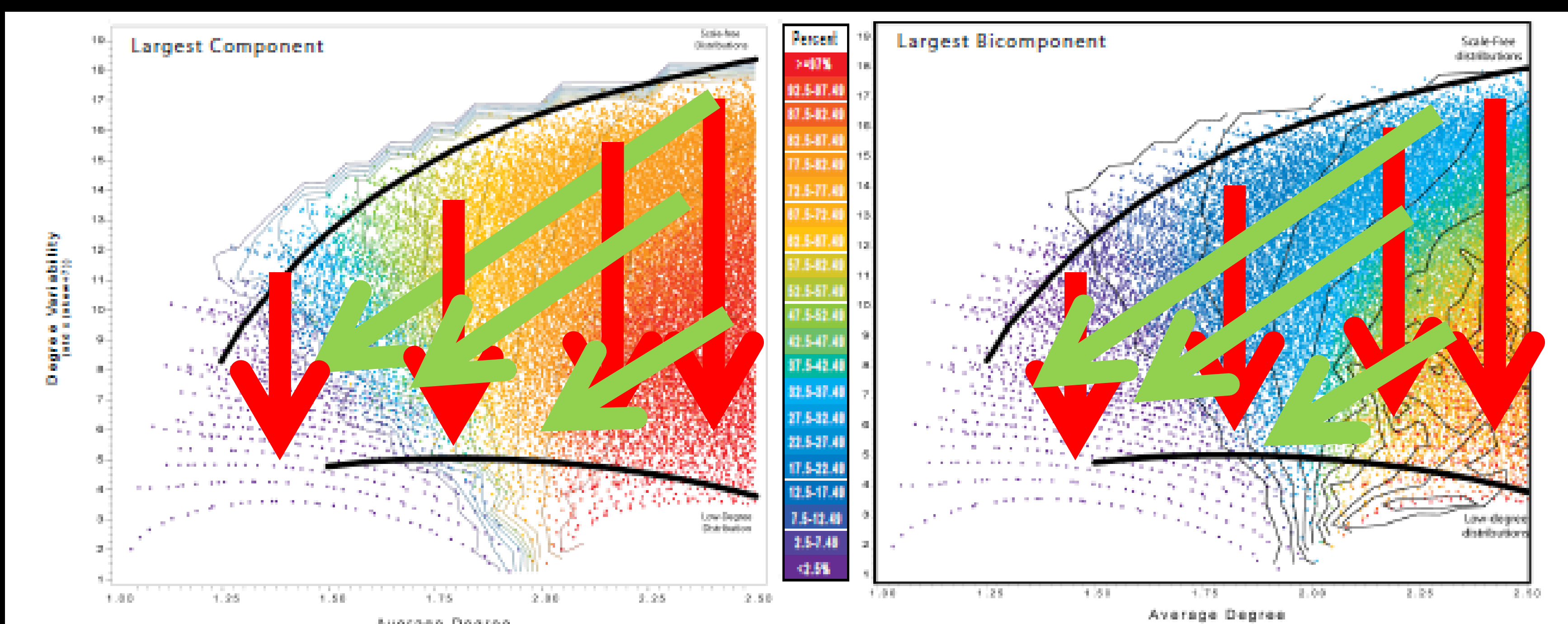
"To stop AID , fi d hub, cientists say"

(Liljeros et al 1999)

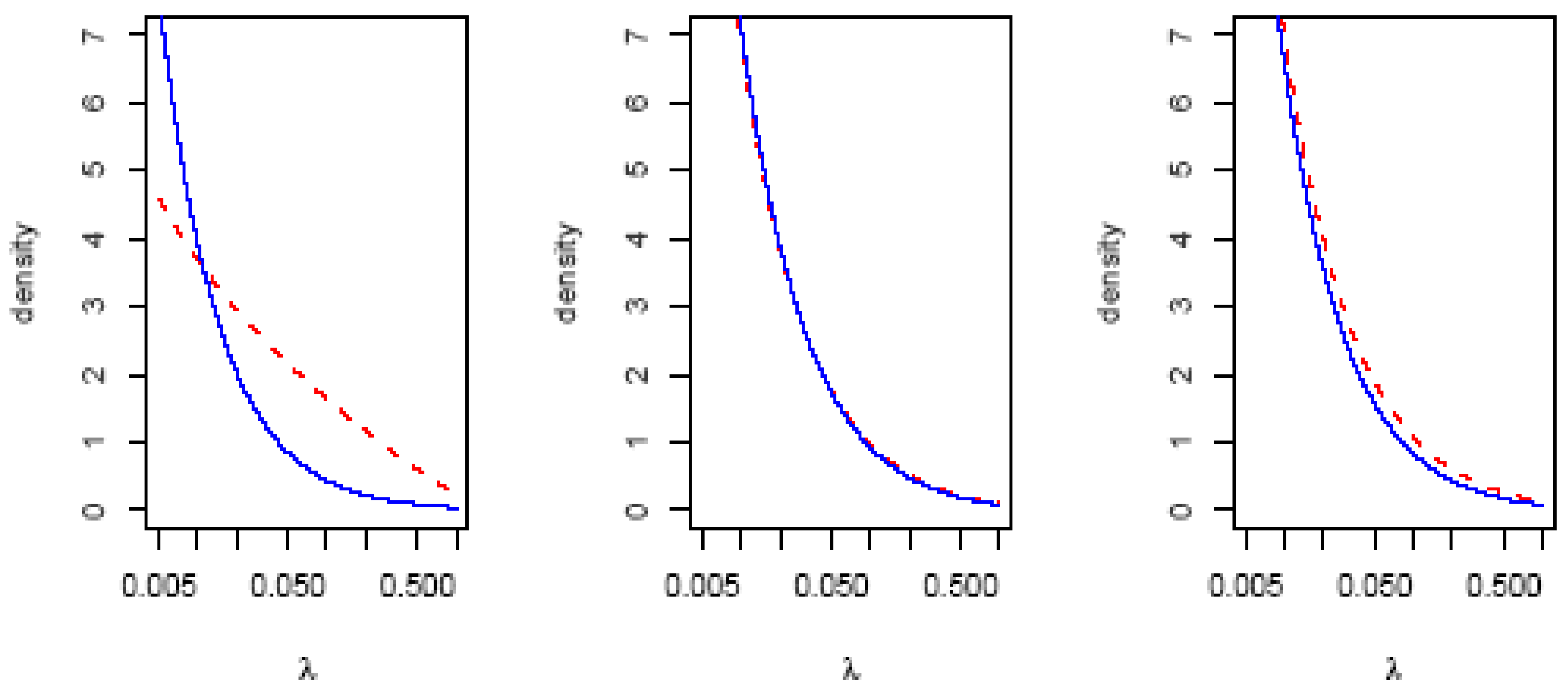
Target everyone for "risk reduction" strategies

(Moody et al 2007)



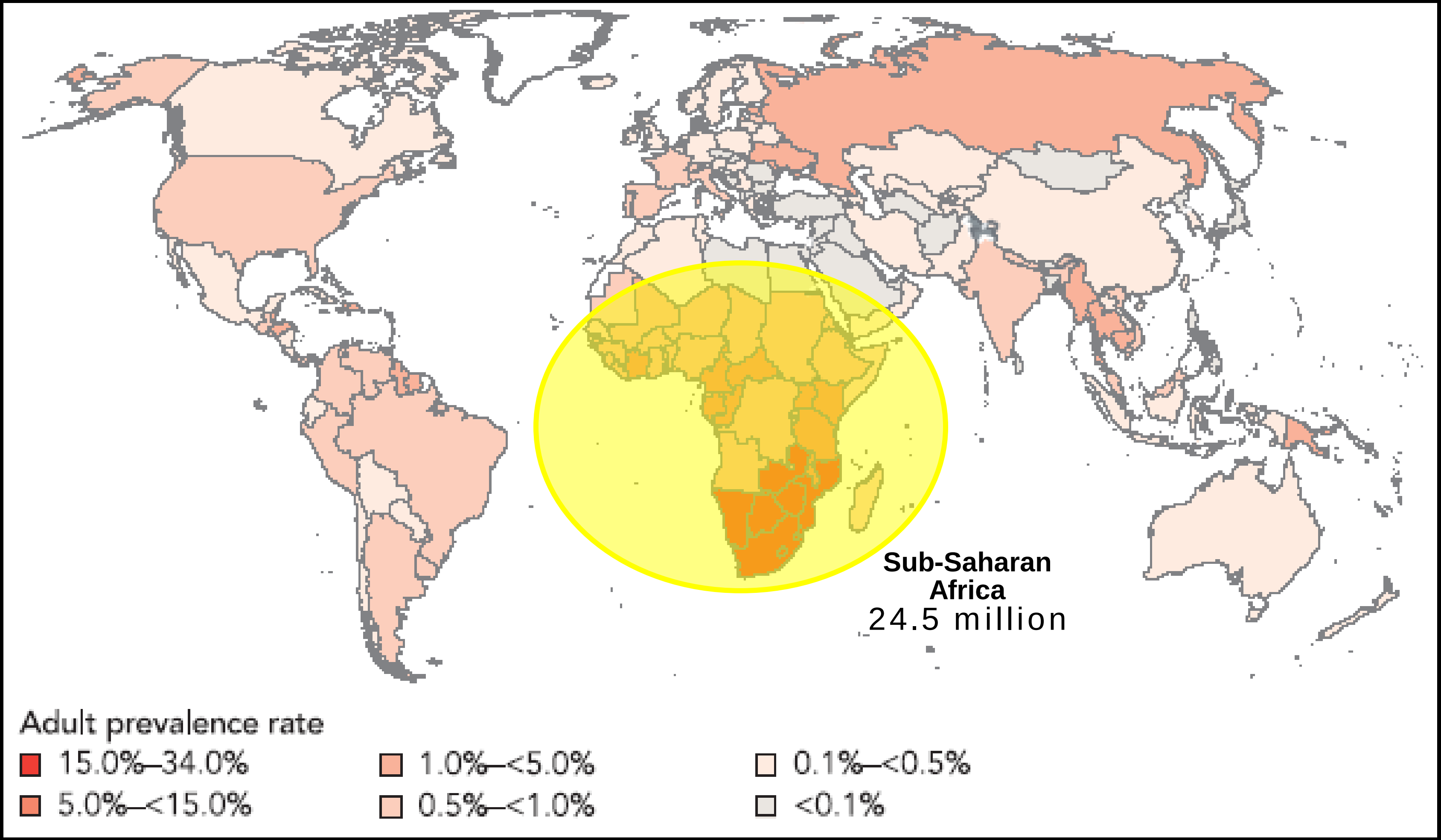


Do Scale-Free Networks "Fit"?



(Source: Handcock and Jones 2005)

Adults and Children Estimated to Be Living with HIV/AIDS as of End 2005

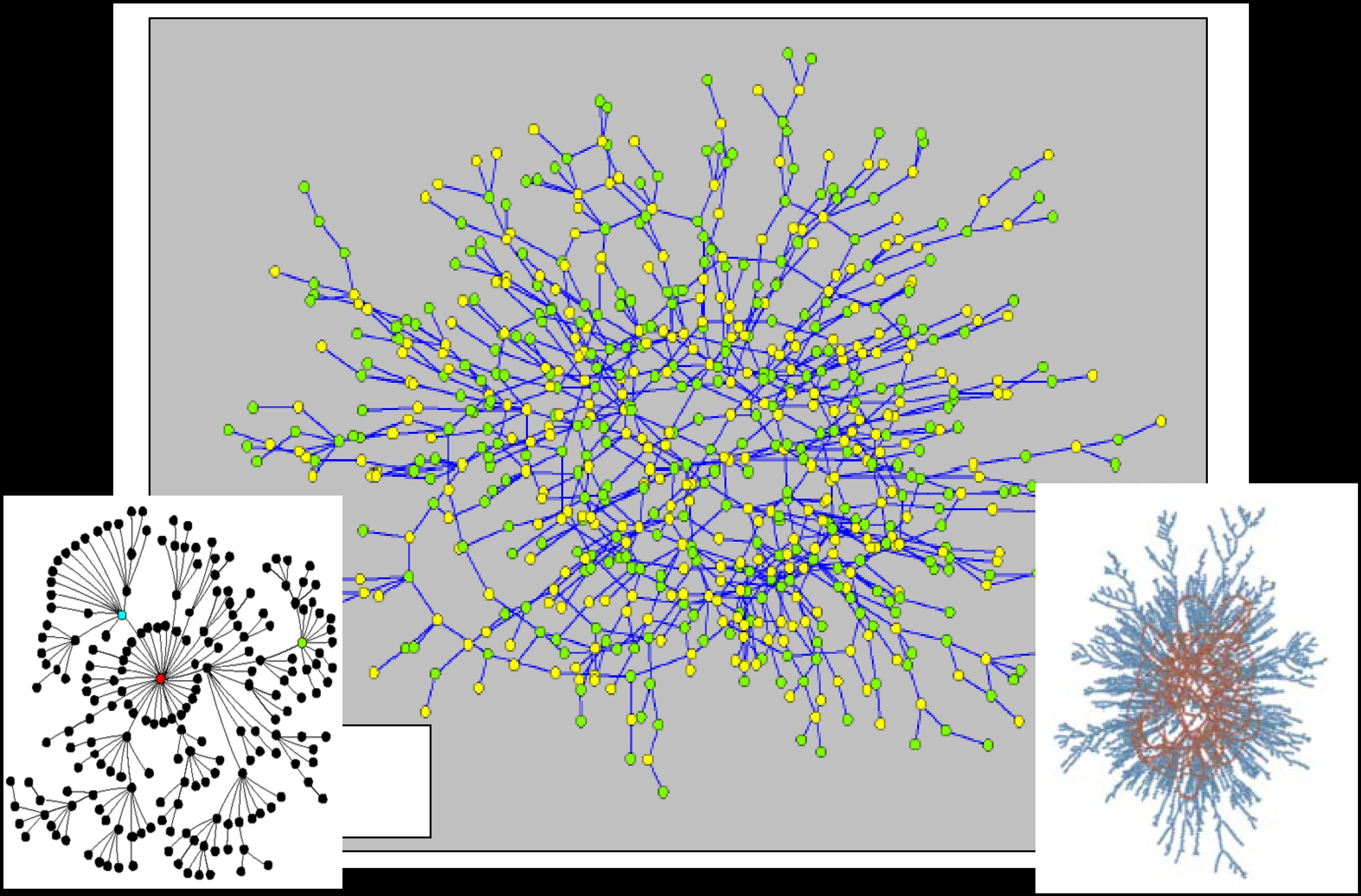


Total: 38.6 million people [33.4 - 46.0 million]

(Source: USAID 2006)

Is degree enough?

A Network Simulation of Epidemic Potential - comparison to observed data



(Source: Helleringer and Kohler 2006)

Is Degree Enough? (No)

- Conditions necessary for disease epidemics are (more) possible in networks without high-degree actors ("hubs")
- Interventions should target everyone
  - (with respect to ABCs):
- Strategic interventions should focus also on patterns of *network structure:*
- **Today's Questions**
  - **What are the relevant patterns of network structure?**
  - **How do different "risky" behaviors contribute to those patterns?**

Examining Racial Differences in Sexually Transmitted Infections

The Differential Importance of Sex & Drug Ties in a High Risk Population

(w/ James Moody, Duke University)

Acknowledgements:

NIDA (Martina Morris, PI)

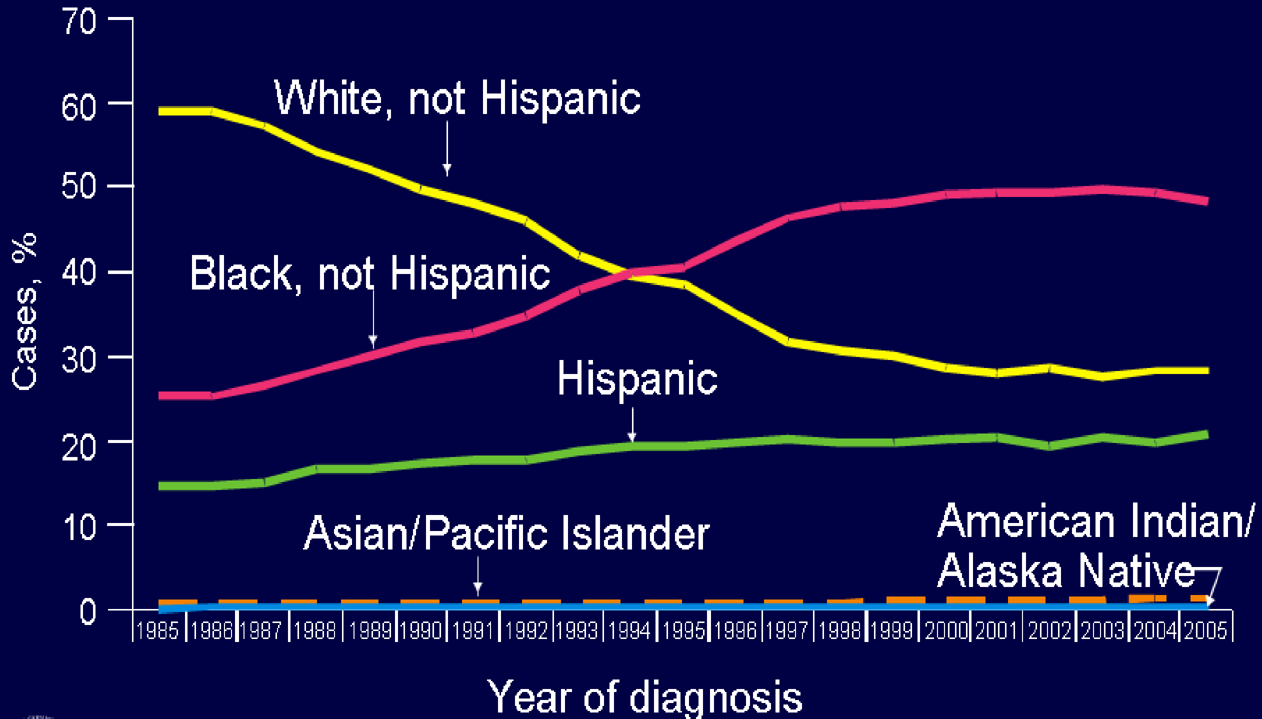
John Potterat, Stephen Q. Muth (project directors)

Peter Bearman & RWJ H&SS Program, Columbia University

Social Networks & Health Working Group, Columbia University

Structural Dynamics Working Group, SSFD, Arizona State University

Proportions of AIDS Cases among Adults and Adolescents, by Race/Ethnicity and Year of Diagnosis 1985–2005—United States and Dependent Areas



Note. Data have been adjusted for reporting delays.

Revised June 2007

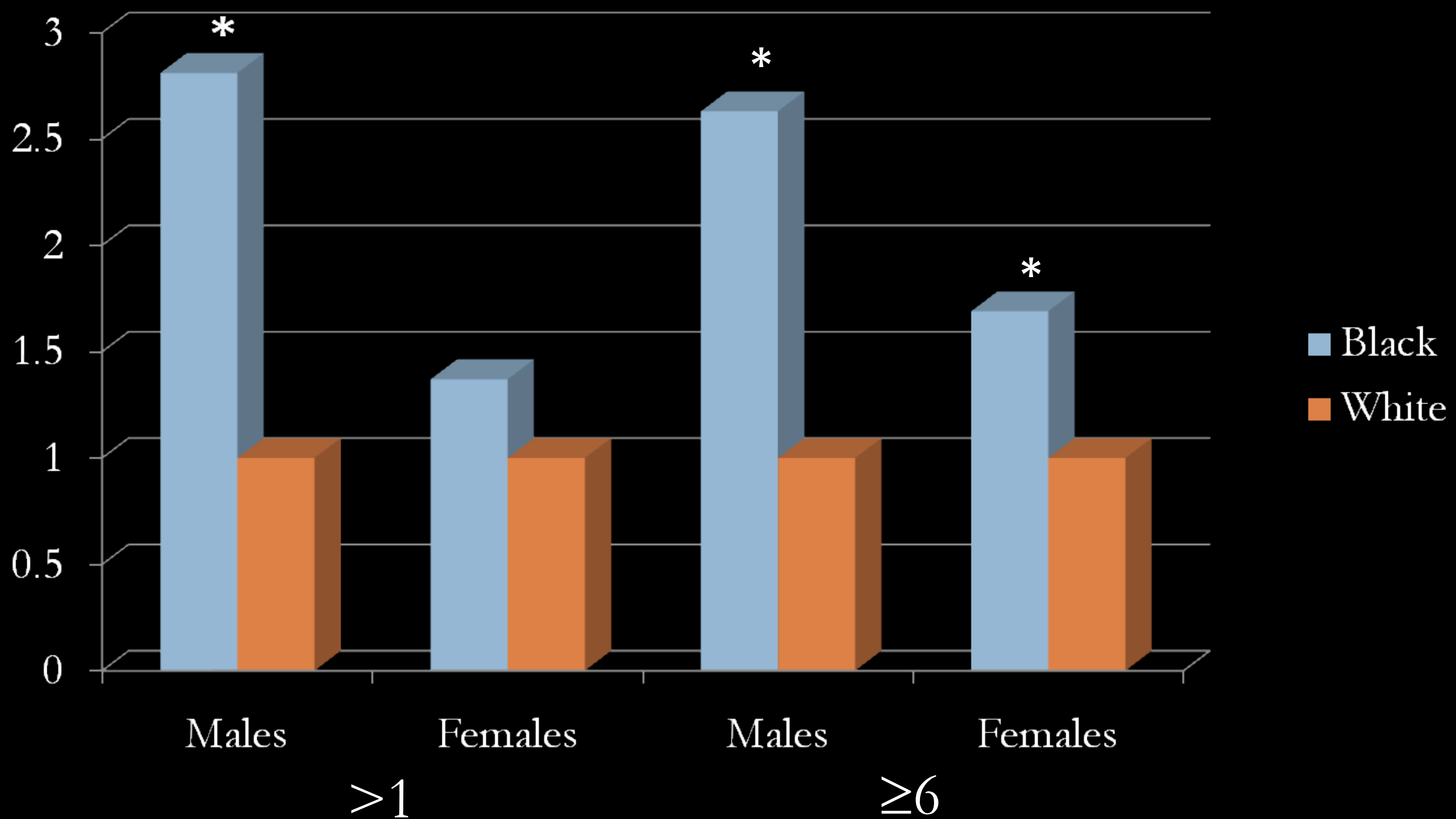
Racial Discrepancies in STD Prevalence

Existing Explanations

- Individual Risk Factors:
  - Poverty, healthcare access and use and community prevalence rates (e.g., Aral 1996; CDC 1995) and drug use (Kottiri et al 2002)
  - Number of sexual partnerships (Santelli et al 1998)
  - Concurrency (Morris and Kretzchmar 1995)
    - Higher for blacks than whites (Adimora et al. 2002; Billy et al. 1993; Manhart et al. 2002; Ford and Norris 1997)

Reported Number of Sexual Partners

Existing Explanations for Racial Discrepancies in STD Prevalence



Odds ratios, controlling for age, residence, marital status, alcohol and drug use, and age at first intercourse (Source Santelli et al 1998)

(*'s – difference significant for $p<0.05$)

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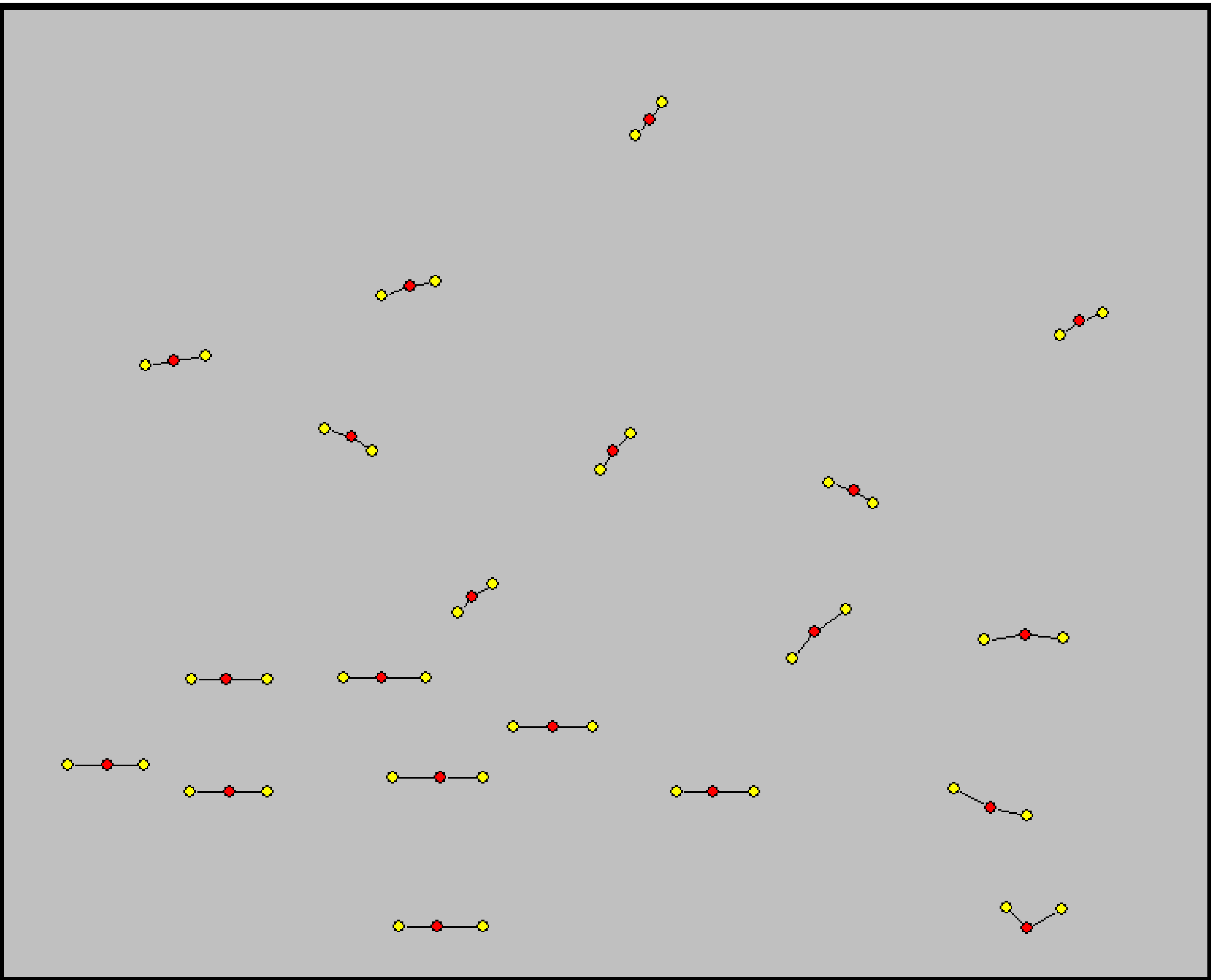

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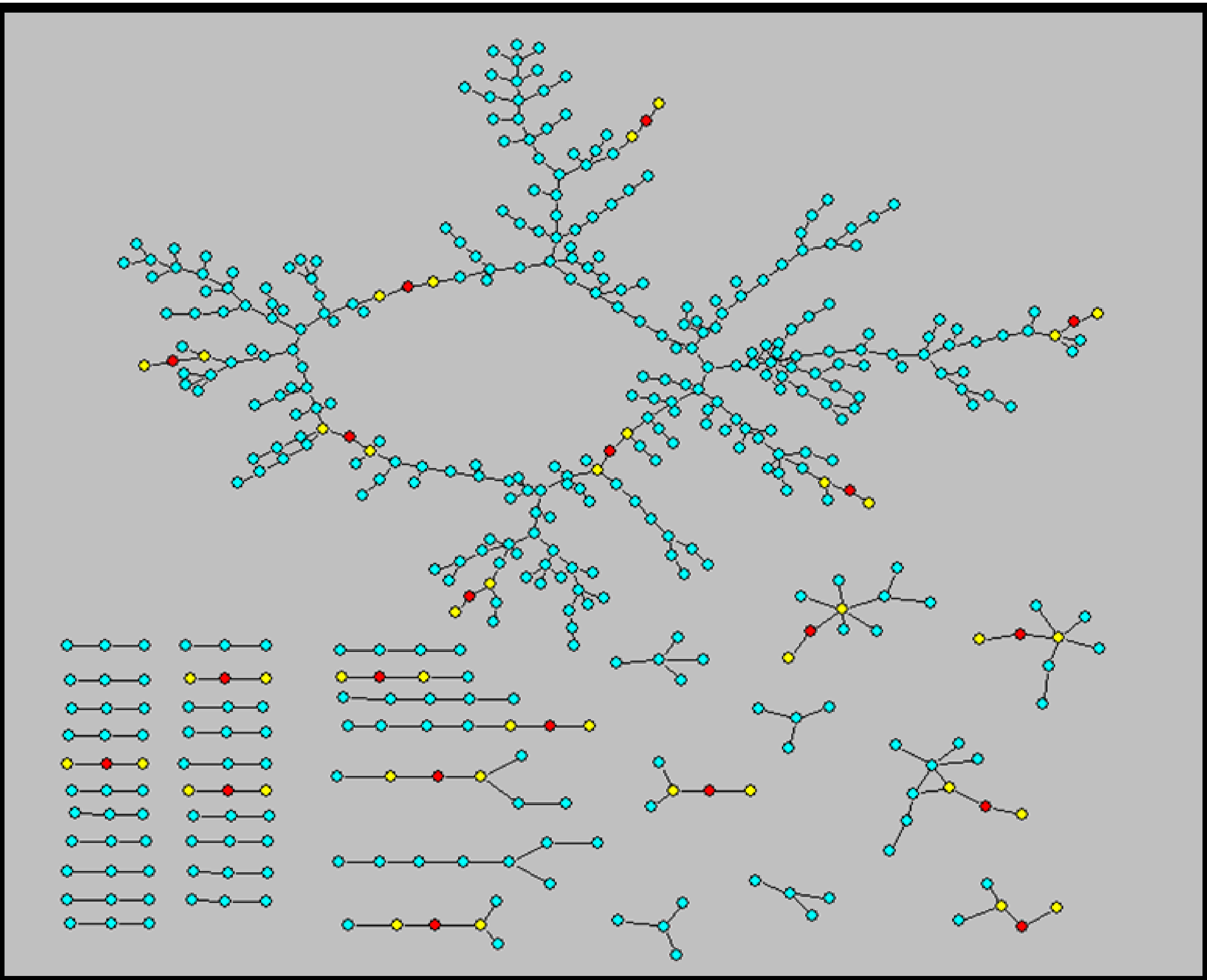

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- Sexual network structure can explain differences not observed through individual level modeling, such as:
  - Network bridges (Morris et al. 1996)
    - More frequently among blacks than whites (Laumann and Youm 1999)
  - "Sexual segregation" can isolate an STI in a particular population

Racial Discrepancies in STD Prevalence

Existing Explanations

Table 2 Characteristics of persons by component size membership

Component size (n)	Sex			Ethnicity					
				Male			Female		
	M	F	M/F ratio	W (%)	AA (%)	Other (%)	W (%)	AA (%)	Other (%)
Large (n=10)	120	155	0.77	16 (13.3)	98 (81.7)	6 (5.0)	59 (38.1)	68 (43.9)	28 (18.0)
Medium (n=66)	639	822	0.78	185 (29.0)	324 (50.7)	130 (20.3)	360 (43.8)	258 (31.4)	204 (24.8)
Small (n=2625)	1013	1610	0.63	356 (35.1)	430 (42.4)	227 (22.4)	766 (47.6)	440 (27.3)	404 (25.1)
Total (n=2701)	1772	2587	0.68	557 (31.4)	852 (48.1)	363 (20.5)	1185 (45.8)	766 (29.6)	636 (24.6)

AA, African American; other, other ethnicity (76.6% Hispanic); W, white.

Racial Discrepancies in STD Prevalence

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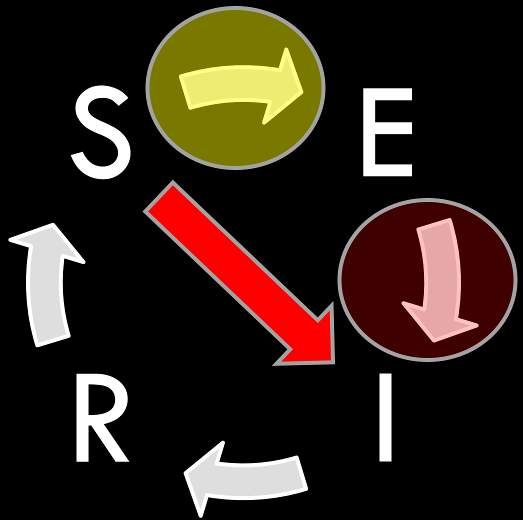
  - "Sexual segregation" can isolate an STI in a particular population

Net of all this, LARGE disparities remain

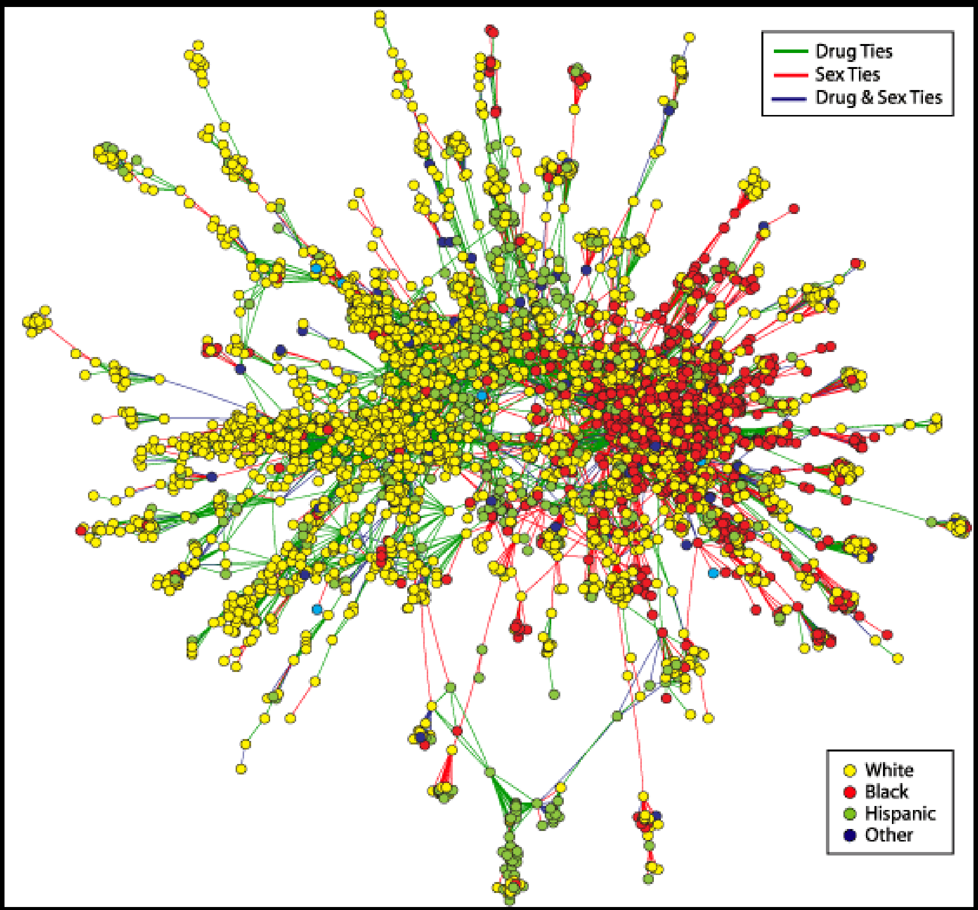
Racial Discrepancies in STD Prevalence

Remaining Gaps – Other Explanations?

- Wide gap in HIV and other STD prevalence remains between blacks and whites in the US
  - *Even controlling for <u>all</u> of the explanations mentioned above.*
- So…Let's examine:
  - Do different types of relations (sex, drugs, both) differentially connect a "high-risk" population?
  - Can those differences help explain race differences in STI rates?

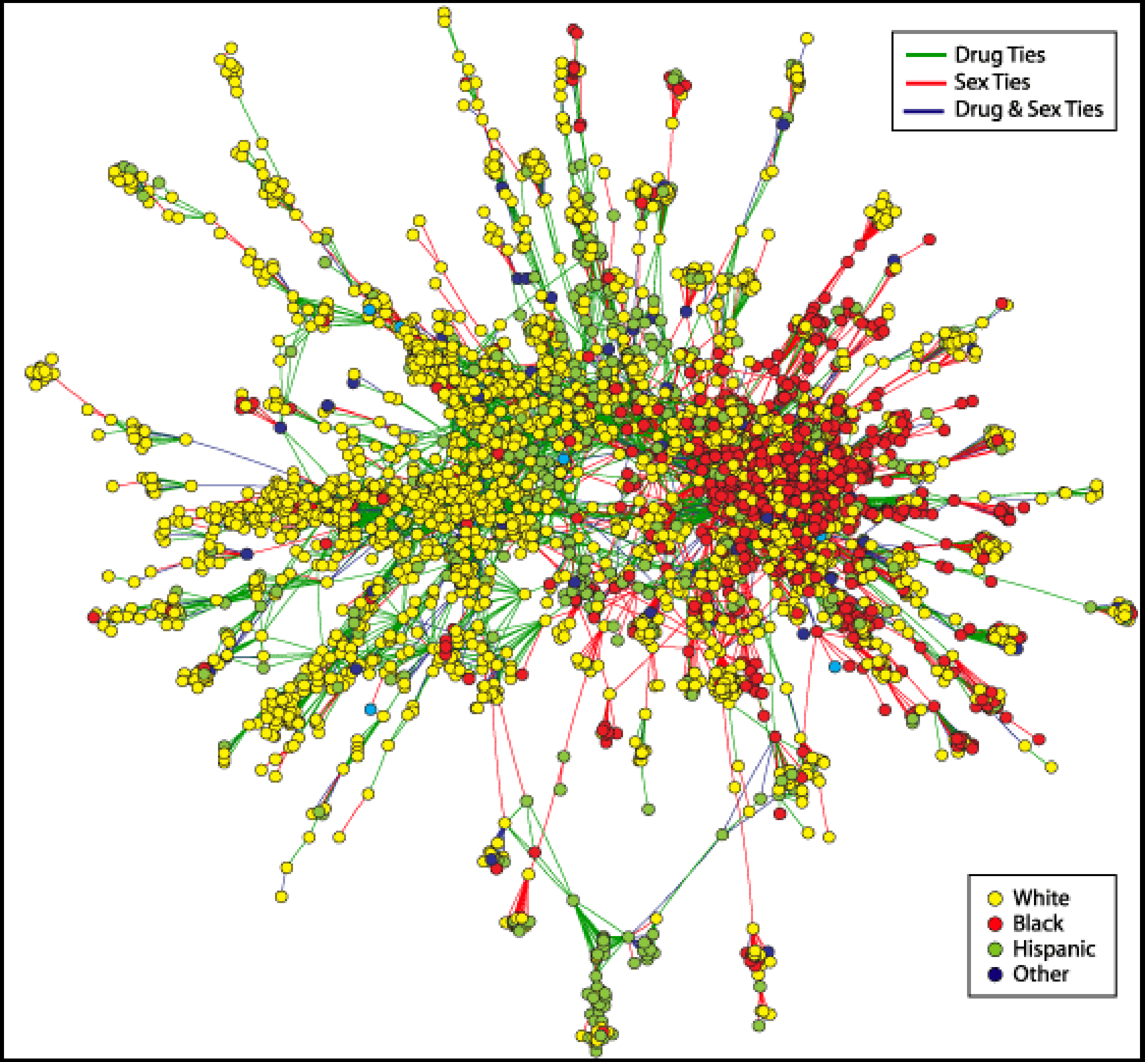


Data – Colorado Springs, Project 90



- CDC Funded (1988-1992)
- To assess the size, structure and epidemic potential of a high-risk partnership network
- HIV-transmission risk in population of:
  - Prostitutes
  - Their sex partners (heterosexual)
  - IDU
- 595 respondents
  - Face-to-face interviews
  - 5 year open cohort design
  - Link tracing design
- Sexual, drug sharing & social contact network data

Data – Colorado Springs, Project 90



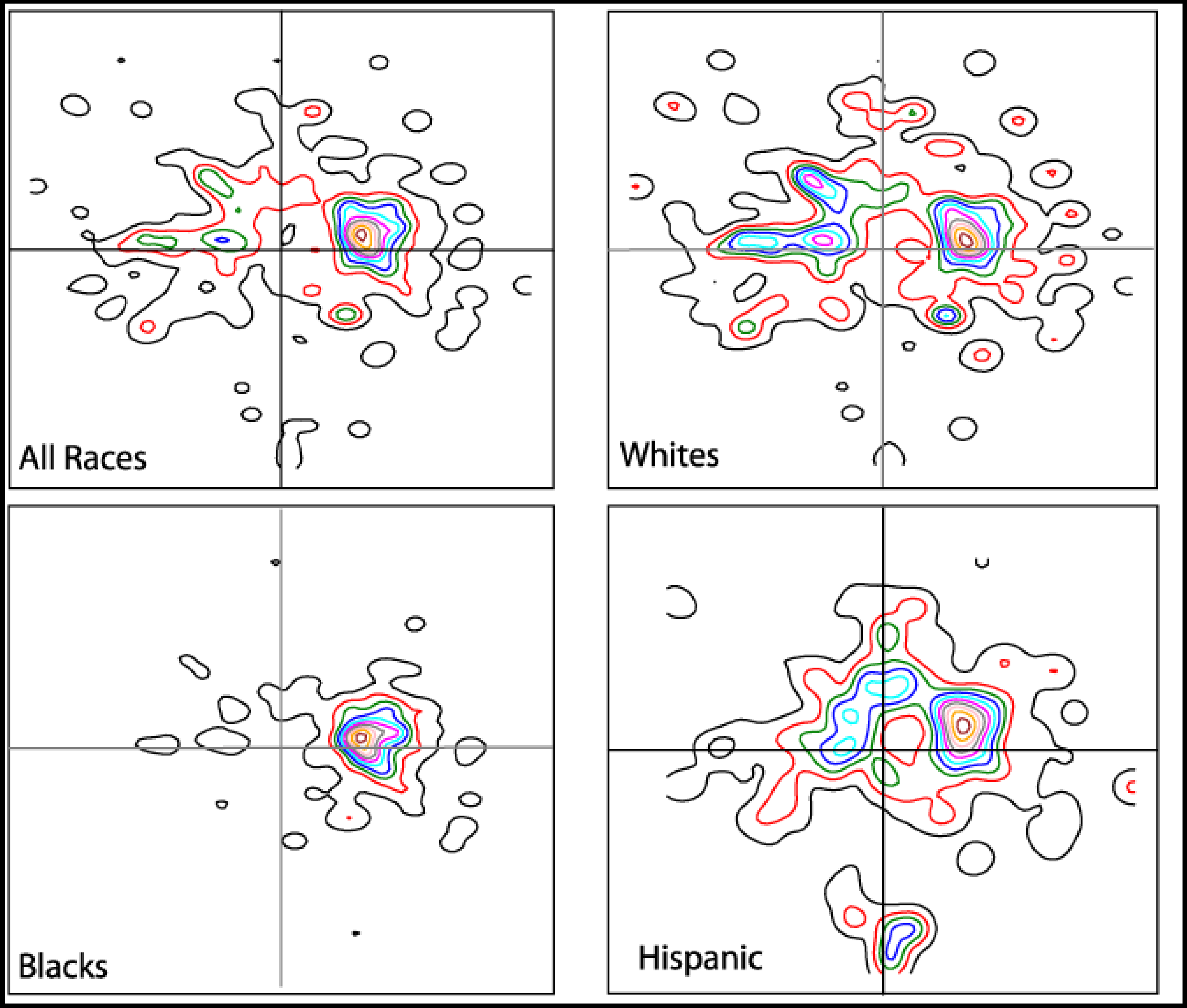
Data – Colorado Springs, Project 90

Node Level Mixing, by Tie-Type

	Sex Only	Drug Only	Both Only	Bridge Only	Both & Bridge
White	1283 (35.2)	1022 (28.1)	42 (1.2)	944 (25.9)	353 (9.7)
Black	418 (34.6)	365 (30.2)	12 (1.0)	305 (25.3)	108 (8.9)
Total	2009 (34.5)	1717 (29.5)	68 (1.2)	1503 (25.8)	530 (9.1)

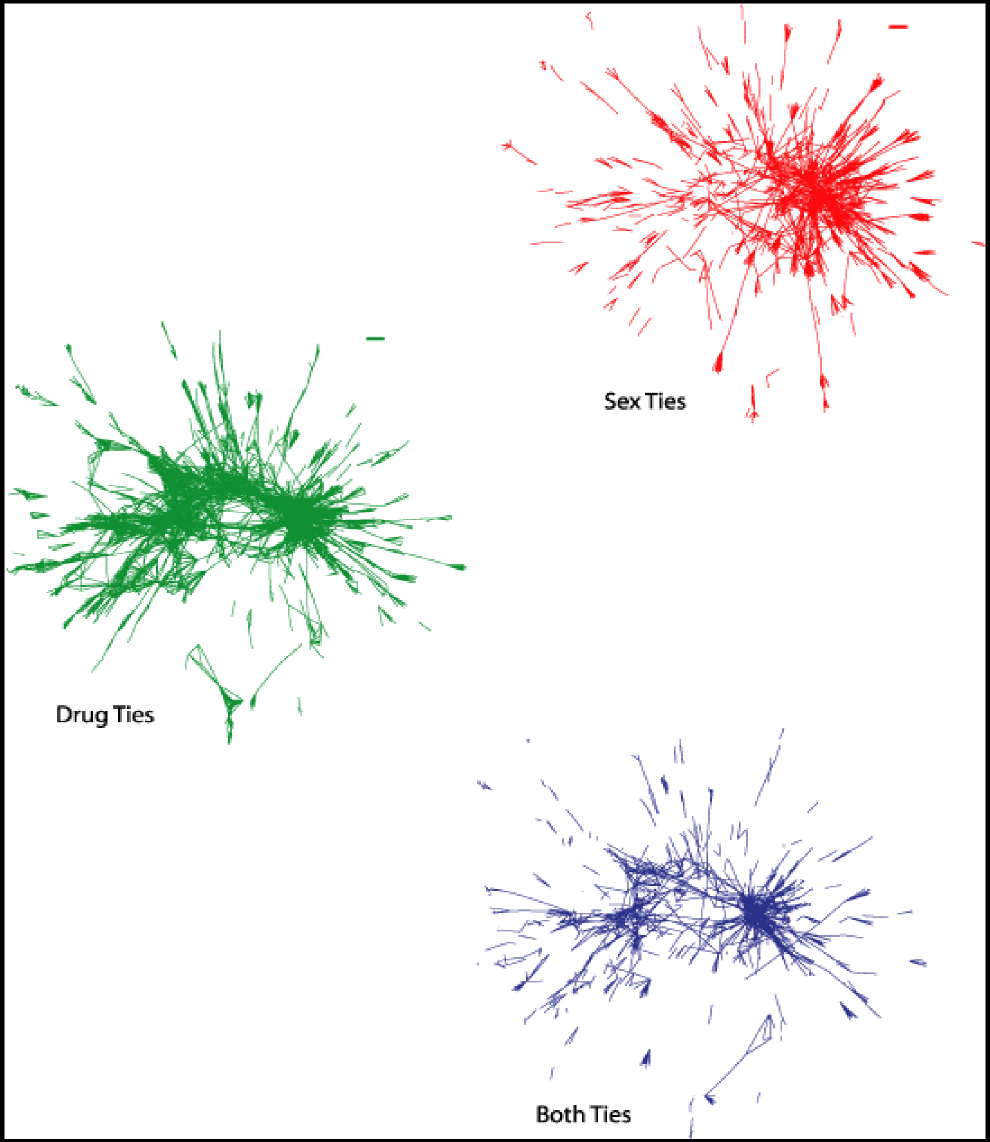
Modeling Group Differences in HIV Risk

Contour Overlay - by Race



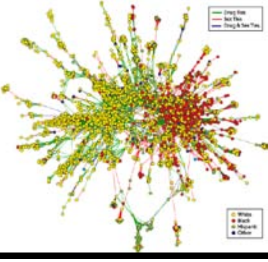
Modeling Group Differences in HIV Risk

Edges Only



Note the distribution of edge types. The large "eastern" cluster is where most of the sex is happening in this network.

Method



We can assess the *connectivity contributions* of each type of tie by *selectively removing* ties from a network and assessing the change in connectivity-relevant measures.

- That is:
  - Select at random *n* ties of type *k*
  - Calculate the connectivity measures on the resulting network
  - Repeat this many times (here 500 at each setting).
  - Plot observed (mean) changes by tie type

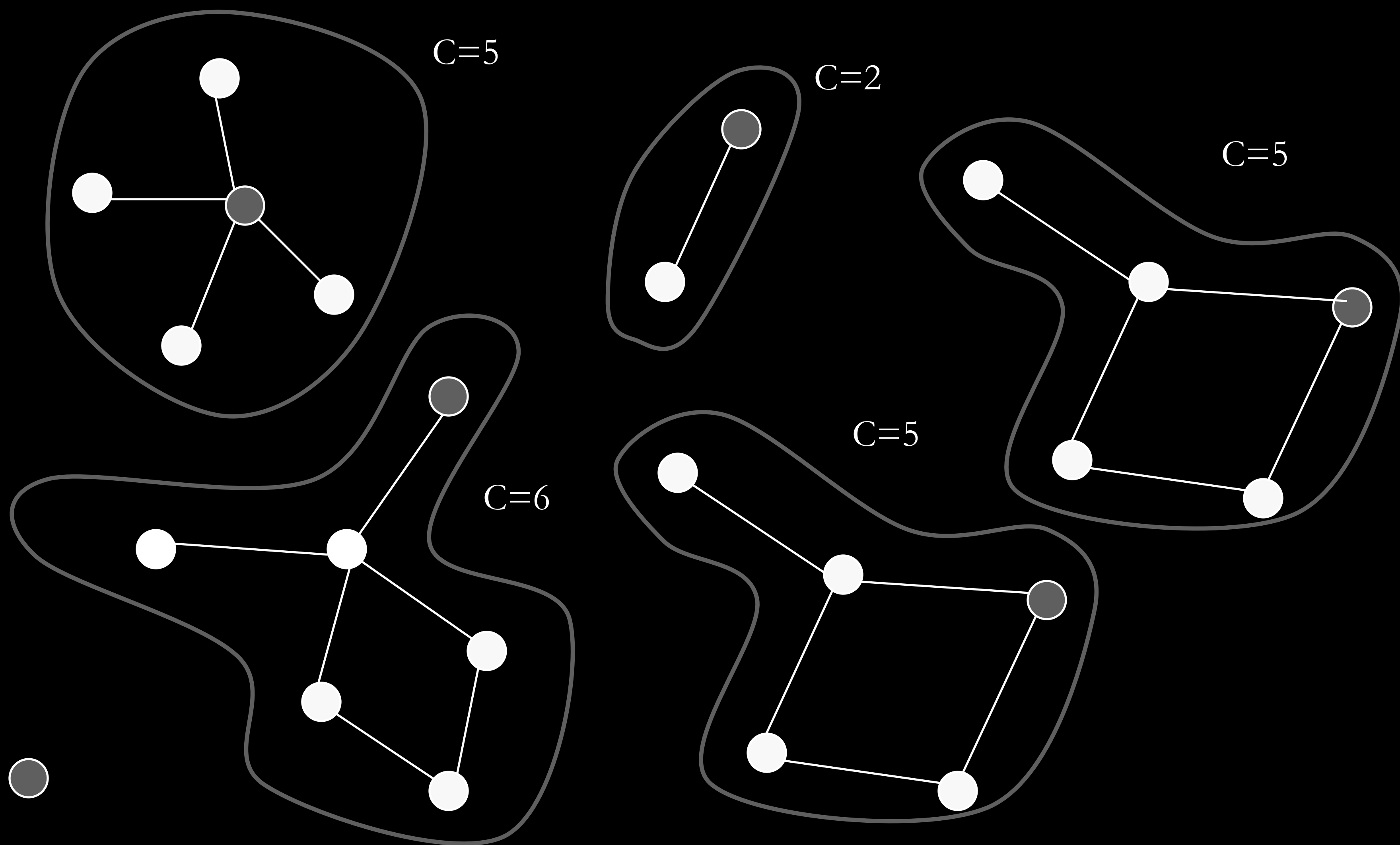
- We remove between 1% and 12% of the total ties observed in the network, separately for:
  - Sex ties
  - Drug Ties
  - Sex & Drug Ties
  - Random Ties

Connectivity Measures

- Size of the largest component
  - The maximum number of people connected by a path of any length
  - Captures the ultimate potential extent of STI diffusion

Full-Network Measures - Range

Component – maximal set on a single connected path

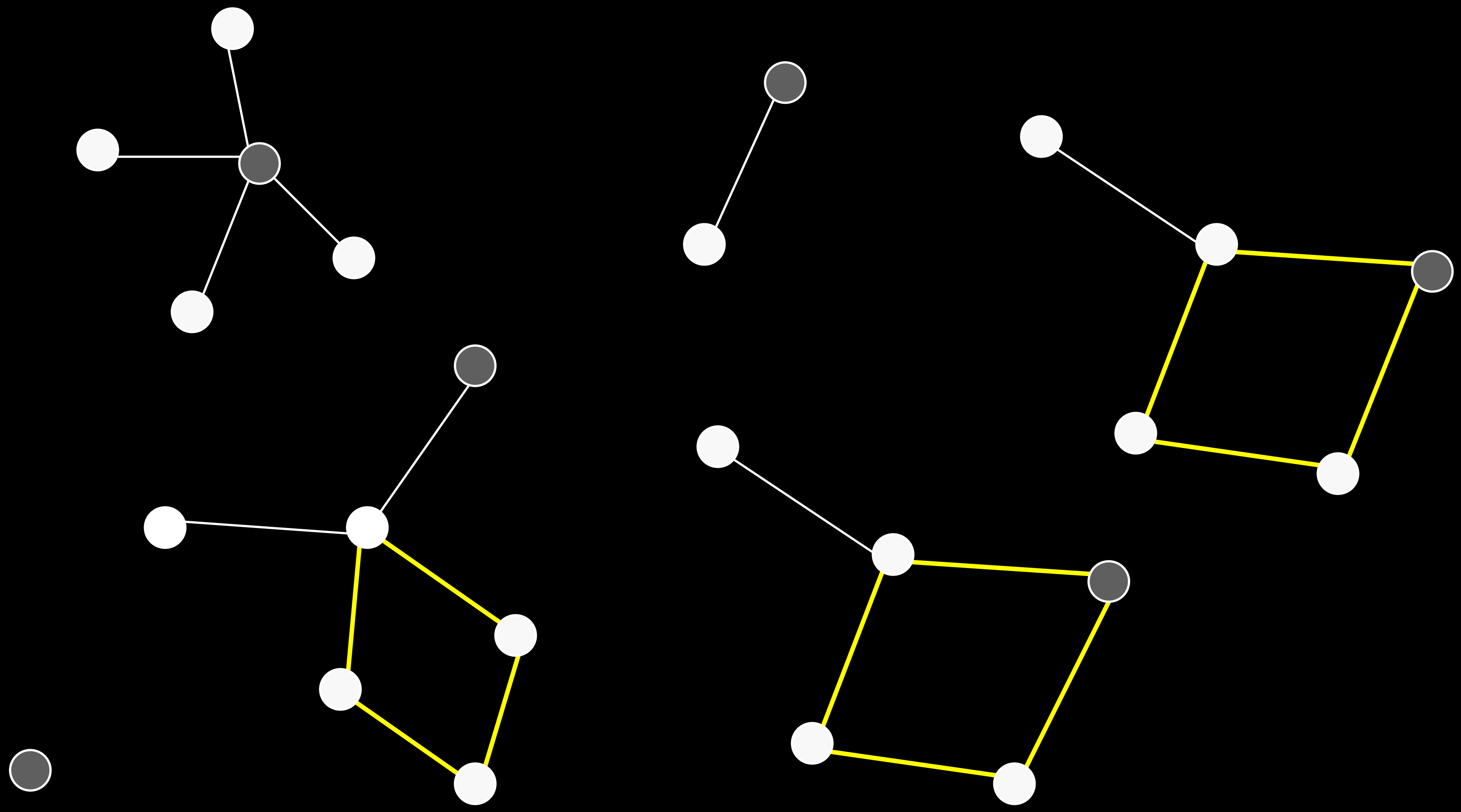


Connectivity Measures

- Size of the largest component
  - Captures the ultimate potential extent of STI diffusion
- Relative size of the largest bi-component
  - The maximum number of people connected by *at least two* node-independent paths (of any length)
  - A measure of the extent of a more robust portion of the network

Full-Network Measures - Connectivity

Bi-Component – subset of a graph connected by *at least* two node-independent paths



Connectivity Measures

- Size of the largest component
  - Captures the ultimate potential extent of STI diffusion
- Relative size of the largest bi-component
  - A measure of the extent of a more robust portion of the network
- Relative average distance among pairs in the networks
  - The number of links between two people (in-/directly) connected in a network
  - Transmission likelihood is higher if there are many shortcuts in the network. We measure this relative to the largest component.

Individual Measures - Distance

M

	0	1	0	0	0
0		1	0	0	0
1	1		1	0	0
0	0	1		1	1
0	0	0	1		1
0	0	0	1	1	

M^2

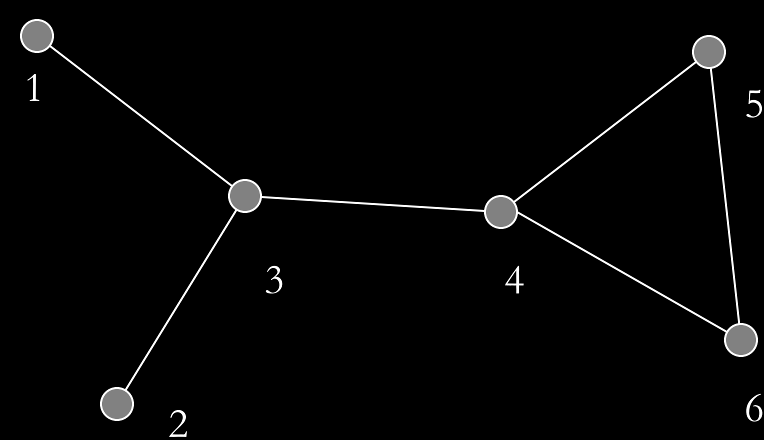
1	1	0	1	0	0
1	1	0	1	0	0
0	0	3	0	1	1
1	1	0	3	1	1
0	0	1	1	2	1
0	0	1	1	1	2

M^3

0	0	3	0	1	1
0	0	3	0	1	1
3	3	0	5	1	1
0	0	5	2	4	4
1	1		4	2	3
1	1		4	3	2

GD_M

	2	1	2	3	3
2		1	2	3	3
1	1		1	2	2
2	2	1		1	1
3	3	2	1		1
3	3	2	1	1	

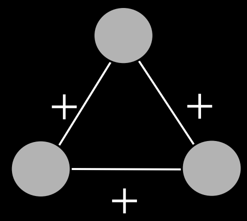


Connectivity Measures

- Size of the largest component
  - Captures the ultimate potential extent of STI diffusion
- Relative size of the largest bi-component
  - A measure of the extent of a more robust portion of the network
- Relative average distance among pairs in the networks
  - Transmission likelihood is higher if there are many shortcuts in the network. We measure this relative to the largest component.
- Transitivity Ratio
  - Given ties between *i-k* and *j-k*, the proportion of times a tie is also observed between *i-j*
  - As ties revert back on themselves ("recursion") transmission is reinforced, but not spread as widely.

Social Balance & Transitivity

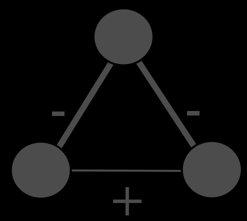
We determine balance based on the product of the edges:



(+)(+)(+) = (+)

Balanced

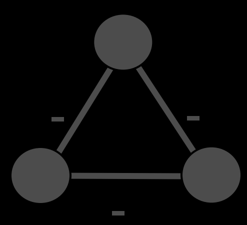
"A friend of a friend is a friend"



(-)(+)(-) = (-)

Balanced

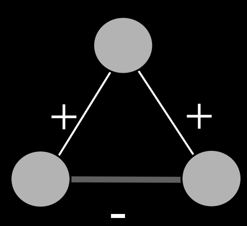
"An enemy of my enemy is a friend"



(-)(-)(-) = (-)

Unbalanced

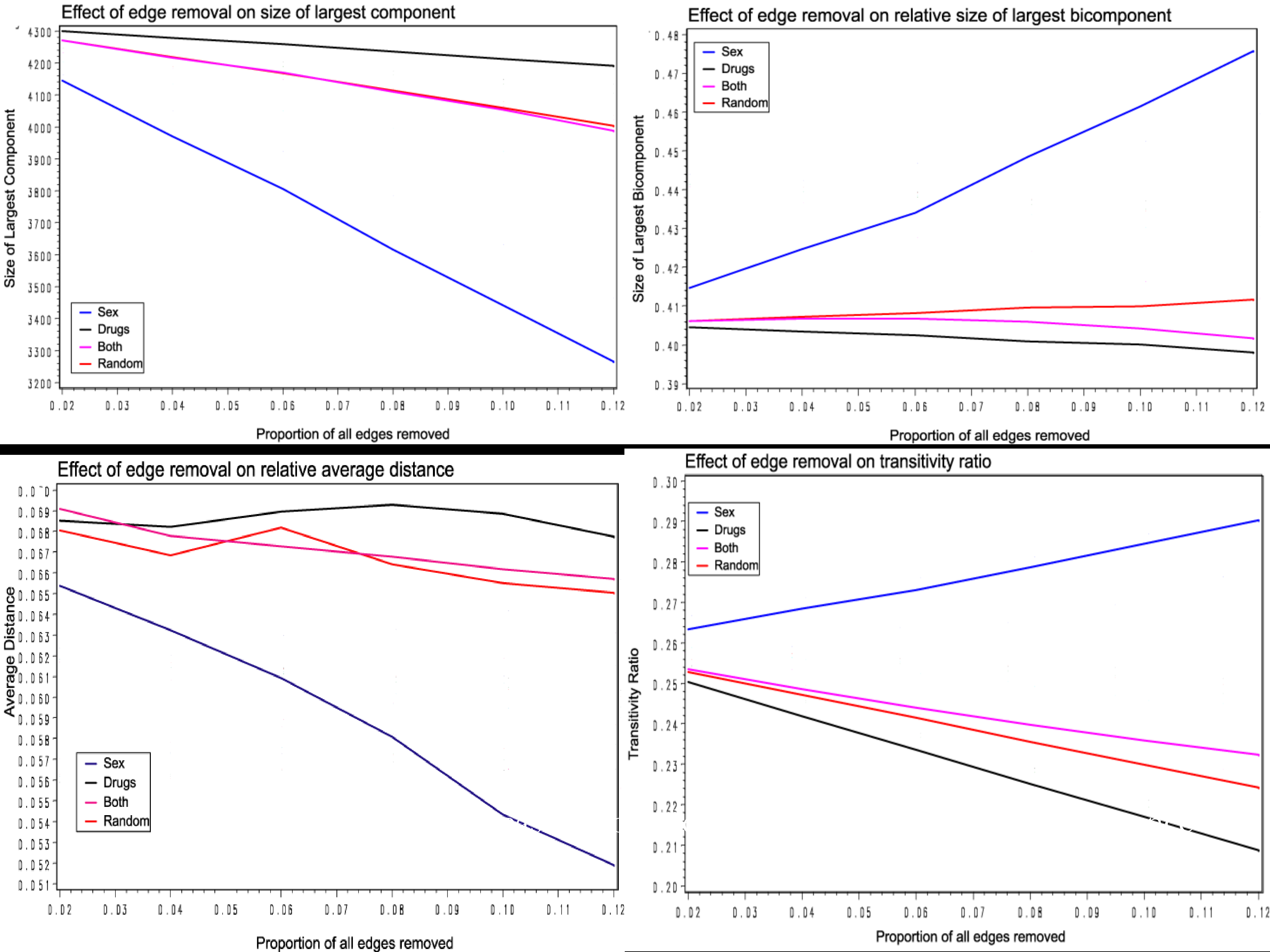
"An enemy of my enemy is an enemy"



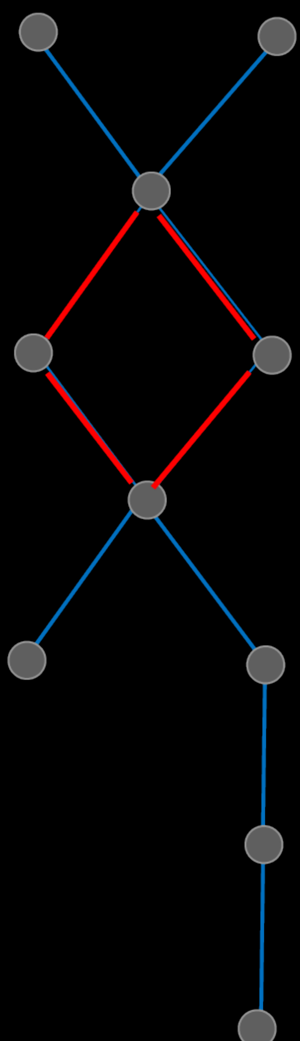
(+)(-)(+) = (-)

Unbalanced

"A Friend of a Friend is an enemy"


Effect of edge removal on size of largest component
Size of Largest Component
Proportion of all edges removed
Sex
Drugs
Both
Random
Effect of edge removal on relative size of largest bicomponent
Size of Largest Bicomponent
Proportion of all edges removed
Sex
Drugs
Both
Random
Effect of edge removal on relative average distance
Average Distance
Proportion of all edges removed
Sex
Drugs
Both
Random
Effect of edge removal on transitivity ratio
Transitivity Ratio
Proportion of all edges removed
Sex
Drugs
Both
Random

Findings - Overall



- Across all measures, *sex ties* provide the most reach; removing them:
  - Quickly decreases the size of the largest component
  - Leaves the network with a relatively larger biconnected core
  - Decreases the average (relative) distance faster than drug or random ties
  - Increases the transitivity (redundancy) of the network
- This suggests that, sex ties:
  - Create "tendrils" that reach out into the wider population
  - But do so in a relatively sparse way
  - With (comparatively) fewer re-connections to the strongest core(s) of the network
  - While drug ties create more redundancies in the network, or provide shortcuts between otherwise connected sections

Connectivity Measures

- Size of the largest component
  - Captures the ultimate potential extent of STI diffusion
- Relative size of the largest bi-component
  - A measure of the extent of a more robust portion of the network
- Relative average distance among pairs in the networks
  - Transmission likelihood is higher if there are many shortcuts in the network. We measure this relative to the largest component.
- Transitivity Ratio
  - As ties revert back on themselves ("recursion") transmission is reinforced, but not spread as widely.
- Racial Segregation index
  - Freeman's segregation index. Extent of cross race ties compared to random (1 = completely segregated, 0 = random mixing).

Segregation Index – Freeman (1972) asked how we could identify segregation in a social network. Theoretically, he argues, if a given attribute (group label) does not matter for social relations, then relations should be distributed *randomly* with respect to the attribute. Thus, the difference between the number of cross-group ties expected by chance and the number observed measures segregation.

$$E(X) = R*C/T$$

X = (17+17)

E(X) = (13.55+13.55)

$$Seg = \frac{E(X) - X}{E(X)}$$

Seg = 27.1 - 34 / 27.1

= -6.9 / 27.1

= -0.25

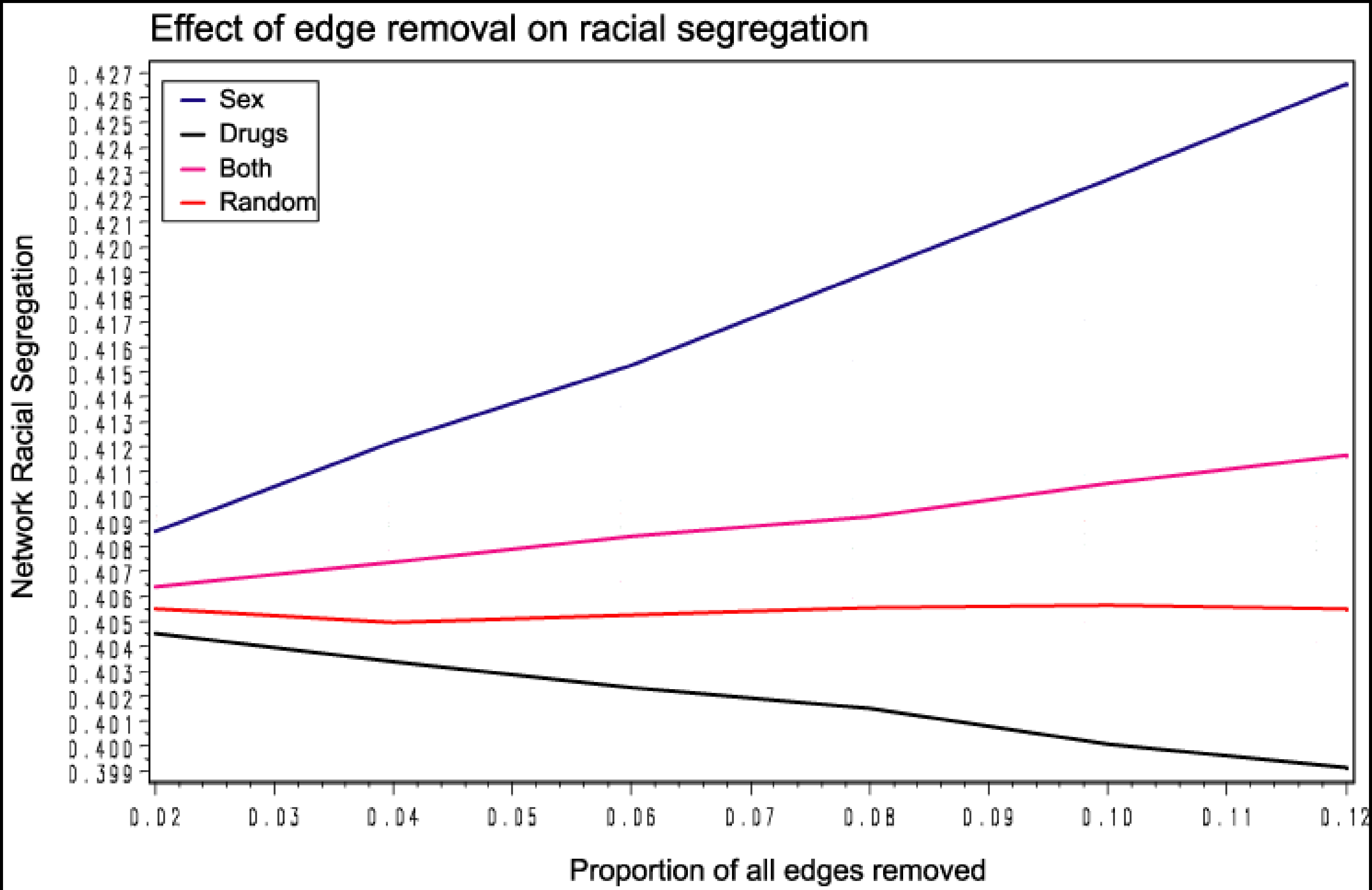
Range:
- 1= Perfect In-Group Preference
- 0 = Random
- -1 = Perfect Out-Group Preference

Observed

	A	B	
A	6	17	23
B	17	16	33
	23	33	56

Expected

	A	B	
A	9.45	13.55	23
B	13.55	19.45	33
	23	33	56



Effect of edge removal on racial segregation
Sex
Drugs
Both
Random
Network Racial Segregation
0.427
0.426
0.425
0.424
0.423
0.422
0.421
0.420
0.419
0.418
0.417
0.416
0.415
0.414
0.413
0.412
0.411
0.410
0.409
0.408
0.407
0.406
0.405
0.404
0.403
0.402
0.401
0.400
0.399
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
0.11
0.12
Proportion of all edges removed

Findings – Racial Segregation

- Again, sex ties have the most different effect:
- Removing them increases the overall racial segregation in the network faster than other tie-types, meaning:
  - In this population, sex-ties are more cross-race than are drug ties or sex & drug ties
    - Thus are potential (*hidden*) bridges

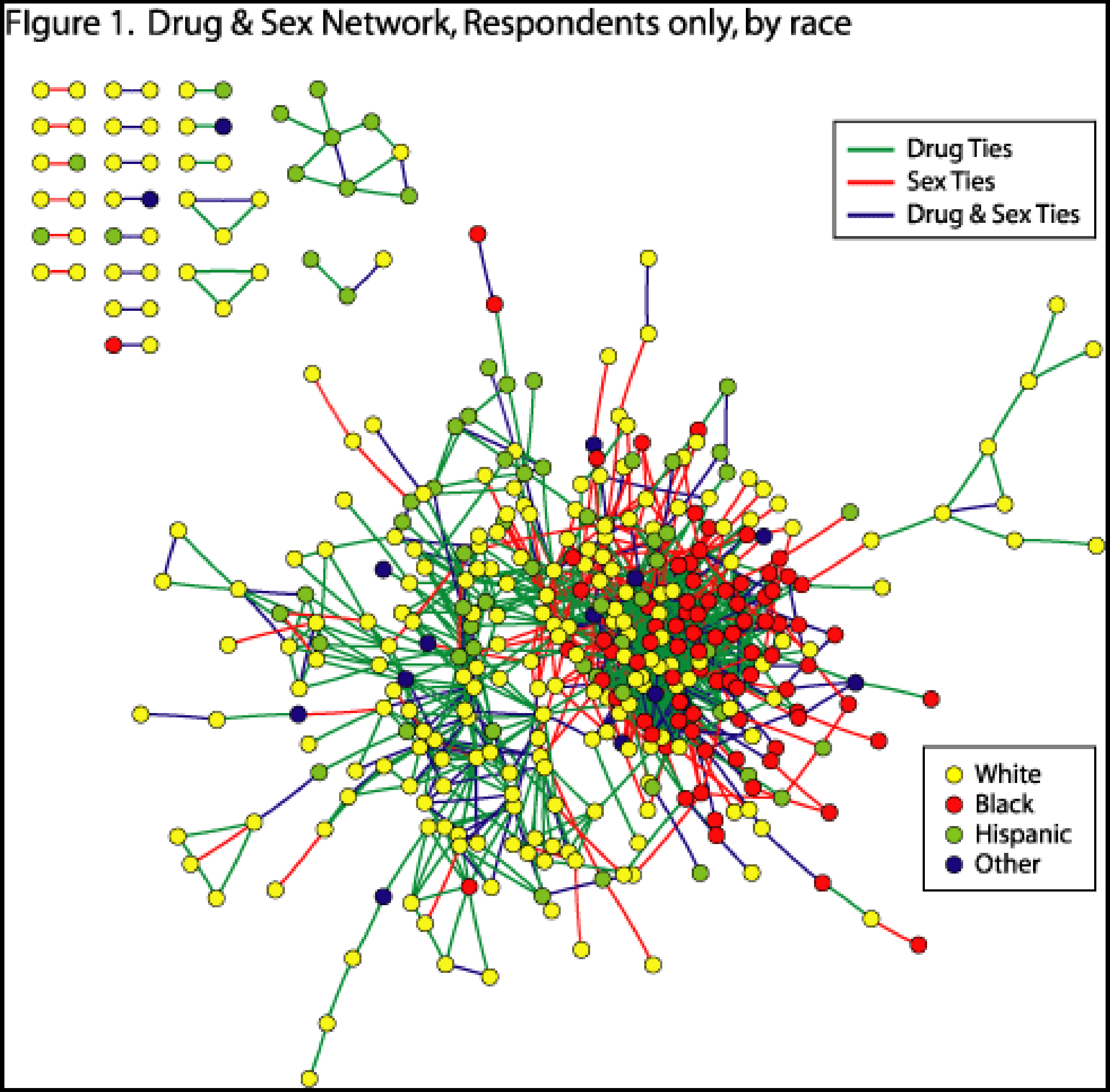
So What?

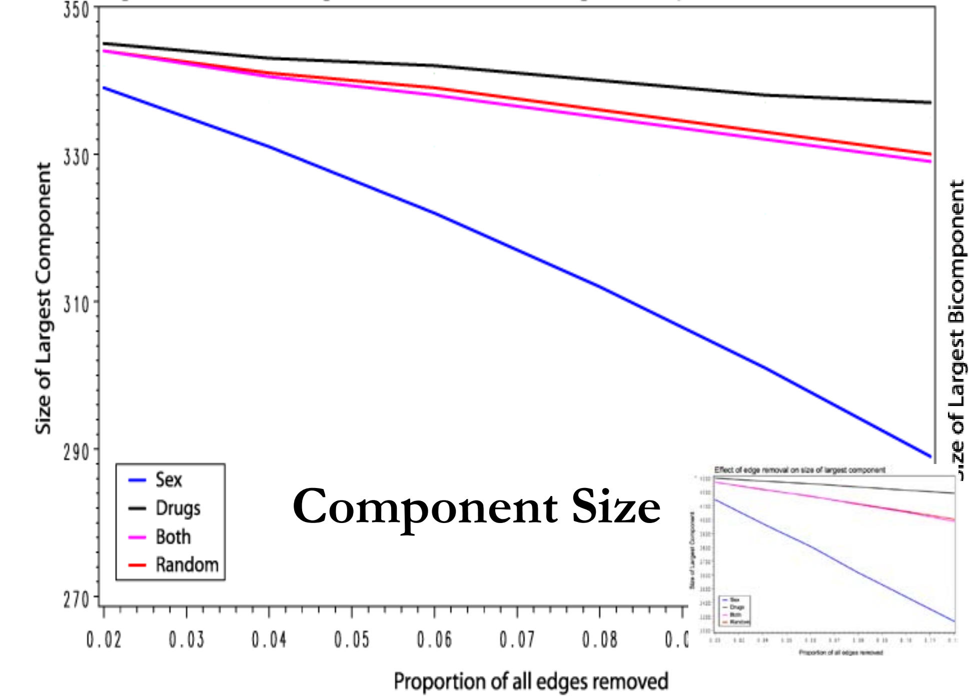
- Epidemiologically –
  - Traditional approach (network studies of sex OR drugs) would substantially mis-estimate epidemic potential:
    - For the population at large
    - AND the potential contribution of sex/drug ties *alone*
  - Basing interventions on one could lead to unexpected results
    - *In this population:*
      - Drug only interventions would be most likely to influence "core group" infections (epidemic **duration**)
      - Sex only interventions would be most likely to influence non-core group infections (epidemic **breadth**)
    - Unless network contributions are well known, condom promotion & needle exchange simultaneously for maximal effect

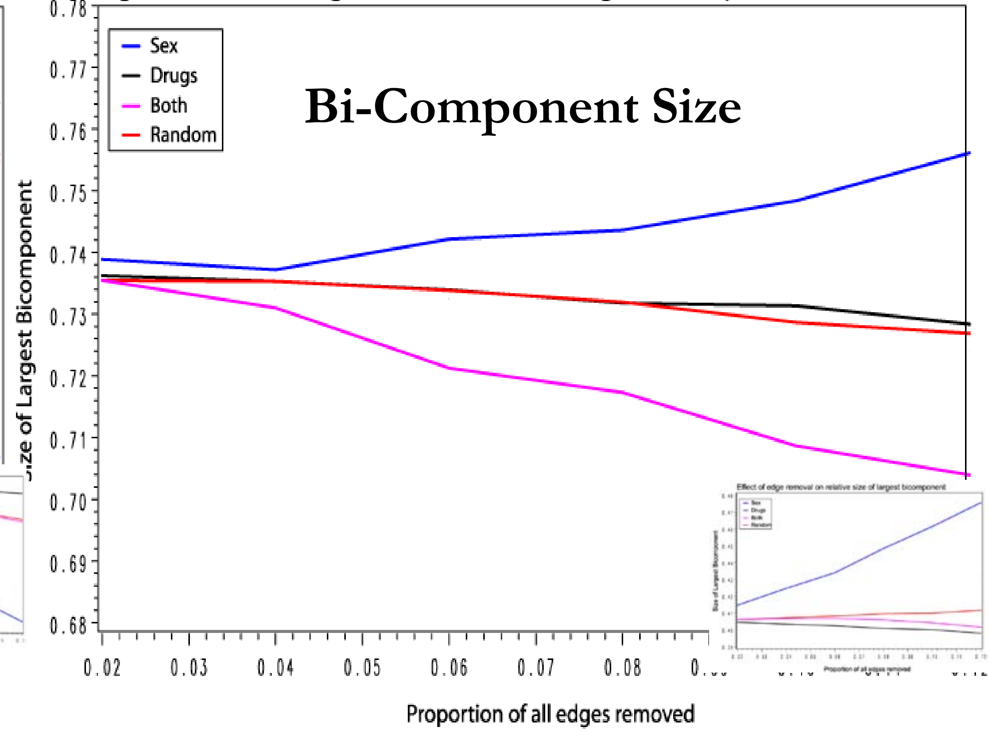
Thank You!

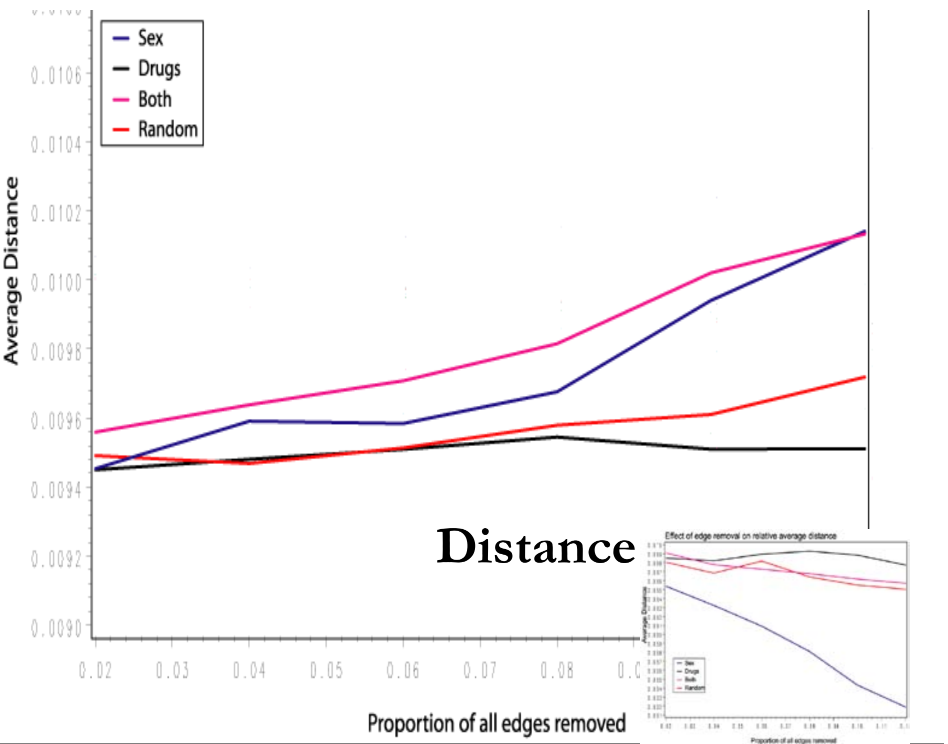
- Questions?
- Contact – jimi.adams@asu.edu

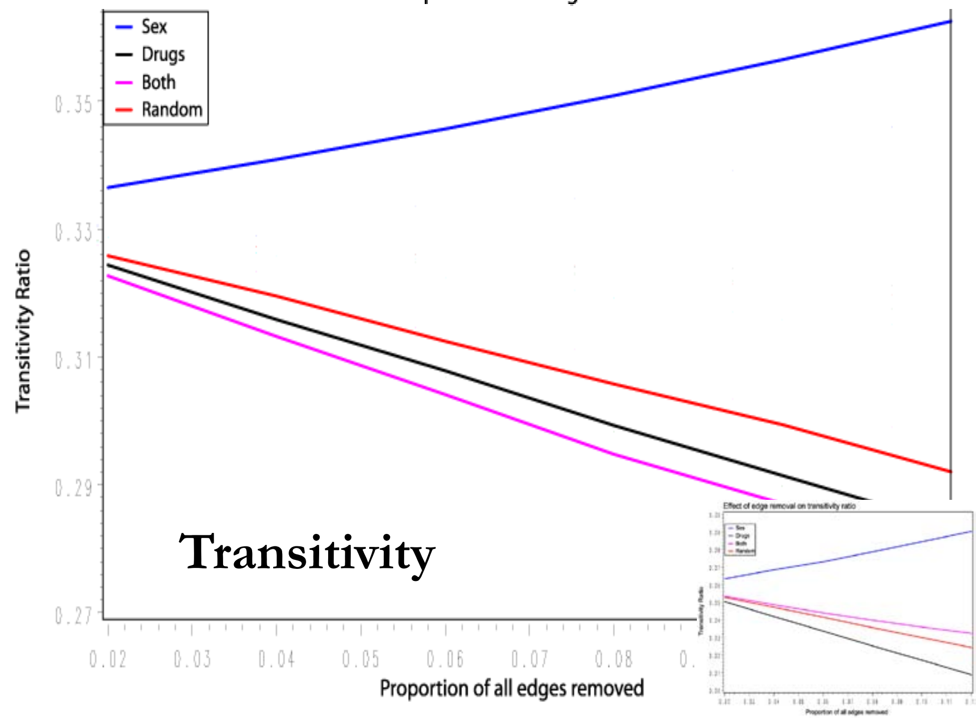
Project 90: Respondent only Contact Network




Component Size
Size of Largest Component
350
330
310
290
270
0.02
0.03
0.04
0.05
0.06
0.07
0.08
Proportion of all edges removed
Sex
Drugs
Both
Random
Effect of edge removal on size of largest component

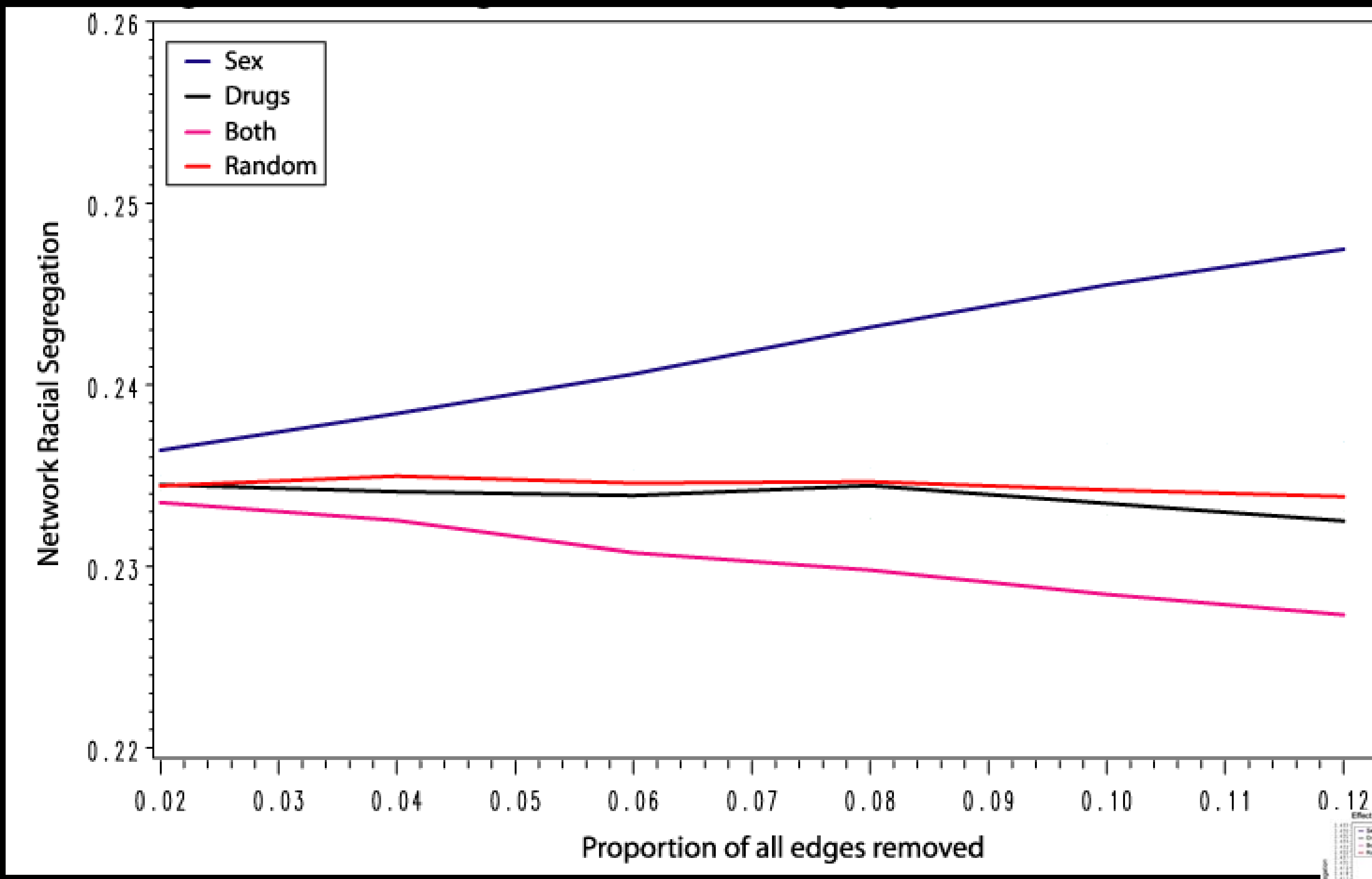

Bi-Component Size
Size of Largest Bicomponent
0.78
0.77
0.76
0.75
0.74
0.73
0.72
0.71
0.70
0.69
0.68
0.02
0.03
0.04
0.05
0.06
0.07
0.08
Proportion of all edges removed
Sex
Drugs
Both
Random
Effect of edge removal on relative size of largest bicomponent

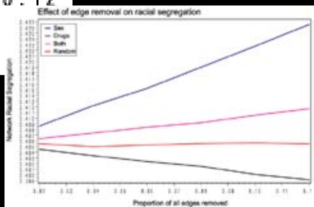

Distance
Average Distance
0.0106
0.0104
0.0102
0.0100
0.0098
0.0096
0.0094
0.0092
0.0090
0.02
0.03
0.04
0.05
0.06
0.07
0.08
Proportion of all edges removed
Sex
Drugs
Both
Random
Effect of edge removal on relative average distance


Transitivity
Transitivity Ratio
0.35
0.33
0.31
0.29
0.27
0.02
0.03
0.04
0.05
0.06
0.07
0.08
Proportion of all edges removed
Sex
Drugs
Both
Random
Effect of edge removal on transitivity ratio

Results I

Effect of edge removal on *Racial Segregation Index*





Segregation is Freeman's (1972) Segregation Index using a 4 category race variable

Findings – Comparison

- Sex Ties still the most different
  - Distance effect reverses
- "Both" ties important for RR redundancy

- A few notes:
  - The *base level* of segregation is higher across the full network than the RR-only network, suggesting:
    - Respondents were more likely to have cross race ties than non-Rs
  - The racial segregation sex-*sampling* effect is lower in the full than the RR network