Diversity in humans and pathogens: implications for the dynamics of epidemics and the impact of interventions

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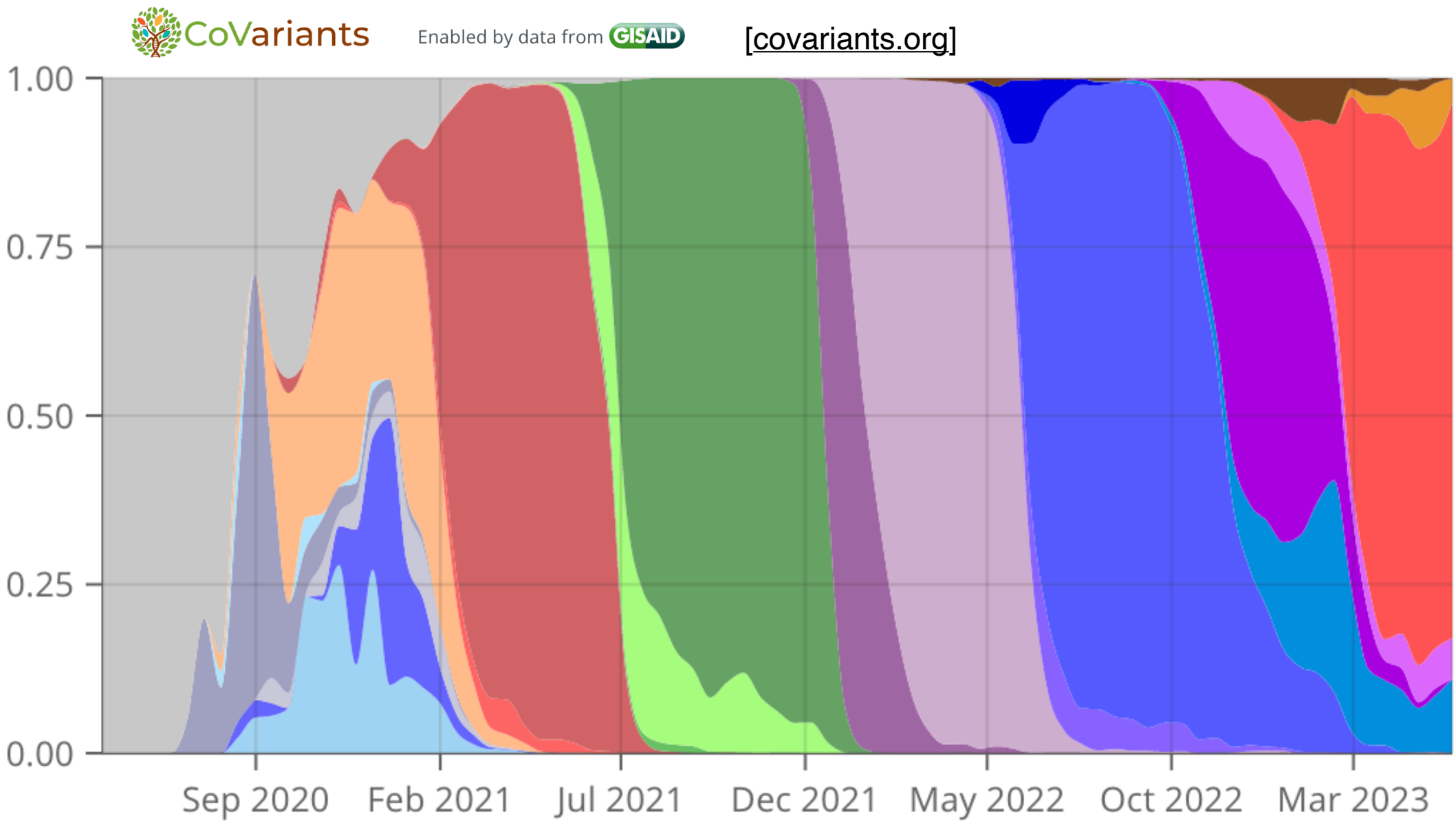
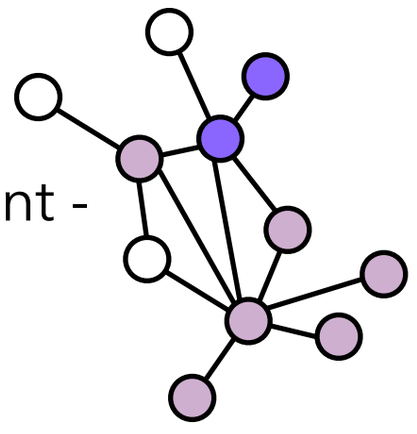
Unifying the epidemiological and evolutionary dynamics of pathogens - Nordita - 13 June 2023

patterns of strain co-circulation



strain traits - strain interaction - host heterogeneities - treatment - vaccination - **contact/spatial structure**

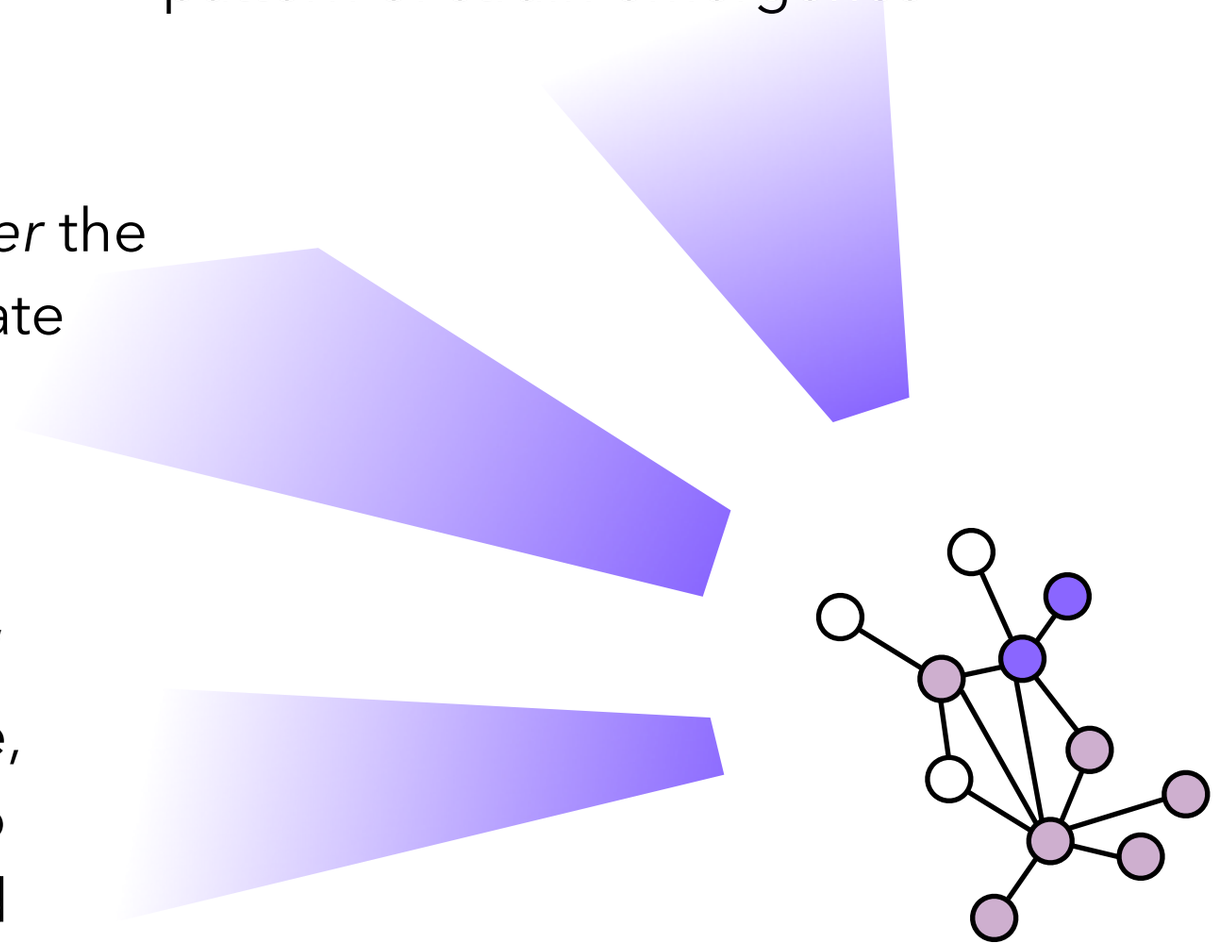


patterns of strain co-circulation

contact and mobility networks determine the pattern of strain emergence

resident strains *alter* the network substrate

depending on hosts' interaction time-scale, either one of the two strains is advantaged



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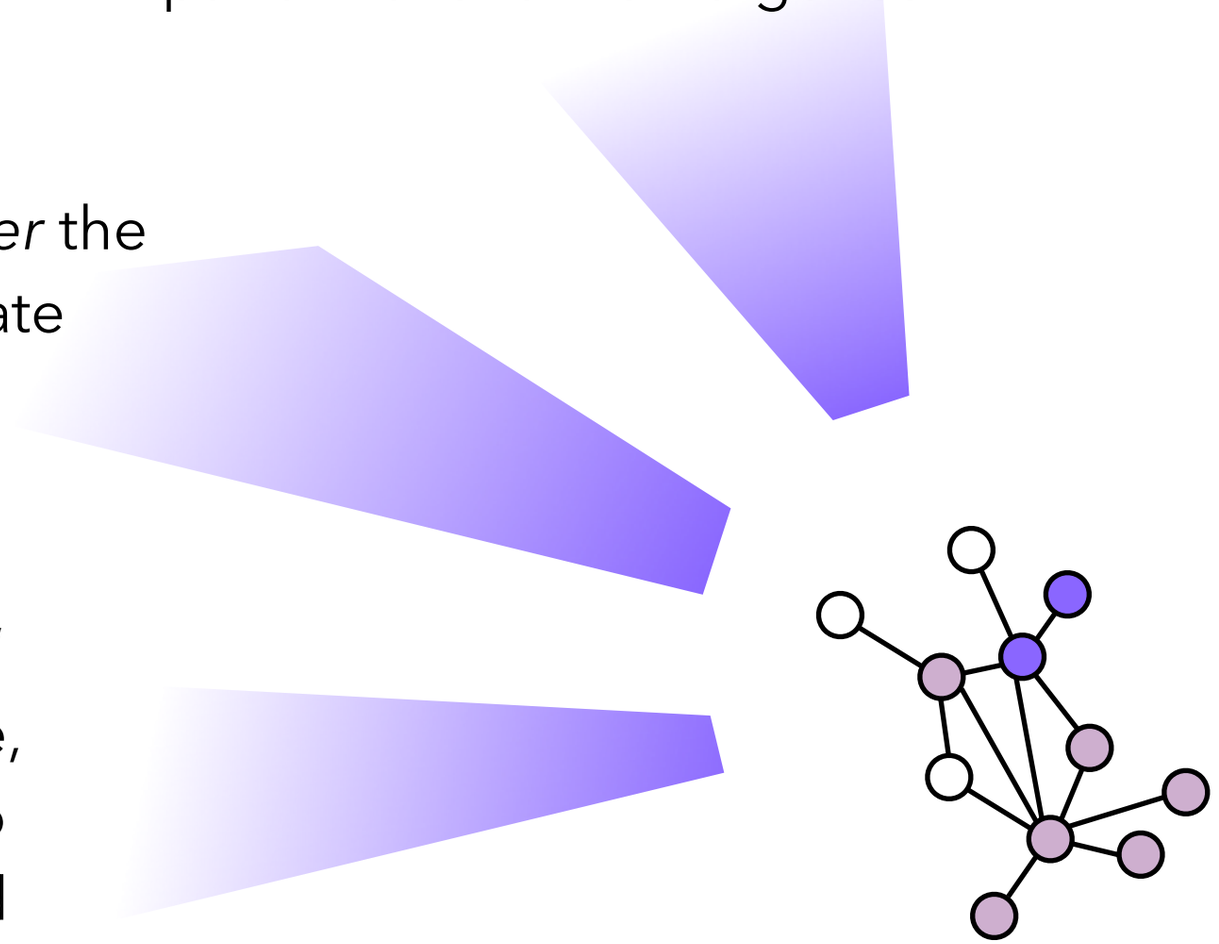
[Poletto et al PLoS Comp Biol 2013; Poletto et al Sci Rep 2015]



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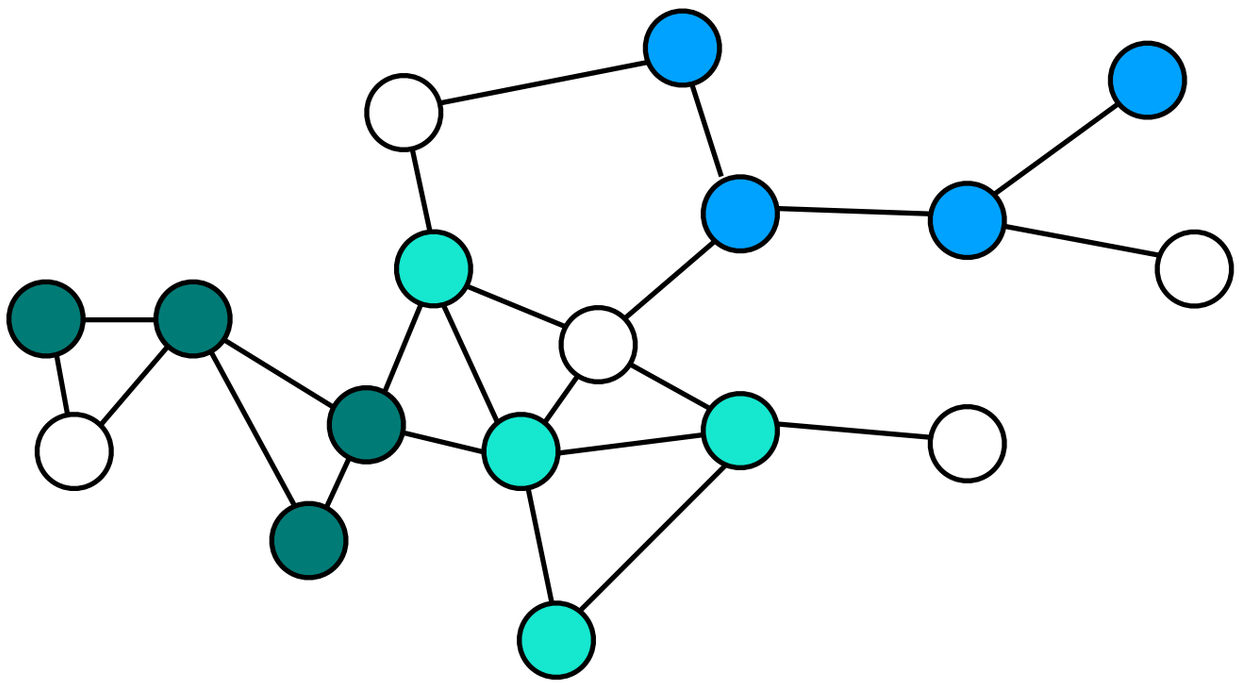
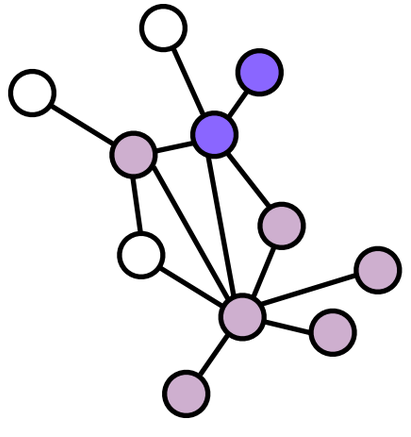


strain responsible for past infections/ resident strain/ fastest strain occupies a portion of nodes

emerging spread on a residual network

[Karrer Newman PRE 2011; Leventhal et al Nature Comm 2015]

resident strains *alter*
the network substrate



patterns of strain co-circulation

ecology of many strains on a network

[F. Pinotti, É. Fleury, D. Guillemot, P.-Y. Böelle, C. Poletto, PLoS Computational Biology 15(5) 2019]

[F. Pinotti et al in preparation]

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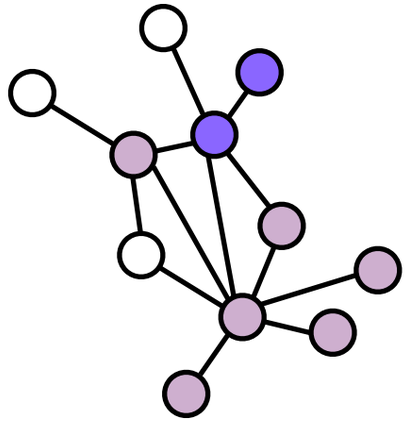

emergence/dominance/co-existence of S aureus strains

contact spatial structure in hospitals:

- small population
(strong stochastic effects)

- high patient turn-over
(strain introduction from the outside)

- ward composition

- host heterogeneities
(patients/health care workers)

[Kouyos et al, PLOS Pathogens 2013; Kouyos et al PLOS Pathogens 2011; Cooper et la, PLOS Comput Biol 2012; Bonten et al CID 2001]

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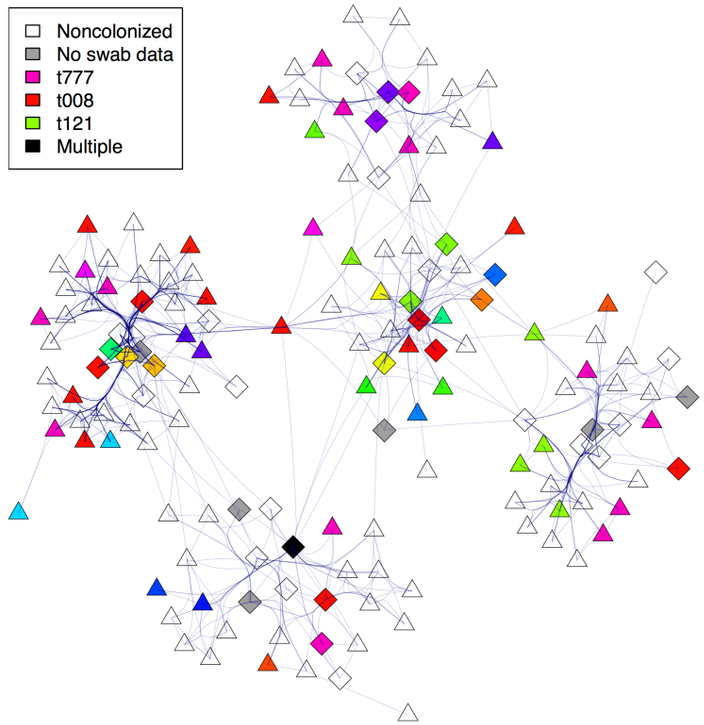
network data: face-to-face contacts / patient transfer

[Liljeros et al Math Popul Stud 2007; Obadia et al. PLOS Comput Biol 2015; Isella et al PLoS ONE 2011; Donker et al PLoS ONE 2012; Nekkab et al PLOS Comput Biol 2017]

Individual-Based Investigation of Resistance Dissemination (I-Bird)

- long term health care facility
- 5 wards
- duration 4 months



Close Proximity Interaction data

- RFID technology
- 329 Patients - 261 Health-Care-Workers
- temporal resolution 30s

[Obadia et al. PLoS Comput Biol 2015; Duval et al Sci Rep 2018; Duval et al. PLoS Comput Biol 2019]

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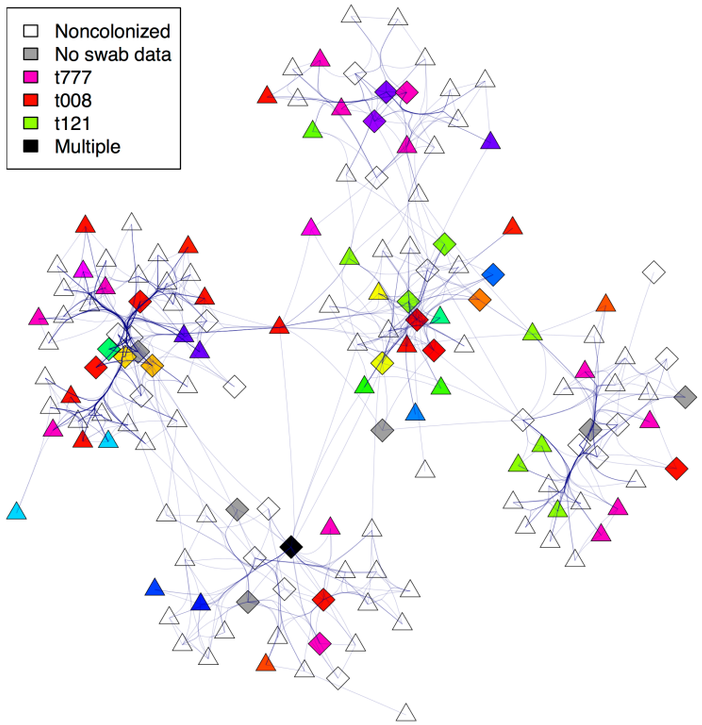

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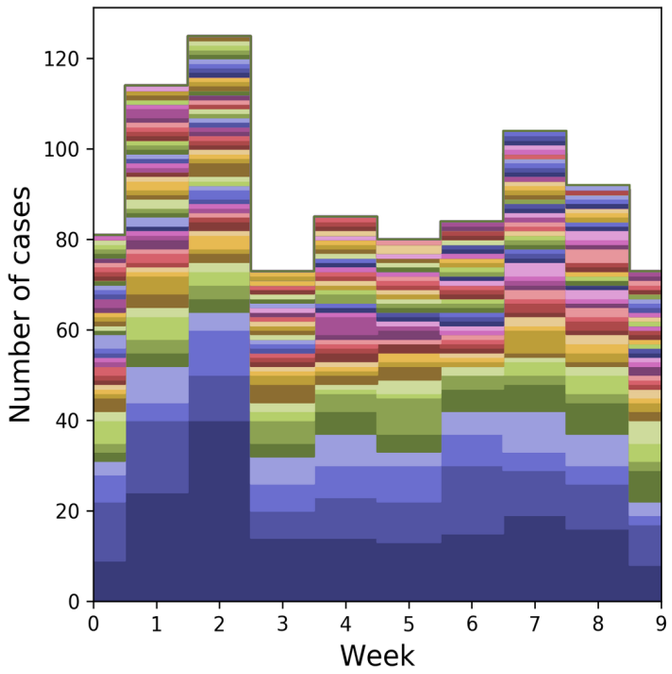
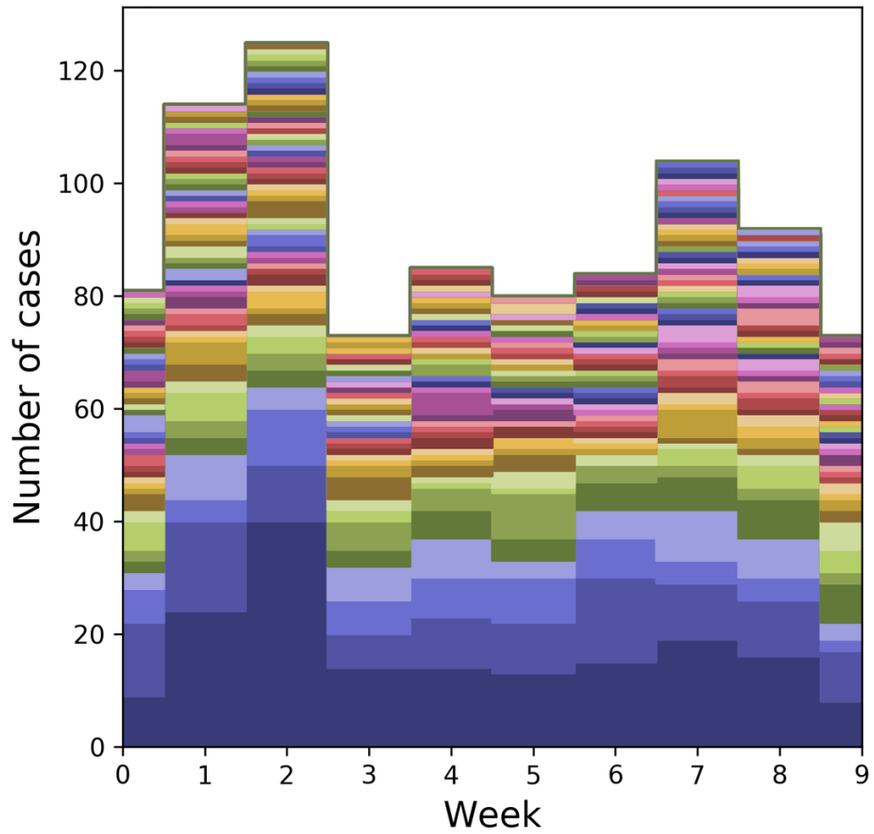


Colonisation

- weekly nasal swabs
- colonisation of S. aureus
- information of spa type + resistance profile

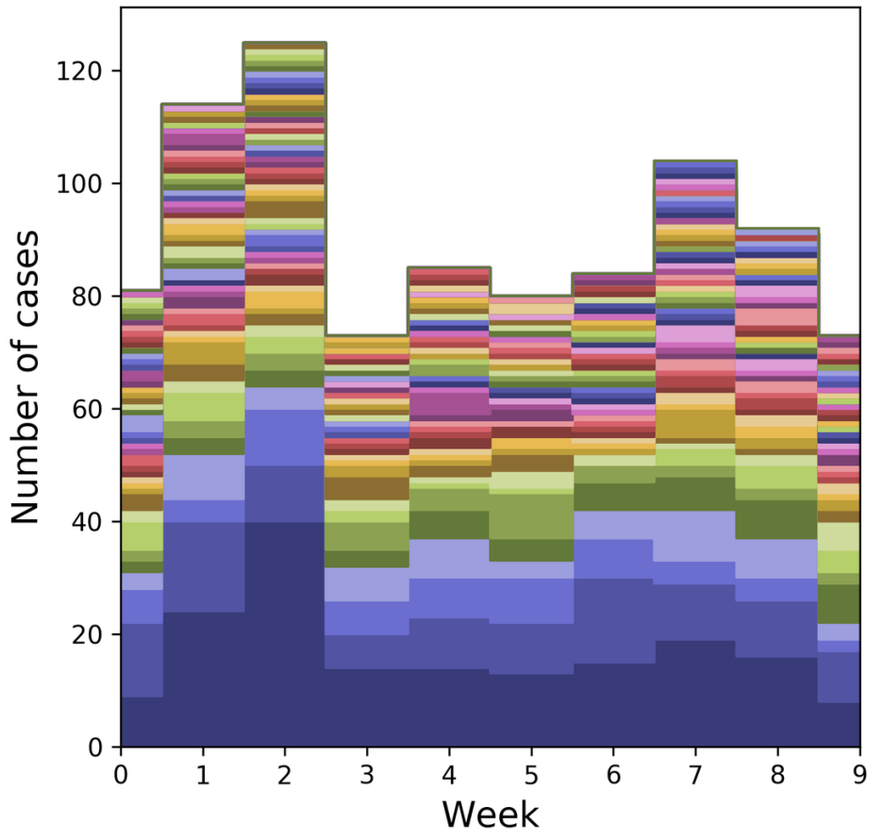
[Obadia et al. PLoS Comput Biol 2015; Duval et al Sci Rep 2018; Duval et al. PLoS Comput Biol 2019]

ecological indicators



- prevalence
- richness : # strains
- evenness/dominance

ecological indicators



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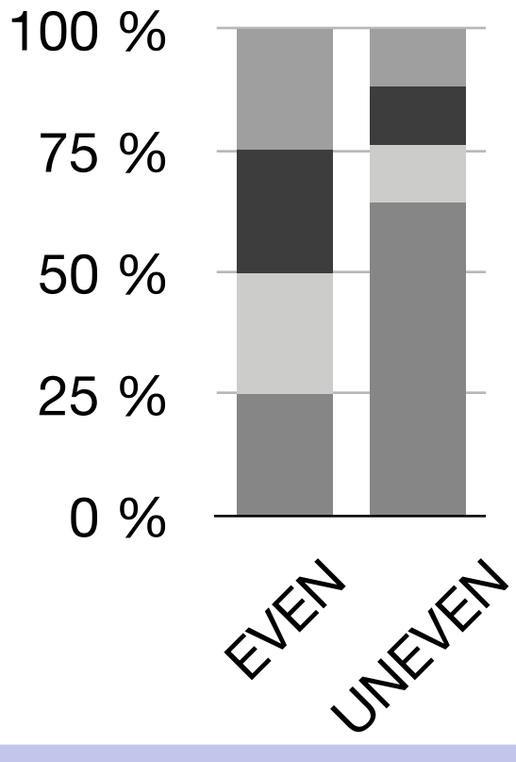
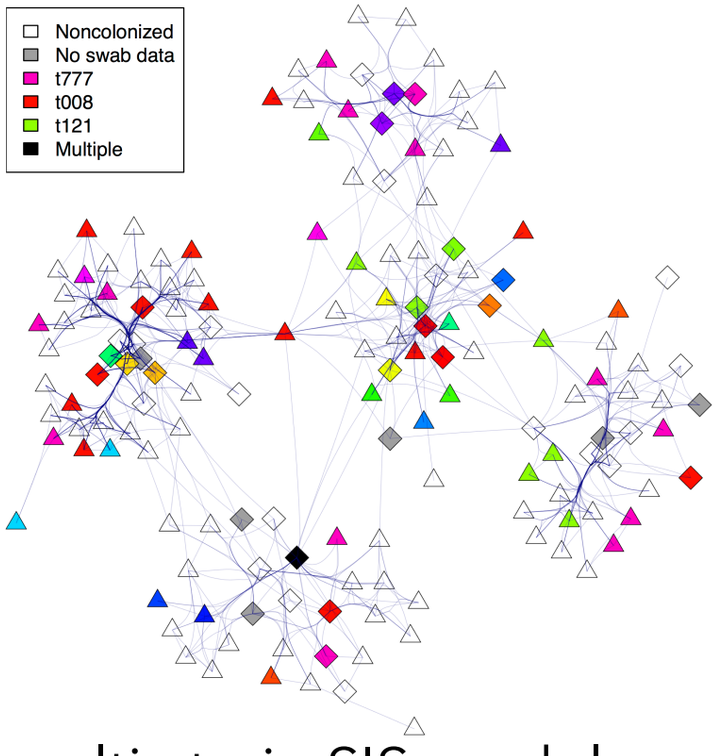
Berger-Parker index

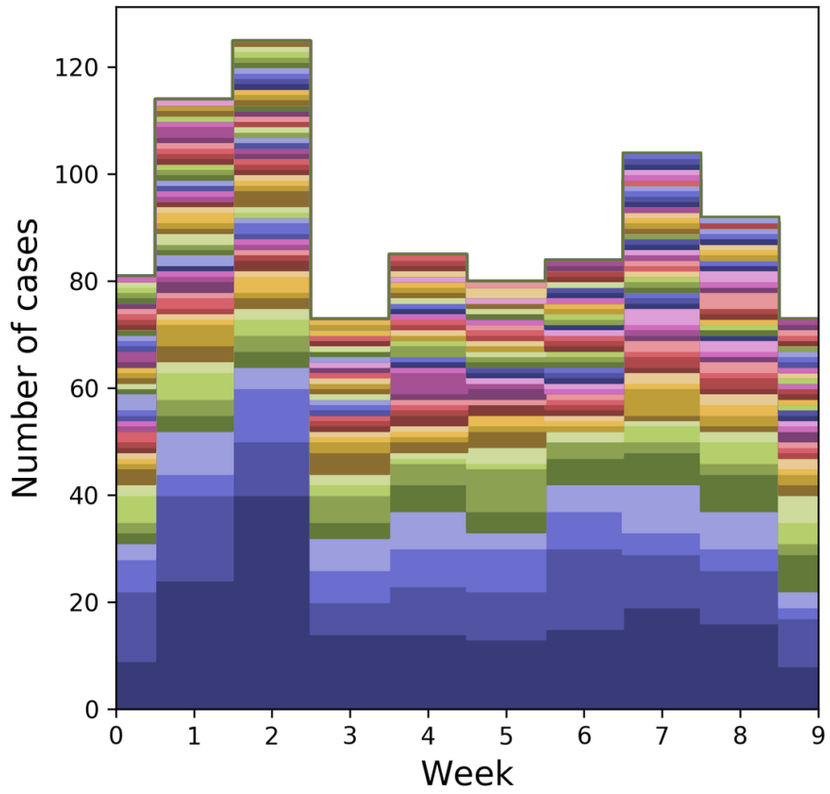


$$\max_i \frac{N_i}{\sum_i N_i}$$

[Morris et al Ecol Evol. 2014]

S. aureus spread in hospitals





- multi-strain SIS model as simple model of S. aura colonisation
- mutual exclusion
- strain injection
- neutral hypothesis: strains have same transmissibility and duration of colonisation

- simulation on the CPIs network
- compare with a randomisation (RAND)

[Pinotti et al, PLoS Comp Biol, 2019]

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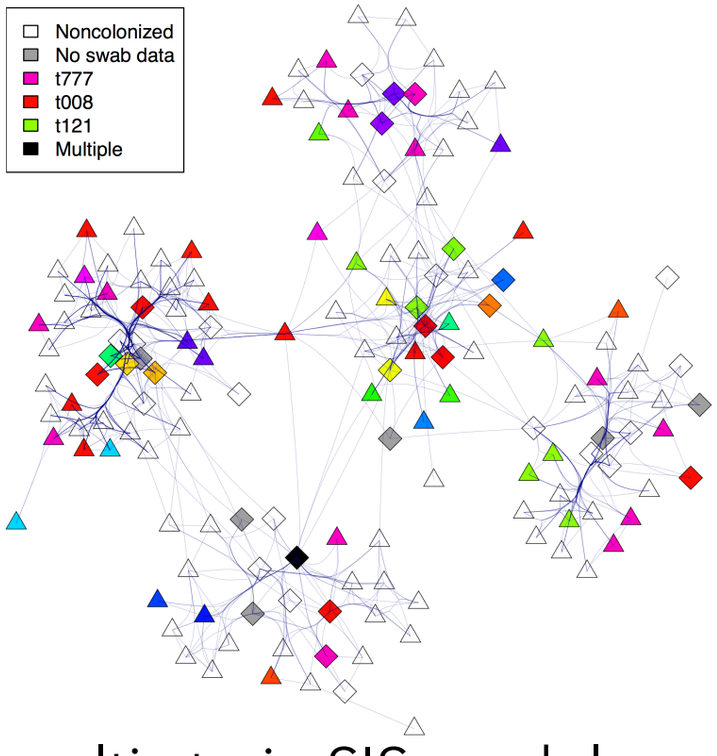

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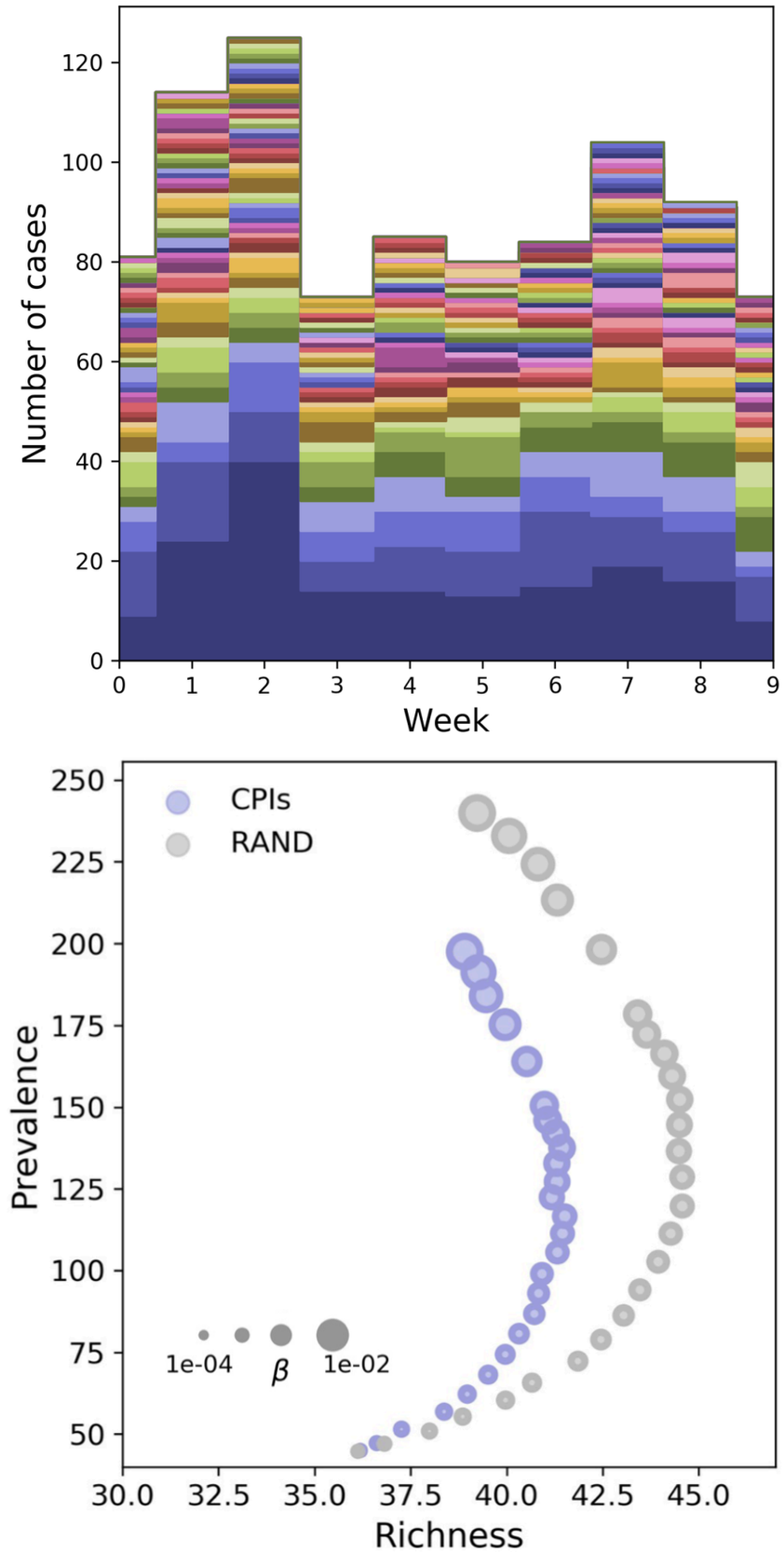
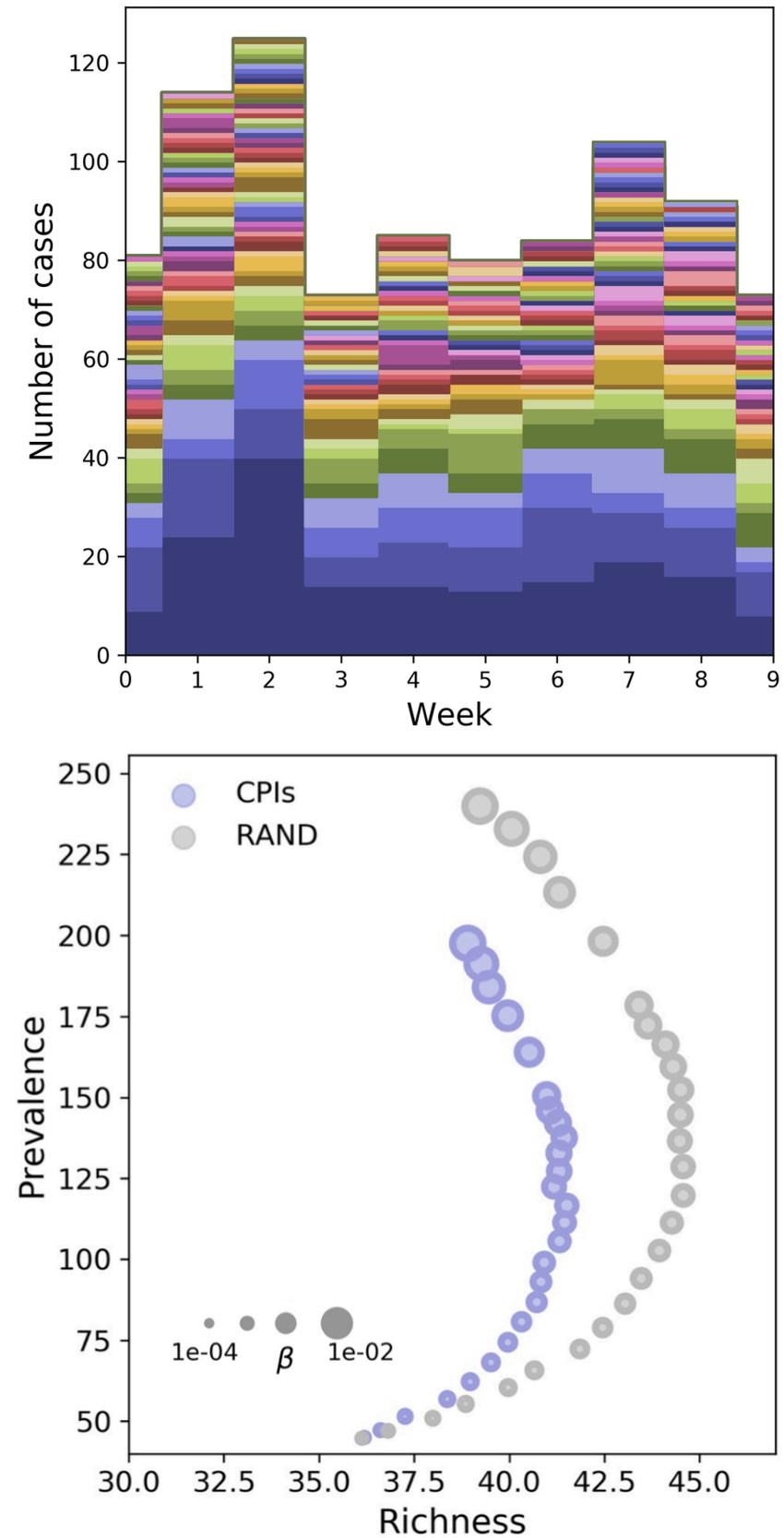


S. aureus spread in hospitals

richness and prevalence

Comparison between RAND and CPIs done at same parameters

CPIs has smaller richness at same prevalence



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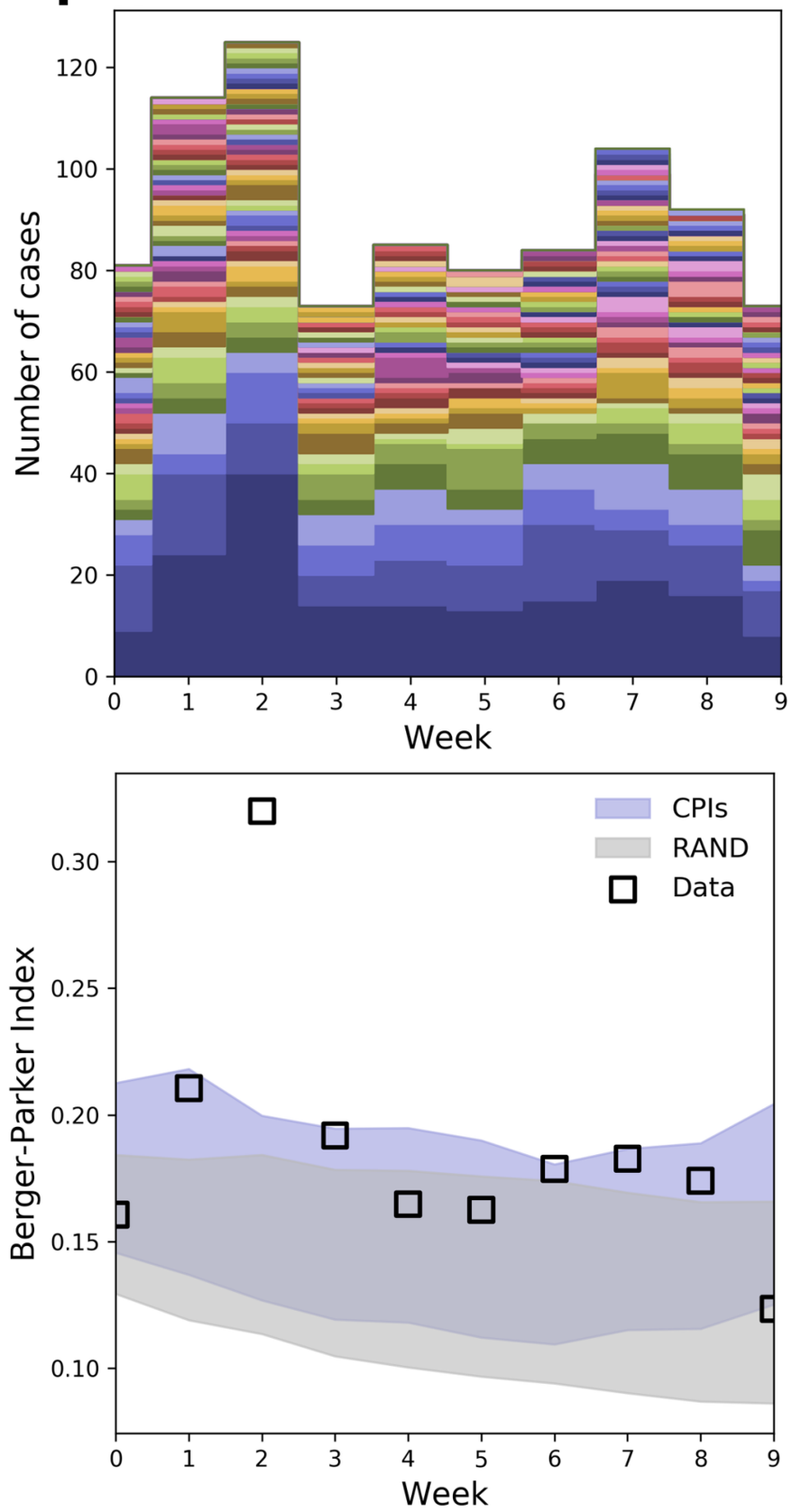
S. aureus spread in hospitals



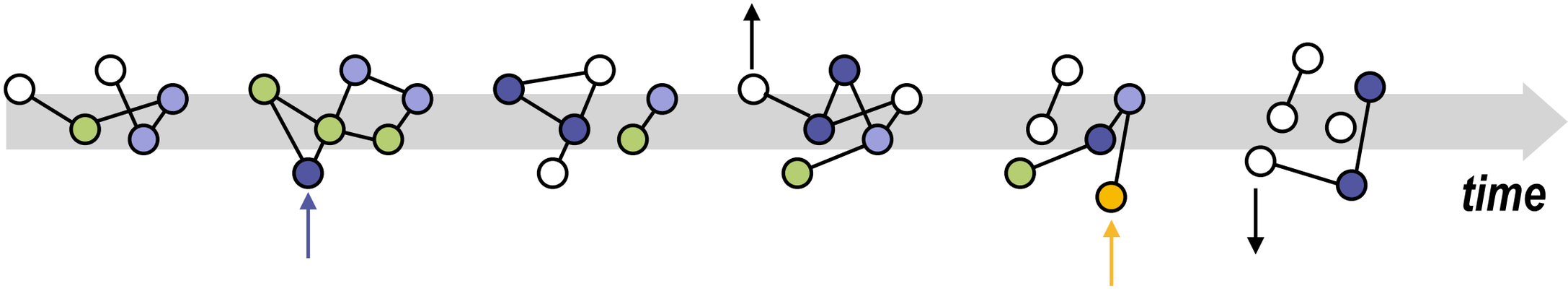
dominance

Comparison between RAND and CPIs done at same richness and prevalence

CPIs has stronger dominance

[Pinotti et al, PLoS Comp Biol, 2019]

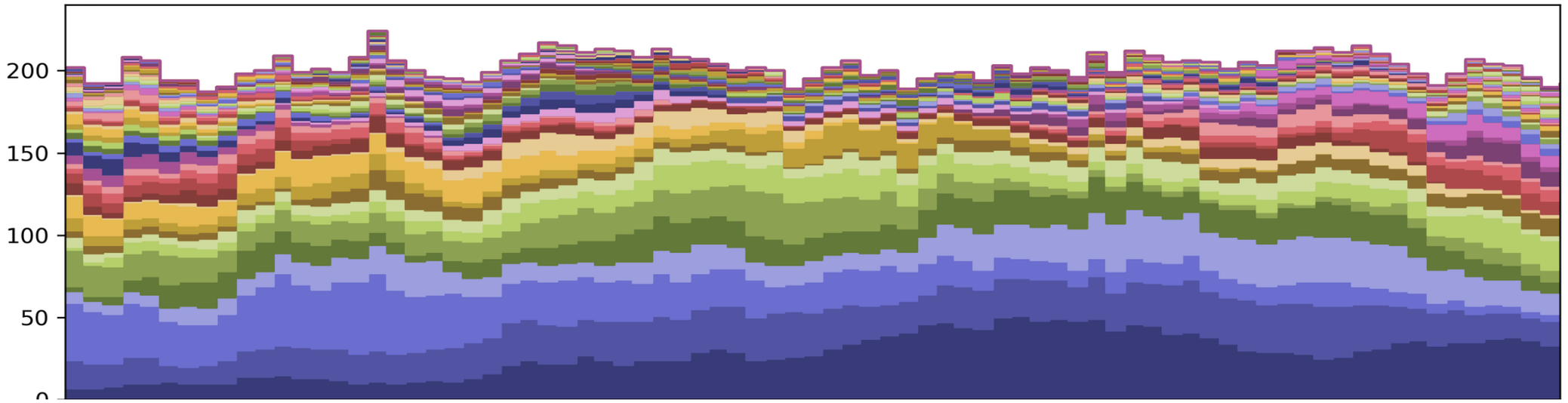
synthetic network model

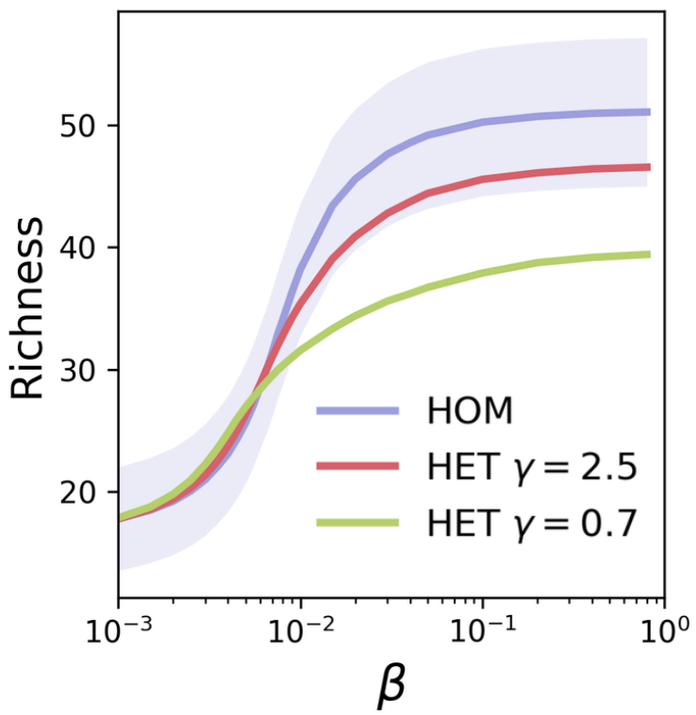


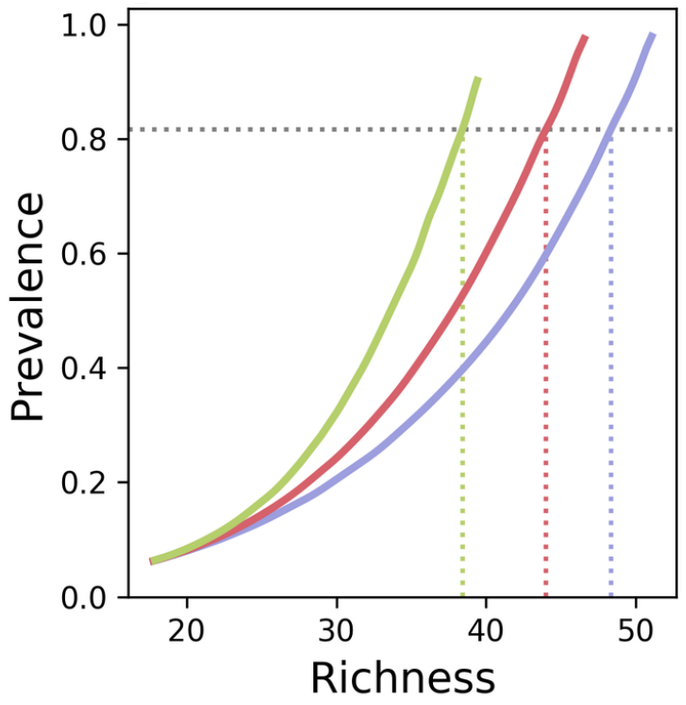
- nodes entering and leaving
- community structure
- forming contacts
    - **HET** heterogeneous activity
    - **HOM** homogeneous activity

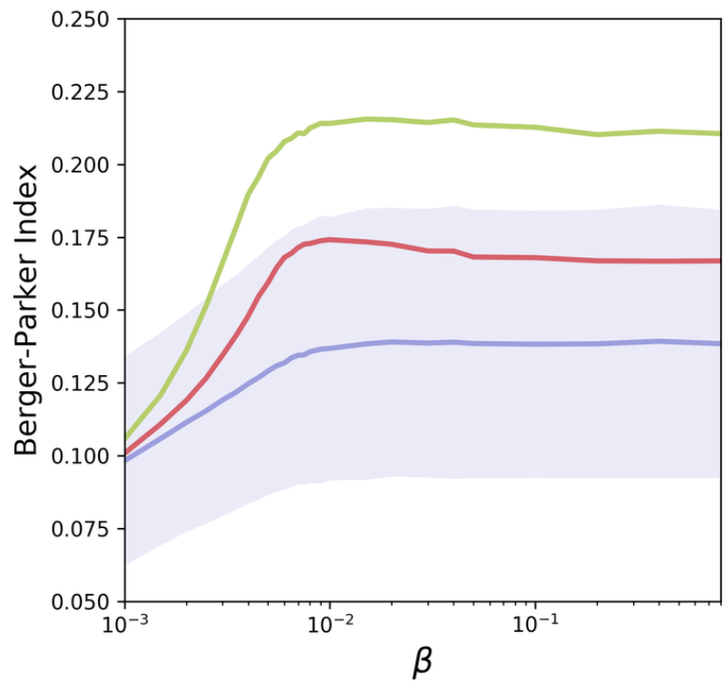
[Pinotti et al, PLoS Comp Biol, 2019]

impact of heterogeneous contact activity









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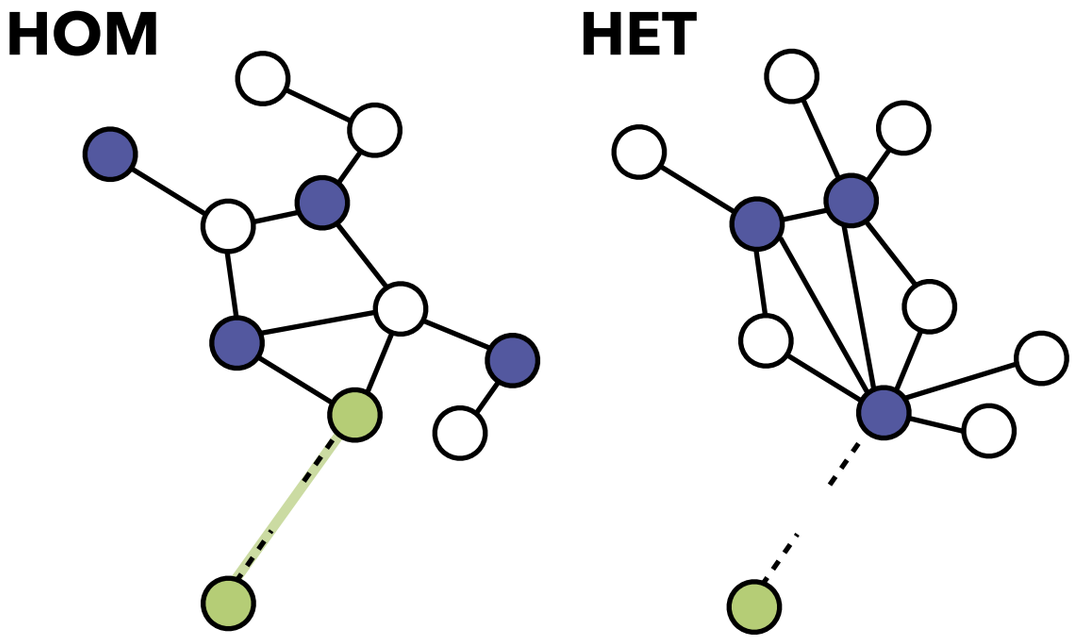
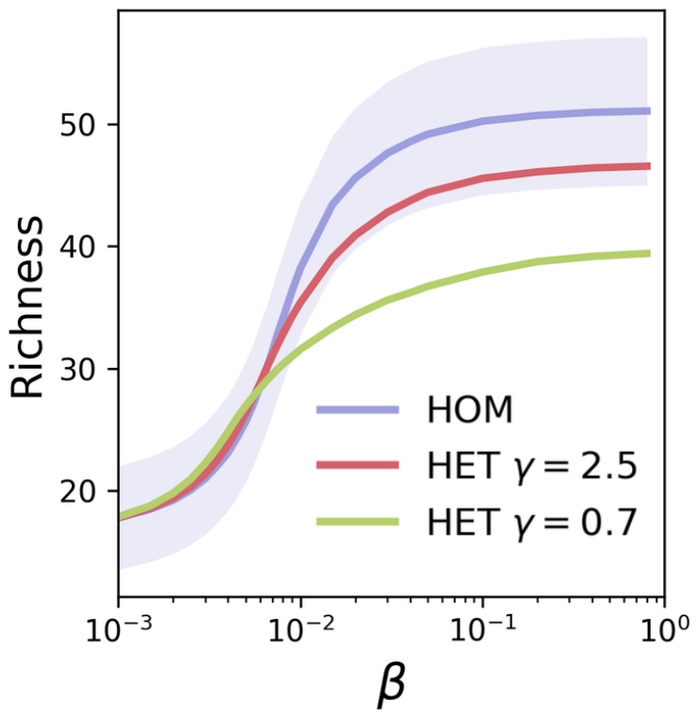


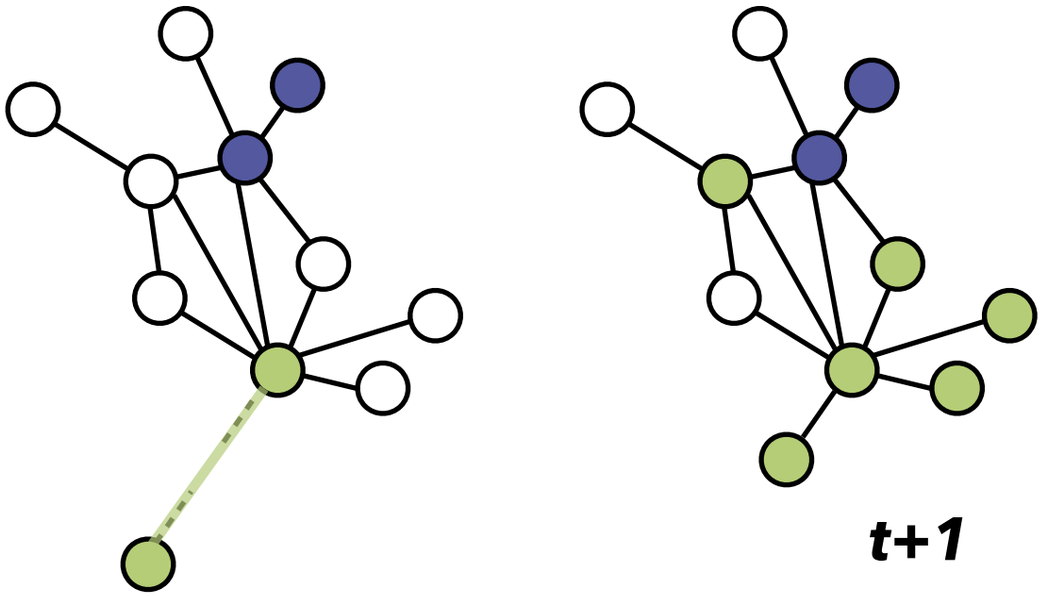


[Pinotti et al, PLoS Comp Biol, 2019]

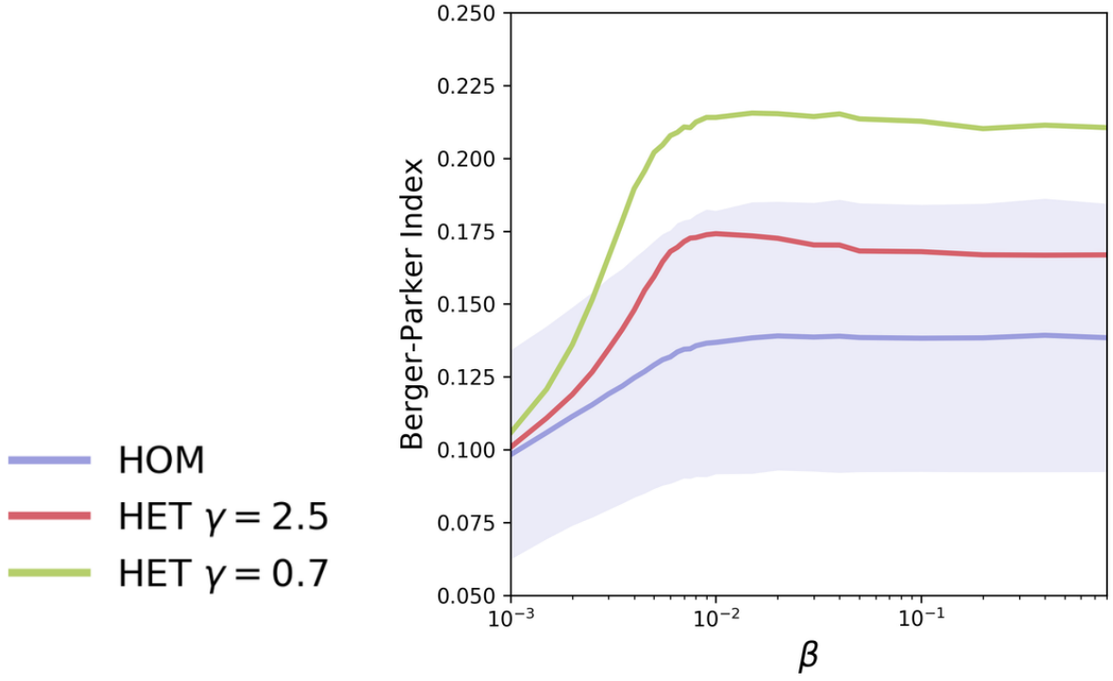
highly active nodes act as ***super-blocker*** hinder the emergence of a strain

[Leventhal et al. Nat Comm 2015]

impact of heterogeneous contact activity



highly active nodes act as ***super-spreader*** enhance the spread of few lucky strains



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Conclusions

- ecological perspective to characterise strain population

- contact heterogeneities:
  - hinder the introduction of strains from the outside

[Leventhal et al Nature Comm 2015]

  - amplify certain strains, making outbreaks more likely

- importance of contact network to properly interpret ecological date

ack:

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PLoS Computational Biology 15(5) 2019

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