Modelling and Simulating Social Systems with MATLAB

Social discovery and its impact on the spread of infectious diseases

Team *Transmissionary*

Steffen Arnold, Joris Cadow

December 15, 2015

People discovery

- Instance of general *social discovery*
- Personalized recommendations based on users' preferences
- Find *new* contacts outside of one's social neighborhood
- In some contexts–e.g. dating–new contacts might be short-lived

CNN Money Business Markets Tech Media Personal Finance Small Biz Luxury CNN U.S. Edition Log In stock tickers

Connect

Tinder and hookup apps blamed for rise in STDs

Recommend 6k

By David Goldman @DavidGoldmanCNN

Rhode Island's Department of Health says that sexually transmitted diseases are way up in the state, in part because of the increase of hookup apps like Tinder.

Between 2013 and 2014, cases of syphilis grew by 79%. HIV infections were up 33% and gonorrhea cases increased by 30%. STD cases for young adults are growing at a faster rate than the rest of the population.

from http://money.cnn.com/2015/05/26/technology/rhode-island-tinder-stds/

Research questions

- *Question 1*

  Can we *model* the claimed effects?

- *Question 2*

  How does people discovery affect the *dynamics* of a disease?

  Can these effects be *balanced* in some way?

- *Question 3*

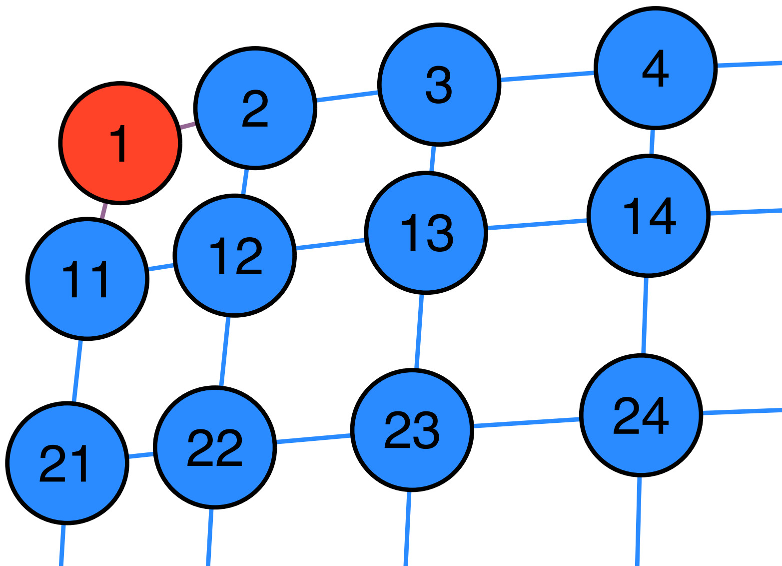
  How does our model *relate* to existing ones?

Ingredient 1: epidemiological SIR (1)

- 3 **compartments**: **S**usceptible, **I**nfected, **R**ecovered
- Each individual assigned to exactly one of these compartments
- 2 possible **transitions**:
  - Infection: $S \to I$ under certain conditions?
  - Recovery: $I \to R$
- Transitions happen with some **probability** per unit-time step

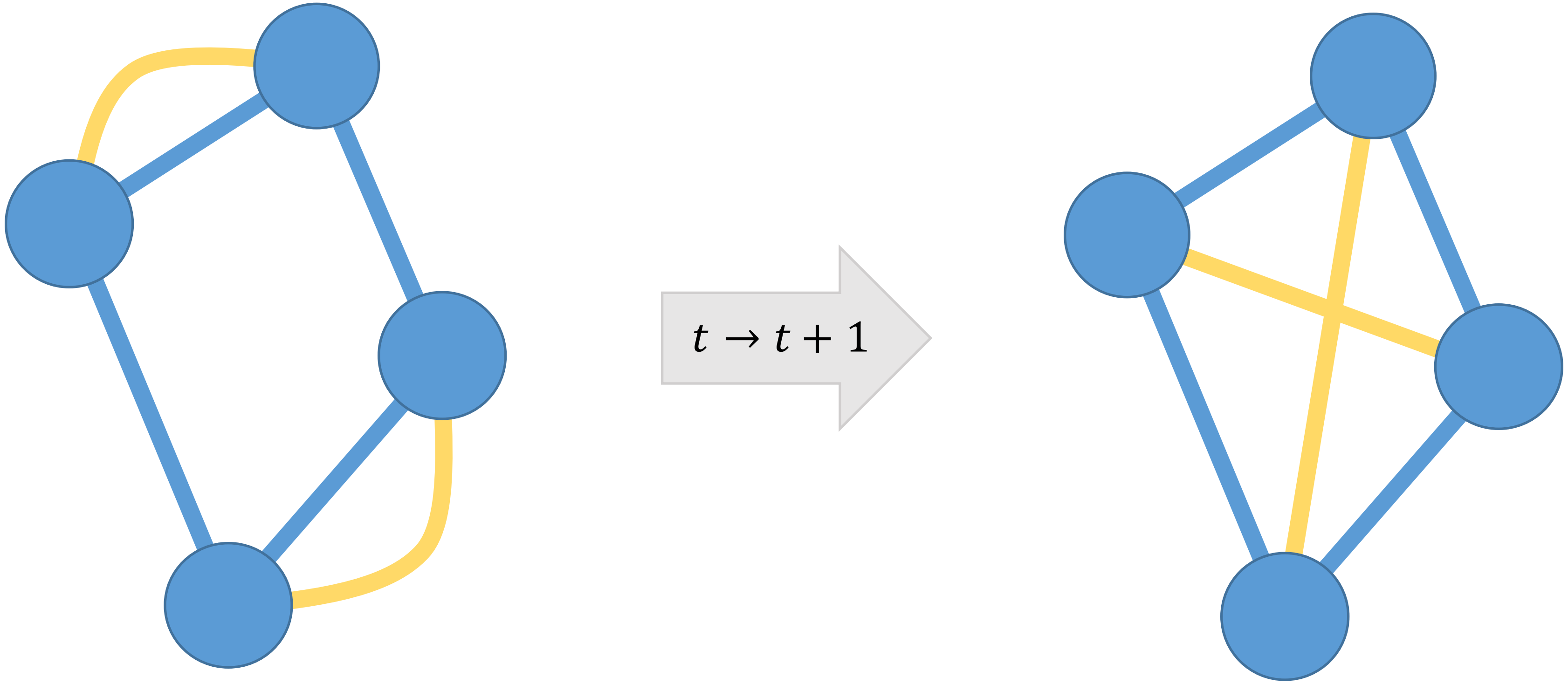
Ingredient 1: epidemiological SIR (2)

- 3 **compartments**: **S**usceptible, **I**nfected, **R**ecovered
- Each individual assigned to exactly one of these compartments
- 2 possible **transitions**:
  - Infection: $S \rightarrow I$ if susceptible has infected neighbor
  - Recovery: $I \rightarrow R$
- Transitions happen with some **probability** per unit-time step
- Infections are constrained to a contact **network**:



- **Monte Carlo** method to obtain meaningful data

Ingredient 2: perturbations



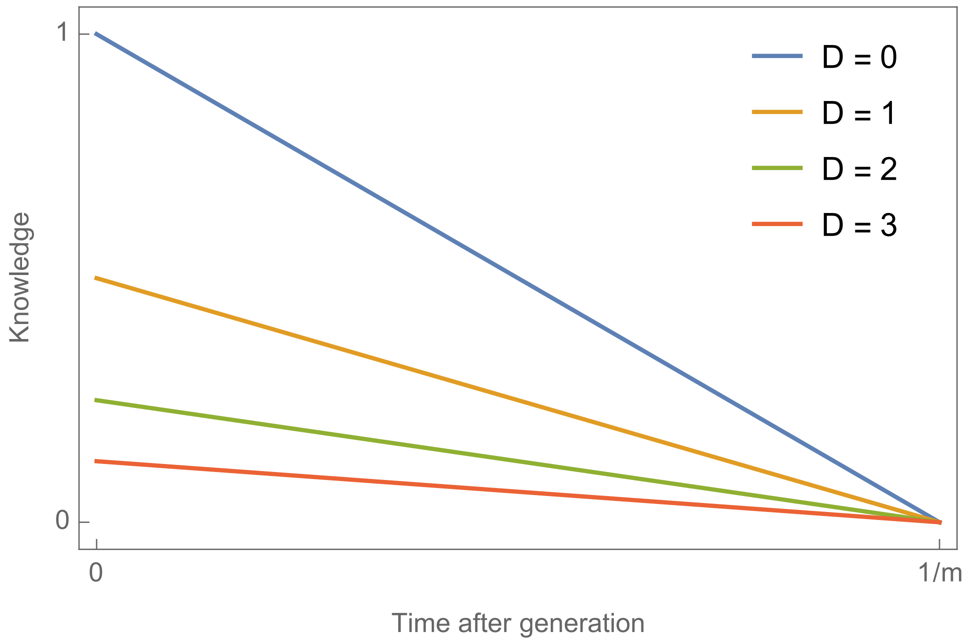
- Again, with some **probability** per individual and per unit-time step

Ingredient 3: awareness

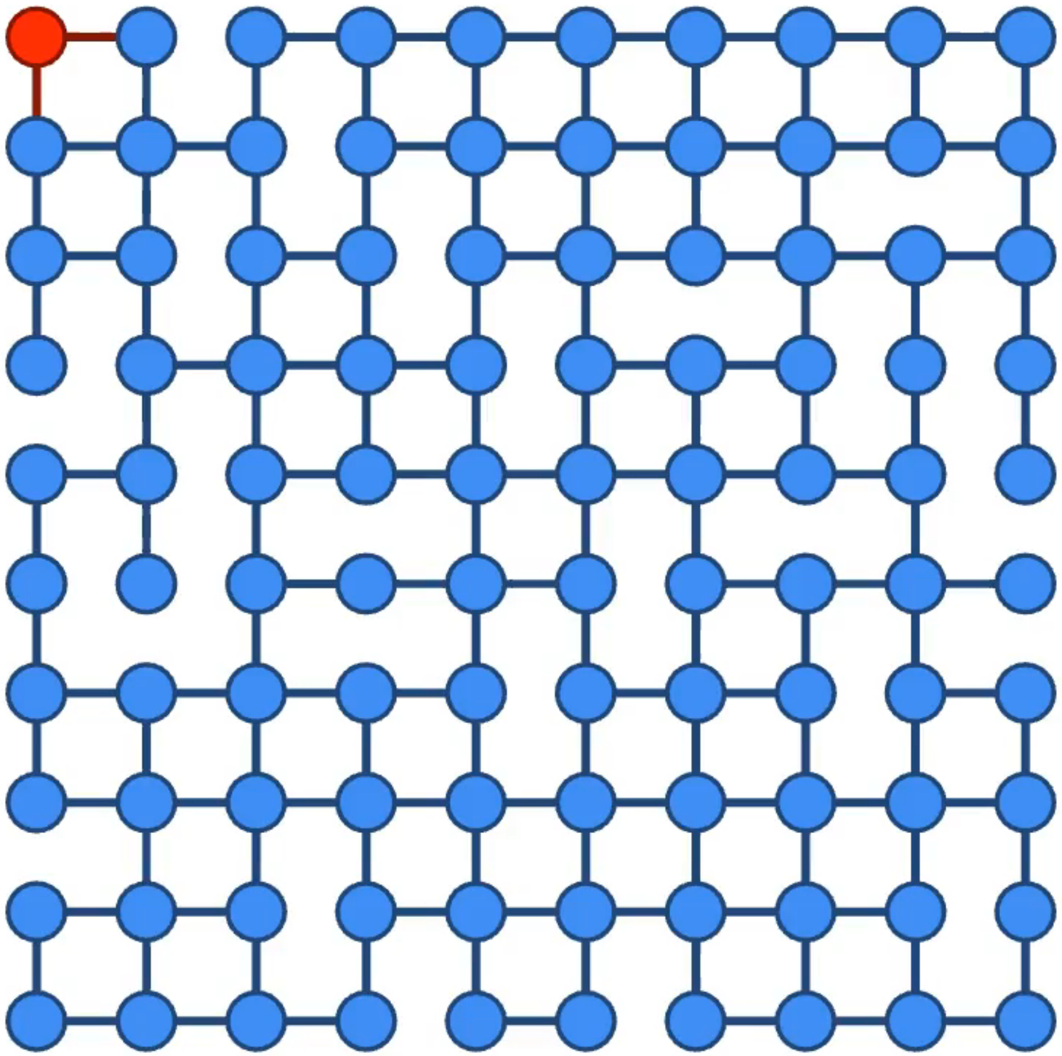
- Reduces **probability** of an infection:

  $P(S \rightarrow I) = \beta\ (1 - Awareness)$ for a single individual

- Sum of potential **knowledge** one has over all other individuals
- **Generated** at infected individuals
- **Propagated** independently
- Damped under **distance**
- Fades away with **unit-time**



Sample run from our simulations



size of nodes = awareness

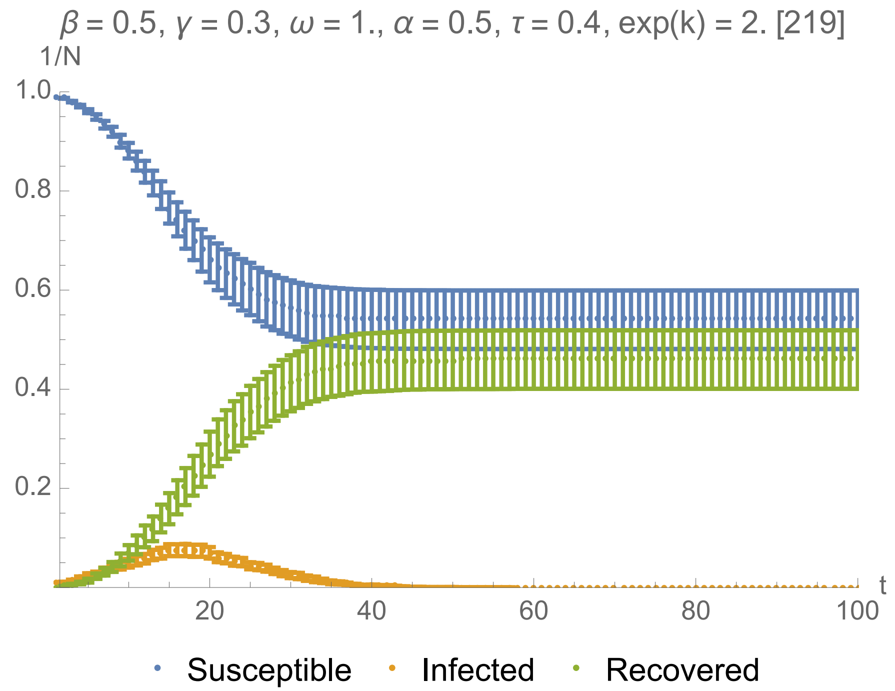
color of nodes = SIR state

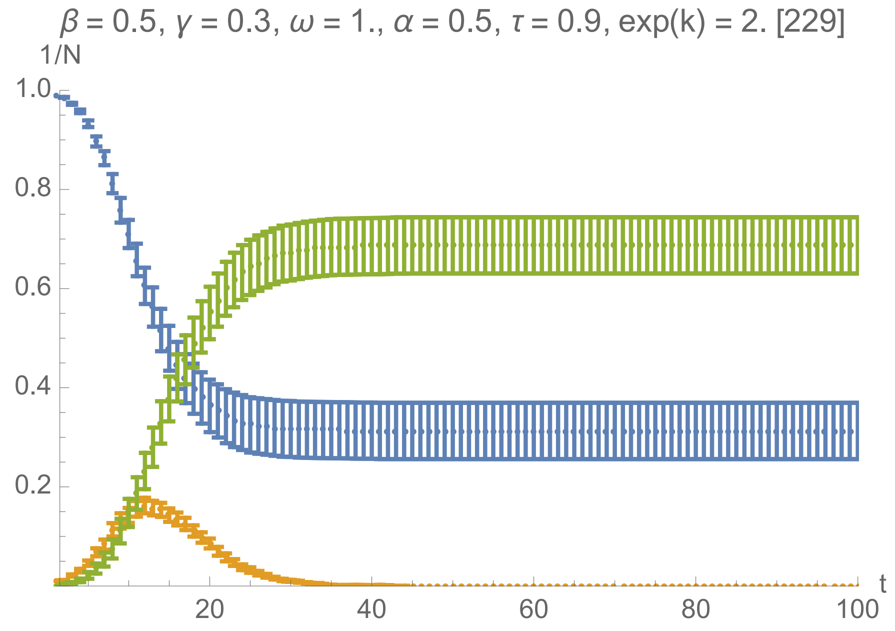
susceptible – blue
infected – red
recovered – green

SIR plots

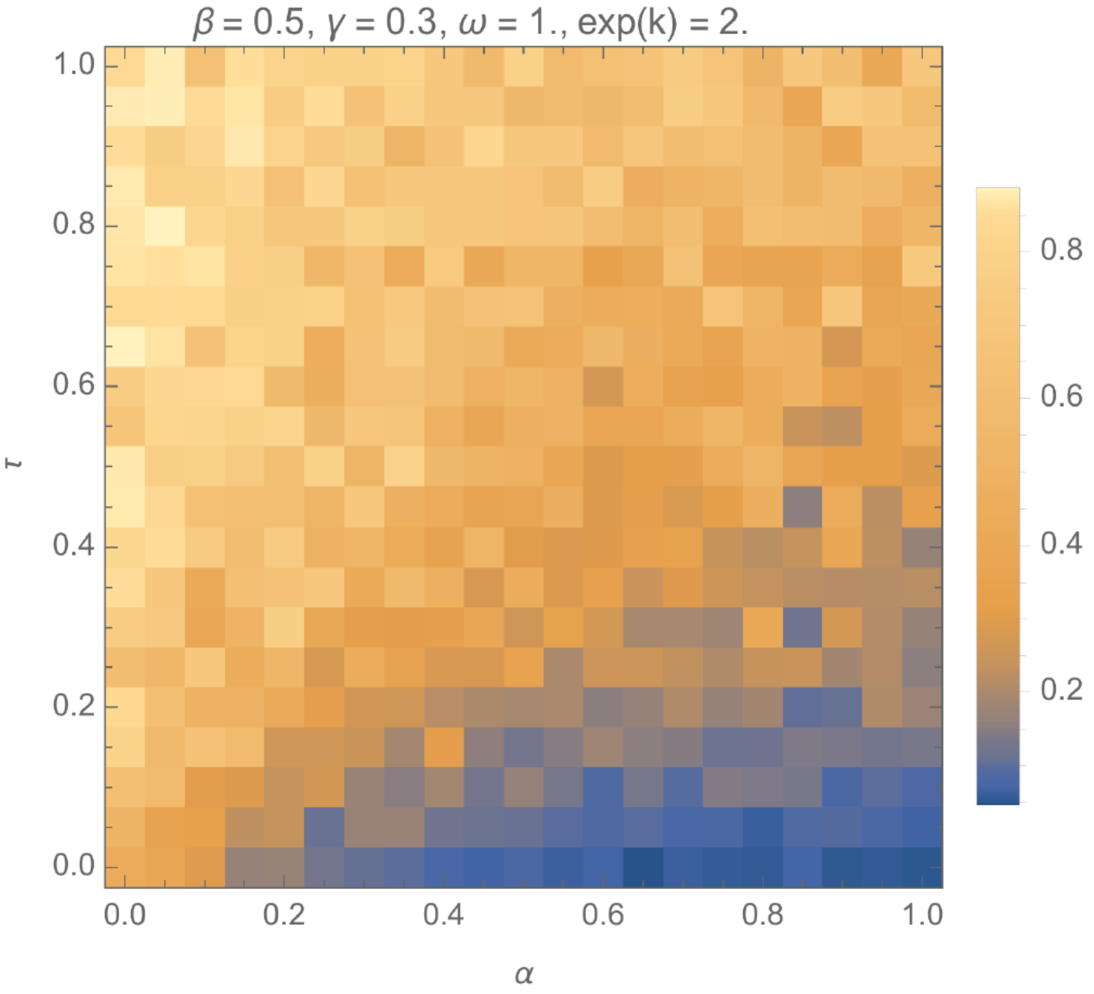
- More perturbation leads to
  1. more infections
  2. peak of simultaneously infected reached in shorter time
  3. prevalent time in population (generally) shorter

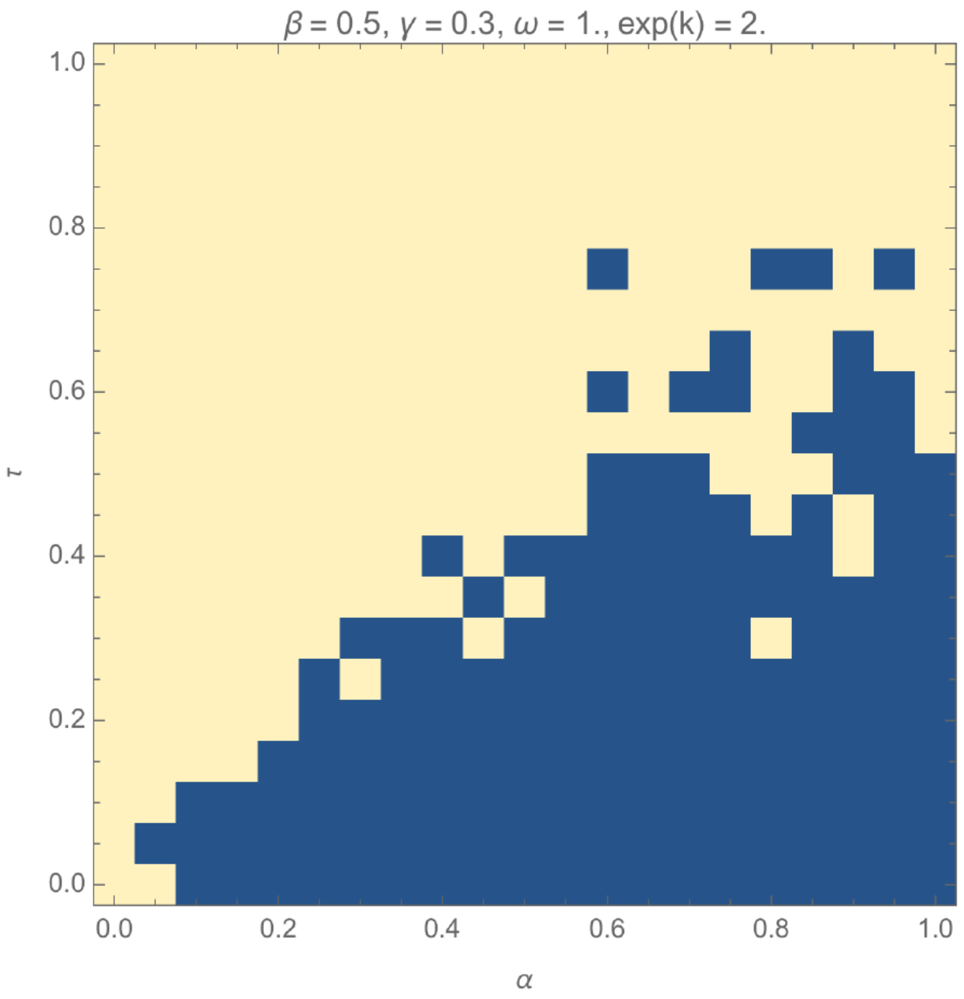
- Measure of **“epidemic outcome”**: # of total infected in last step (= 1 for entire population infected)



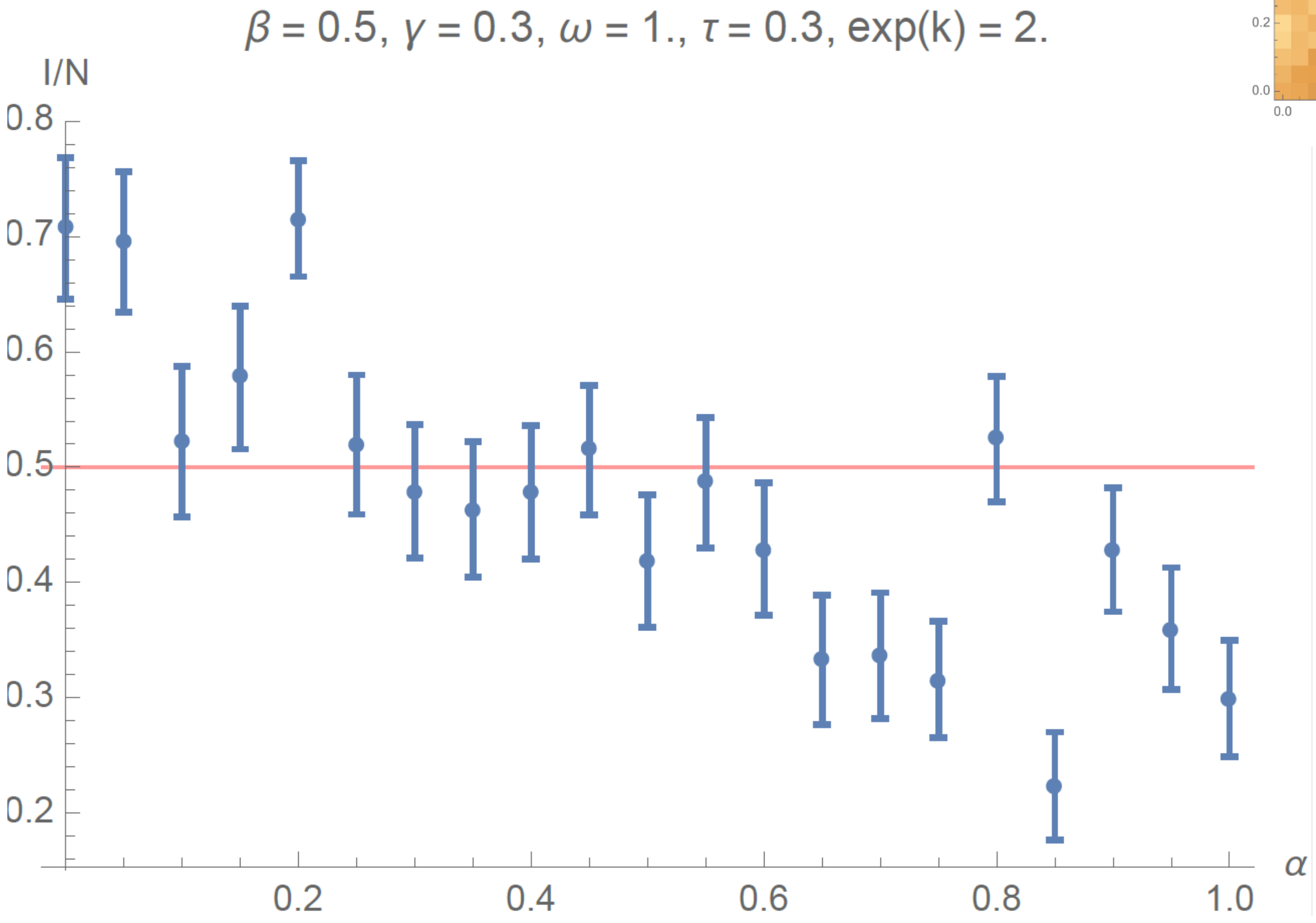


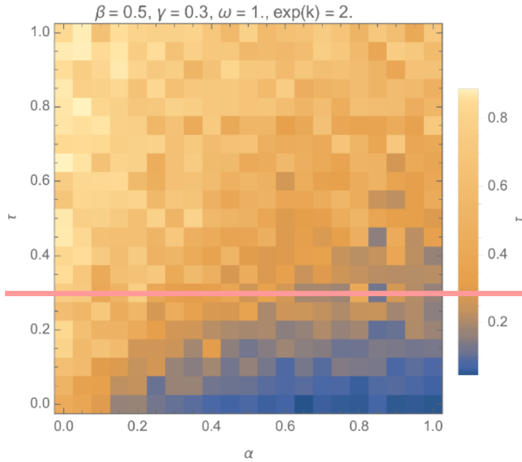
More information can balance more perturbation

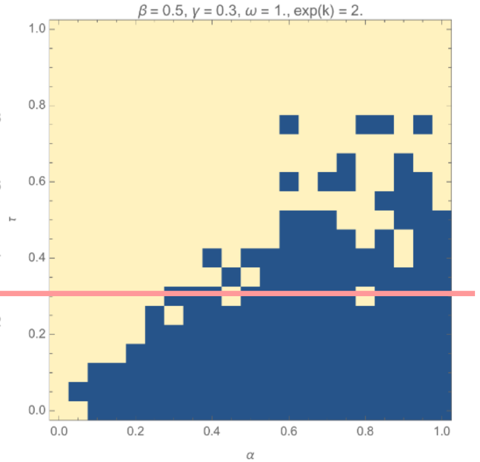




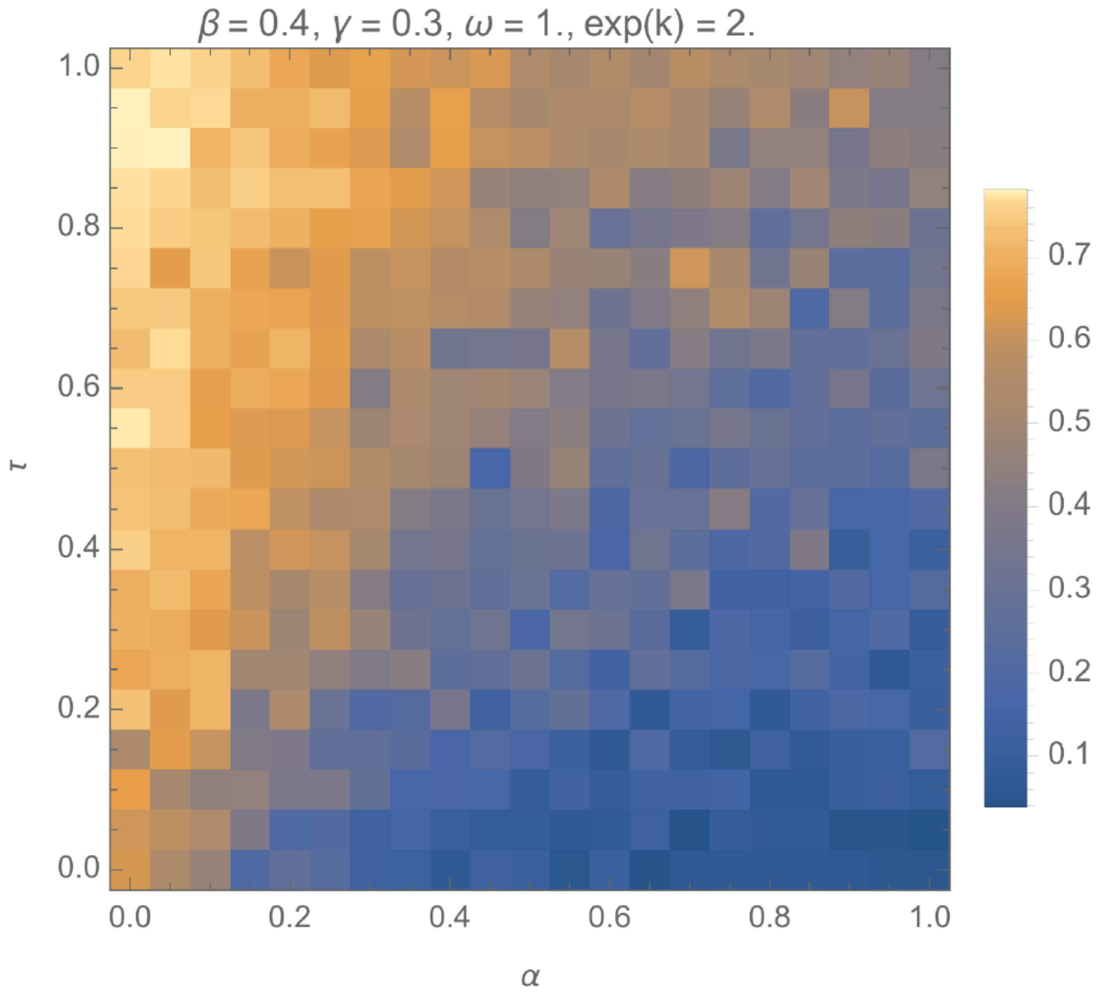
Instability of system

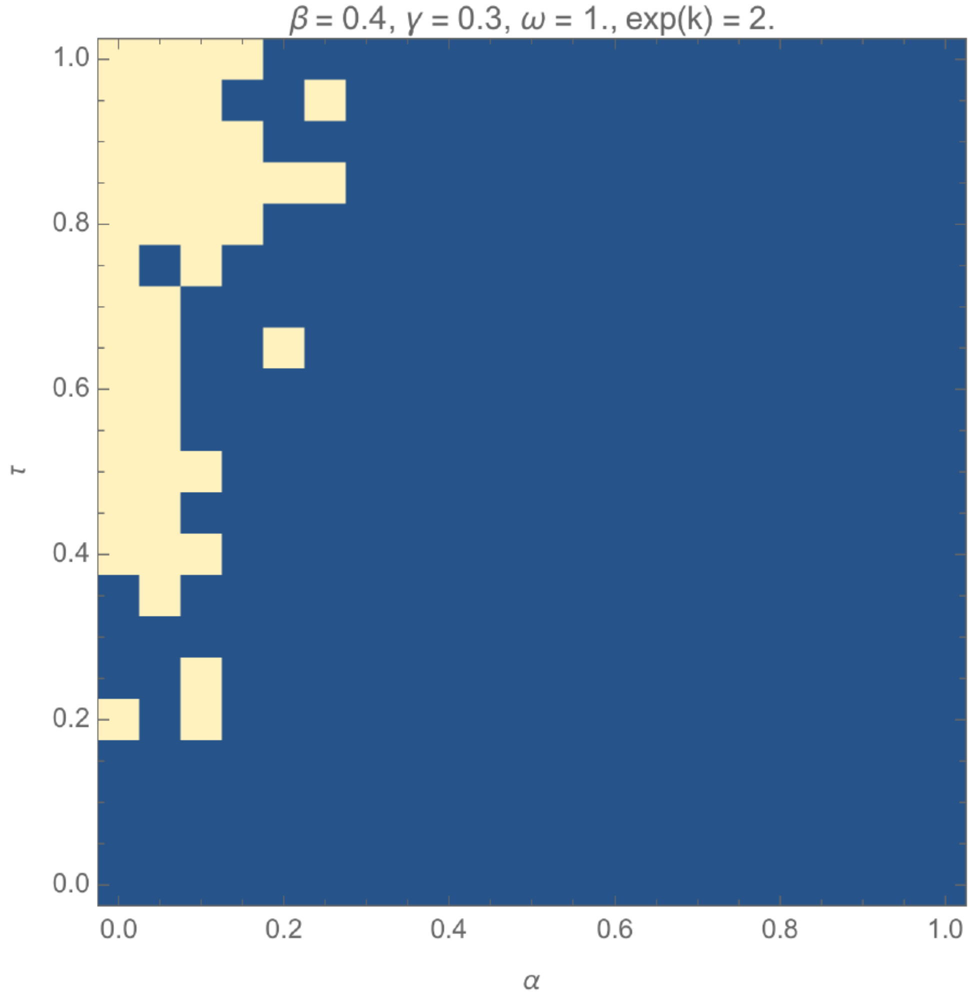






Comparison to divergent but static networks





Implementation & Limitations

- **Topology**: non-periodic grid, 100 nodes, i.e. 10 nodes on each side
- **Statistics**: just 50 runs per parameter set
- **Perturbations**: same probability for each individual, life span of 1 unit-time step
- **Information generation**: always and for sure
- **Information radius**: shortest path length ≤ 3
- **Decay of awareness**: within 2 unit-time steps
- **Authenticity of awareness**: reduced by a factor of 2 for each propagation

Summary & Outlook

- Generally more infections when including social discovery (*perturbations*) and less infections when promoting social distancing (*awareness*)
- Both effects can balance each other but the outcome becomes *unstable*

- Our **assumptions** need to be relaxed and evaluated, in particular:
  - Use of more realistic **network topologies**, after all it is about *social* discovery
  - Model **asymptomatic** time by tuning probability of information generation
  - Random links should depend on **spatial distance** and exclude existing neighborhood, and they should reflect a **distribution** within the population (few individuals making using of social discovery)

References

- S. Funk, E. Gilad, C. Watkins, and V. A. Jansen. **The spread of awareness and its impact on epidemic outbreaks.** *Proc Natl Acad Sci U S A*, 106(16):6872–7, 2009.
- W. O. Kermack and A. G. McKendrick. **A Contribution to the Mathematical Theory of Epidemics.** *Proceedings of the Royal Society of London Series A*, 1927.
- S. Riley, C. Fraser, C. A. Donnelly, A. C. Ghani, L. J. Abu-Raddad, A. J. Hedley, G. M. Leung, L. M. Ho, T. H. Lam, T. Q. Thach, P. Chau, K. P. Chan, S. V. Lo, P. Y. Leung, T. Tsang, W. Ho, K. H. Lee, E. M. Lau, N. M. Ferguson, and R. M. Anderson. **Transmission dynamics of the etiological agent of sars in hong kong: impact of public health interventions.** *Science*, 300(5627):1961–6, 2003.

Questions?