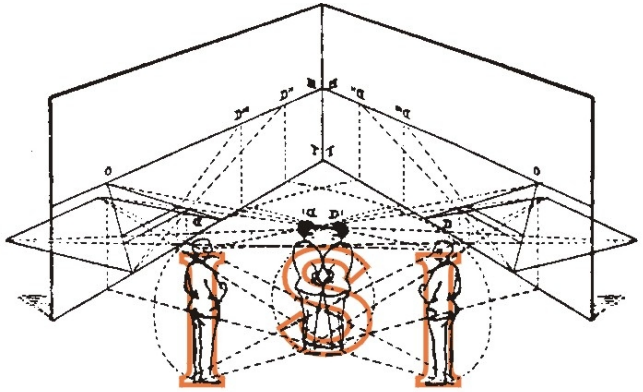
Revealing mesoscale structures to control dynamical processes in temporal networks

Laetitia Gauvin



INSTITUTE
FOR SCIENTIFIC INTERCHANGE
FOUNDATION

in collaboration with André Panisson,
Alain Barrat and Ciro Cattuto

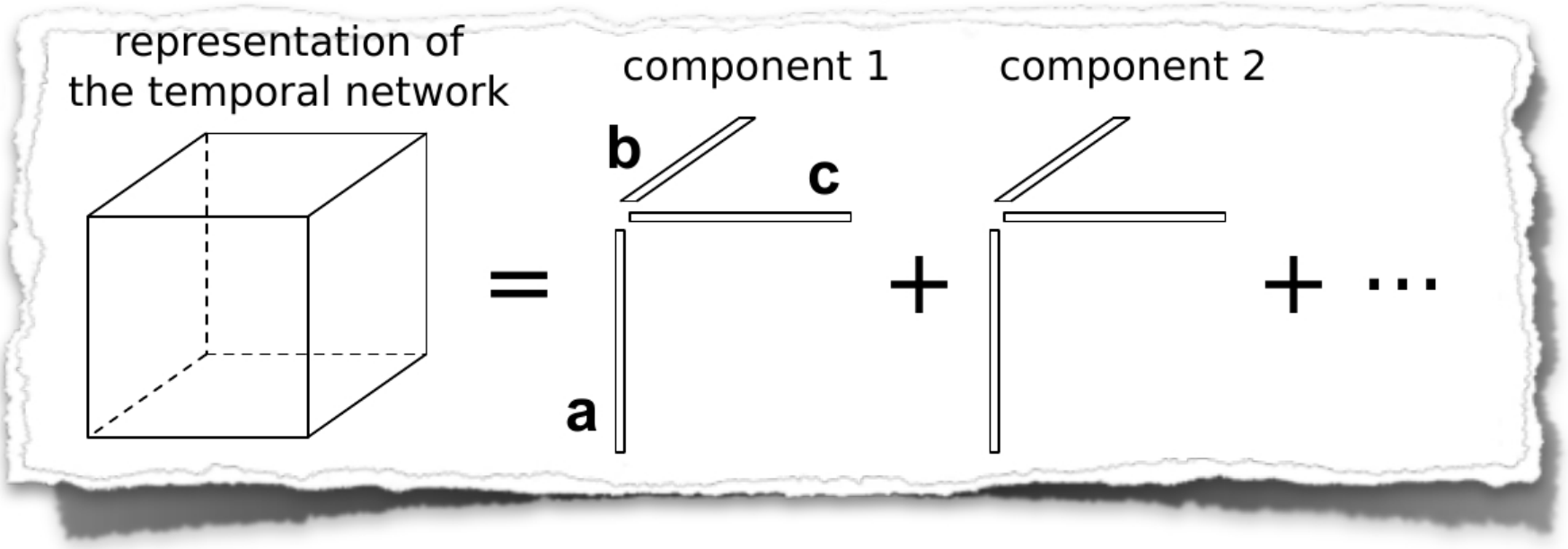
Introduction - Motivation

- Natural systems represented as time-varying networks of interactions

- Interaction patterns of people shape the epidemic spread

How to mitigate epidemic spread
by using properties of temporal network ?

Detection of mesoscale structures



R mesostructures

$$\mathcal{T} = \sum_{r=1}^{R_\mathcal{T}} \mathbf{a_r} \circ \mathbf{b_r} \circ \mathbf{c_r}.$$

temporal activity

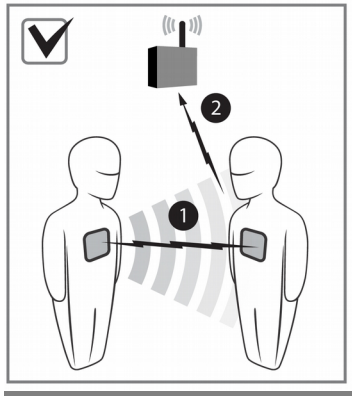
links participation

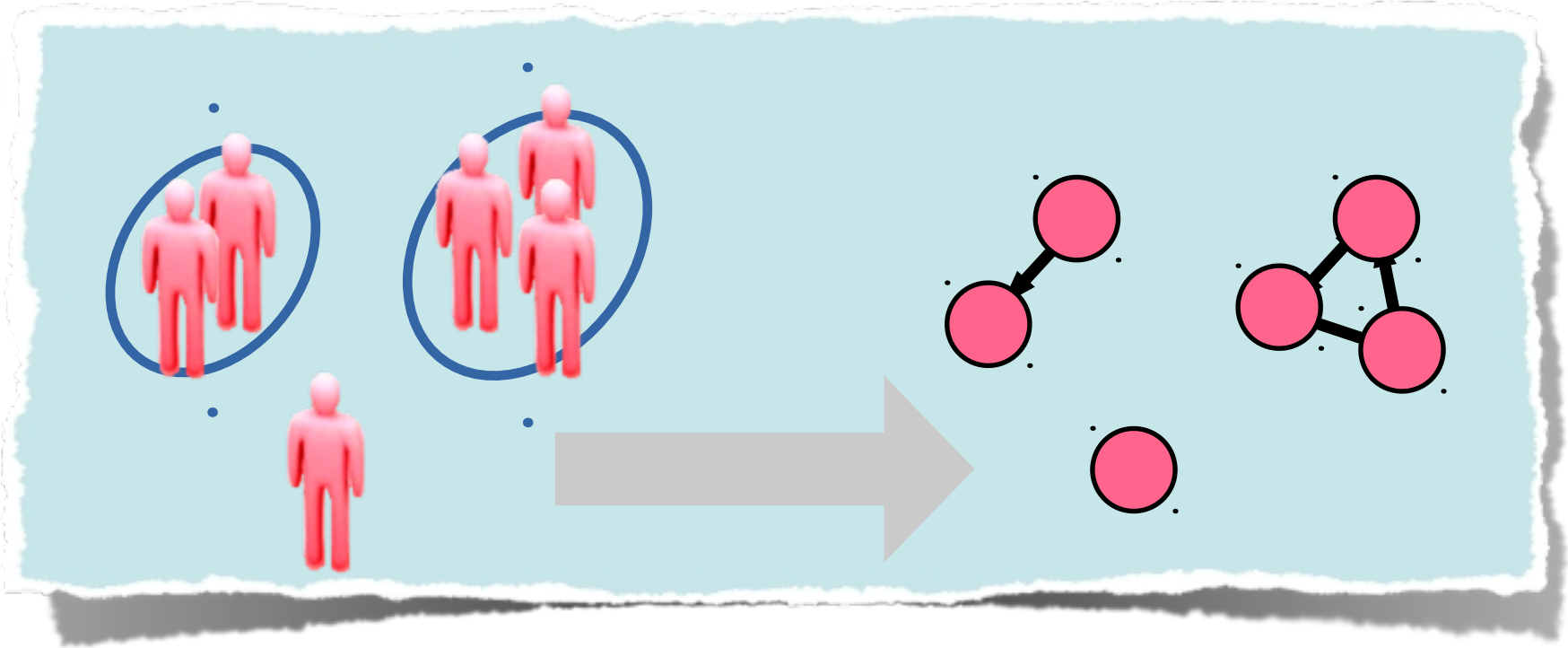
L. G. , A. Panisson, C. Cattuto. PLoS ONE (2014)

Case study

SocioPatterns

Lyon,
France
231 students
10 teachers
2 days





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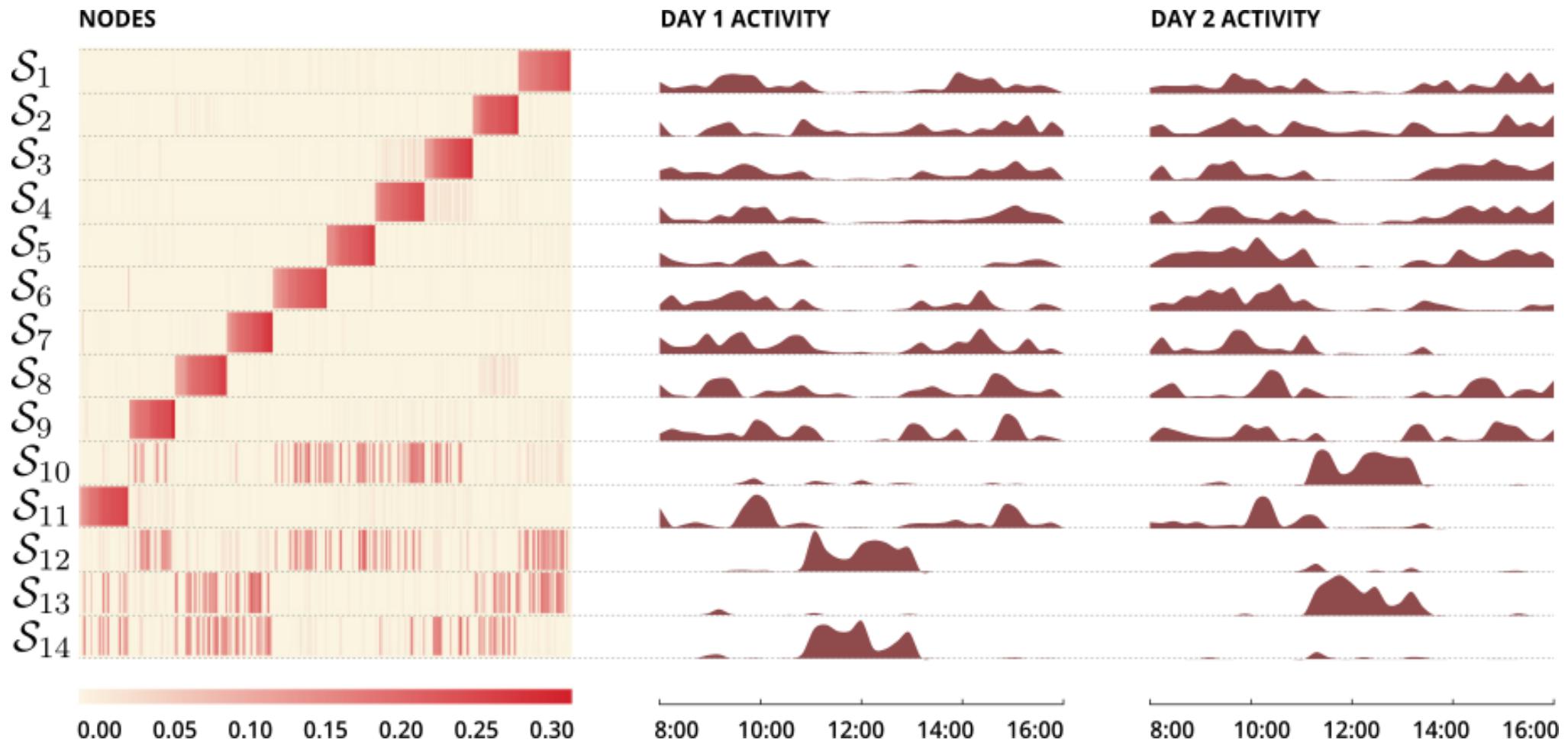

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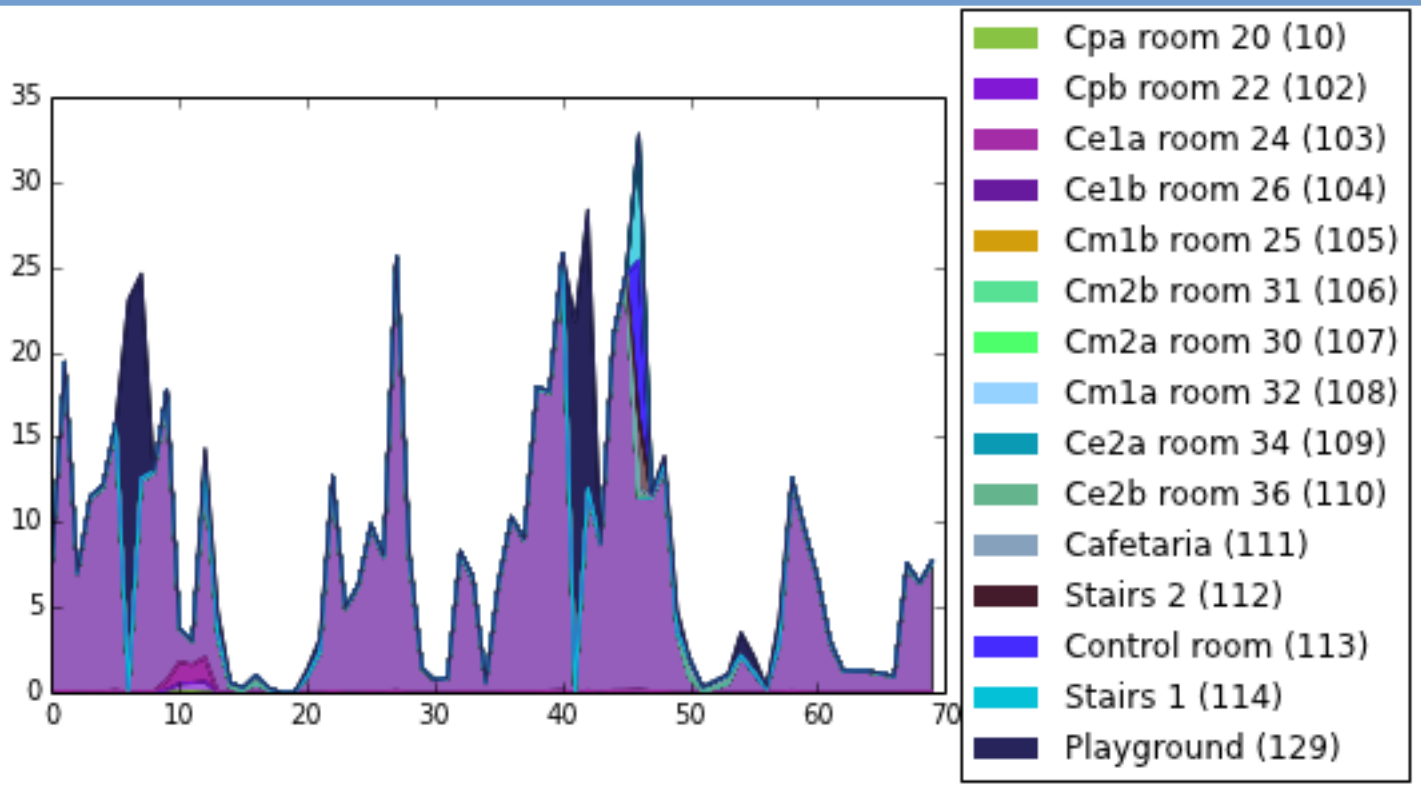
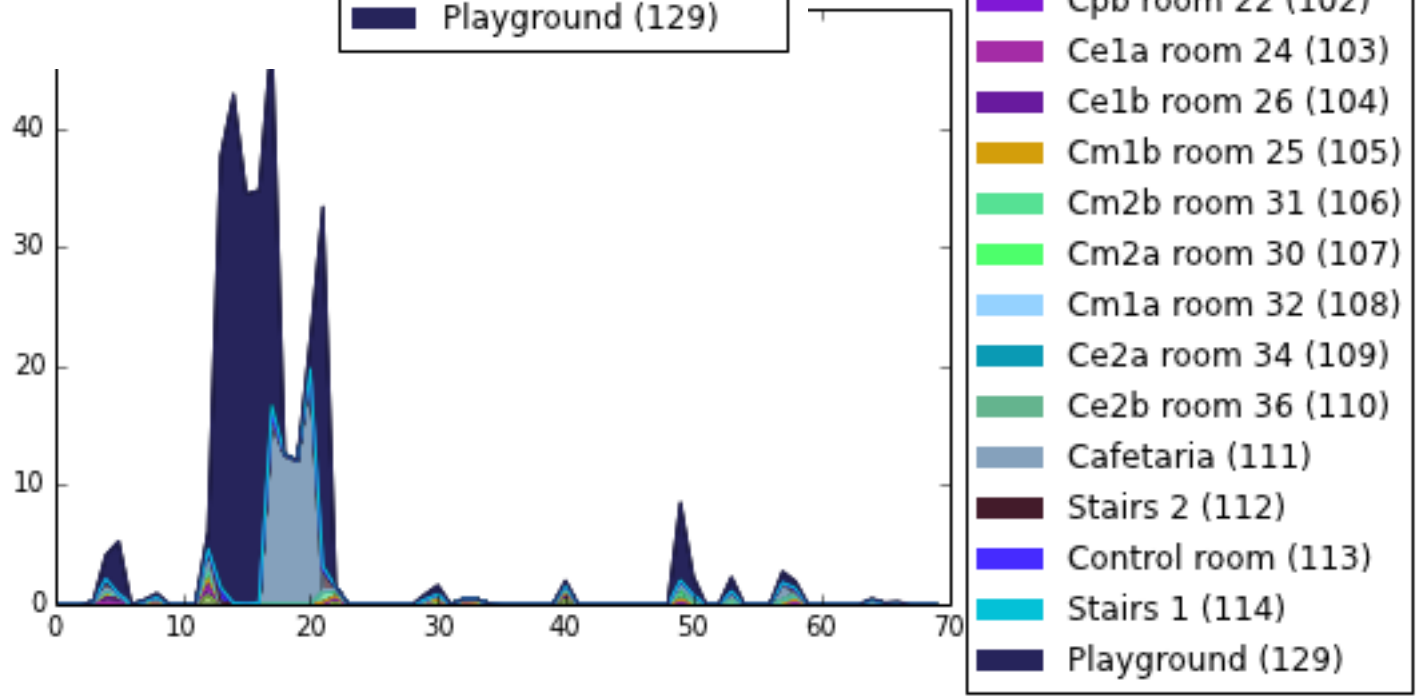
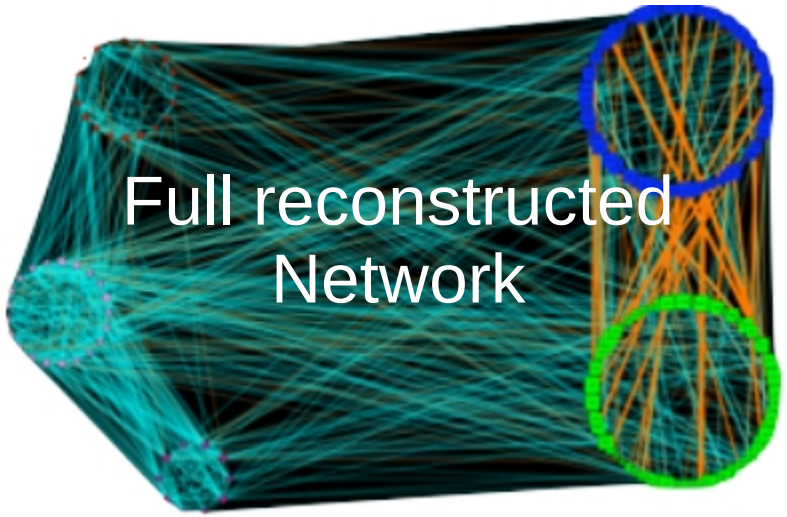


- « class activity »

- mixing events



Mesoscale targeted intervention : SI process



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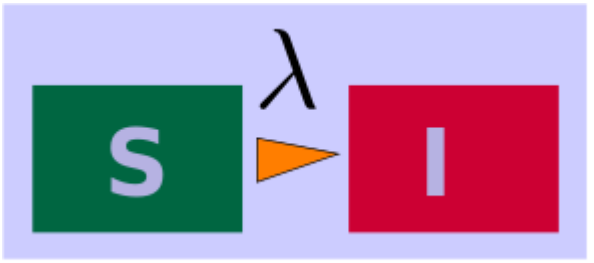

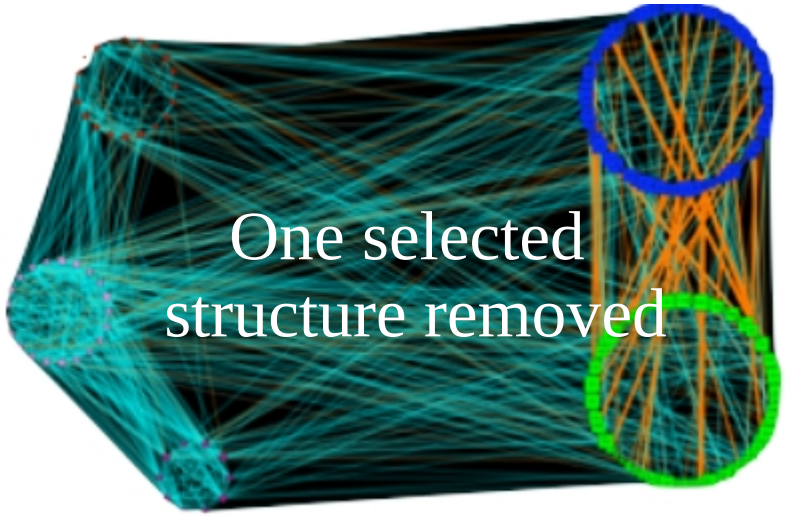

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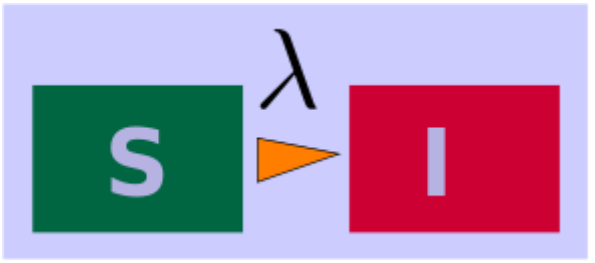
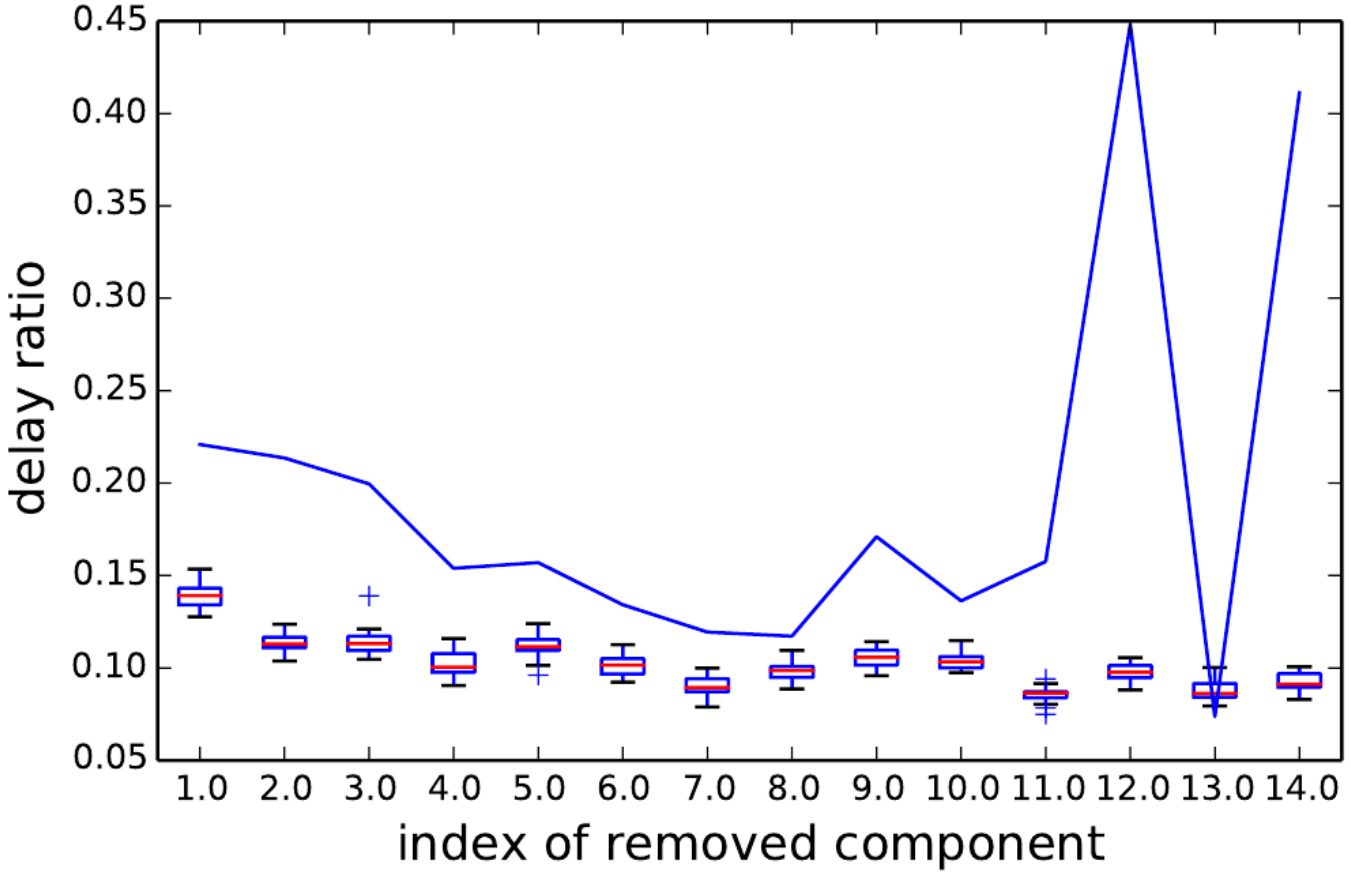


Impact on the epidemic spread

Mesoscale targeted intervention : SI process

r	1	2	3	4	5	6	7
percentage of weights removed	11.3	8.6	8.8	7.1	8.3	6.9	5.7
r	8	9	10	11	12	13	14
percentage of weights removed	6.8	7.5	7.5	4.8	6.8	5.7	6



$$\tau_r = \left\langle \frac{T_j^r - T_j}{T_j} \right\rangle$$

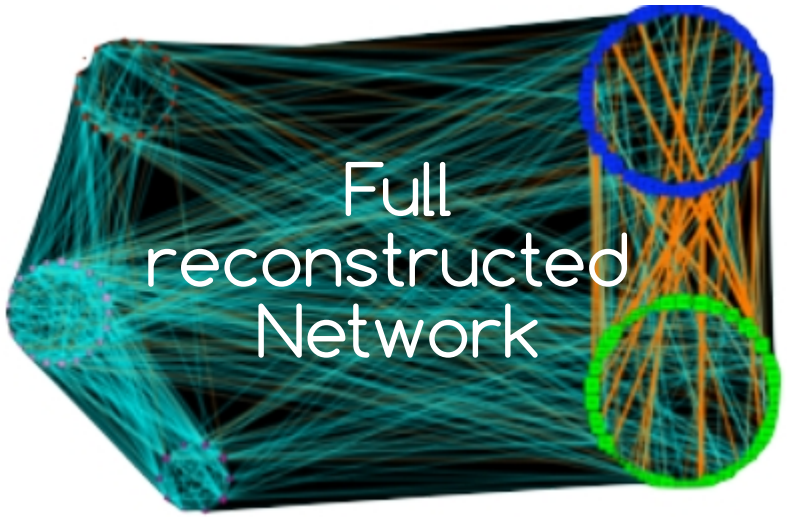
half infection times

T_j^r 1 structure removed

T_j full network

behaviour robust for different stochastic processes

Mesoscale targeted intervention : SIR process



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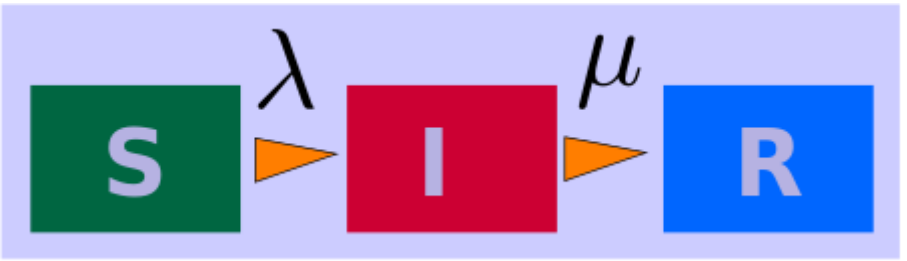

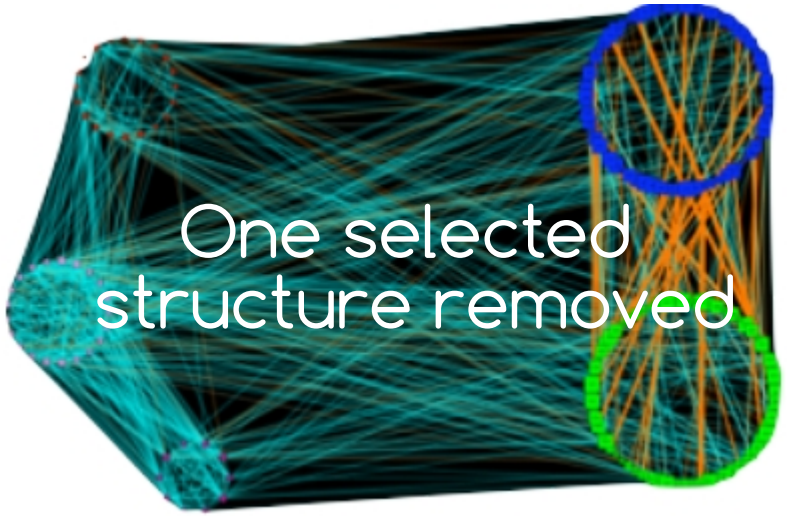

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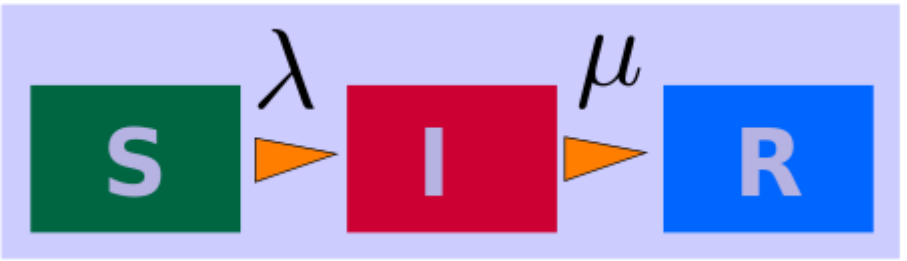
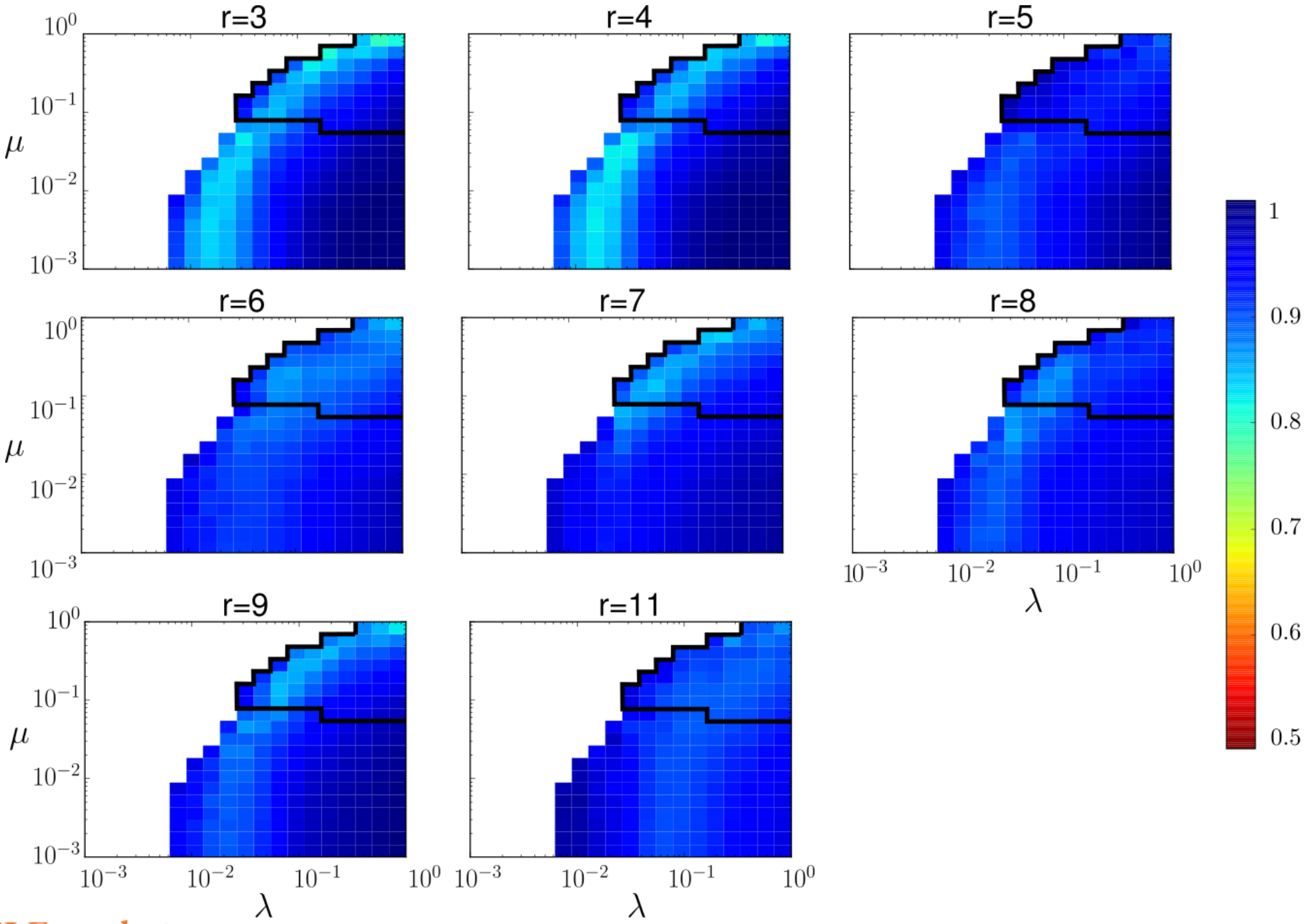


Impact on the epidemic spread

Mesoscale targeted intervention : SIR process



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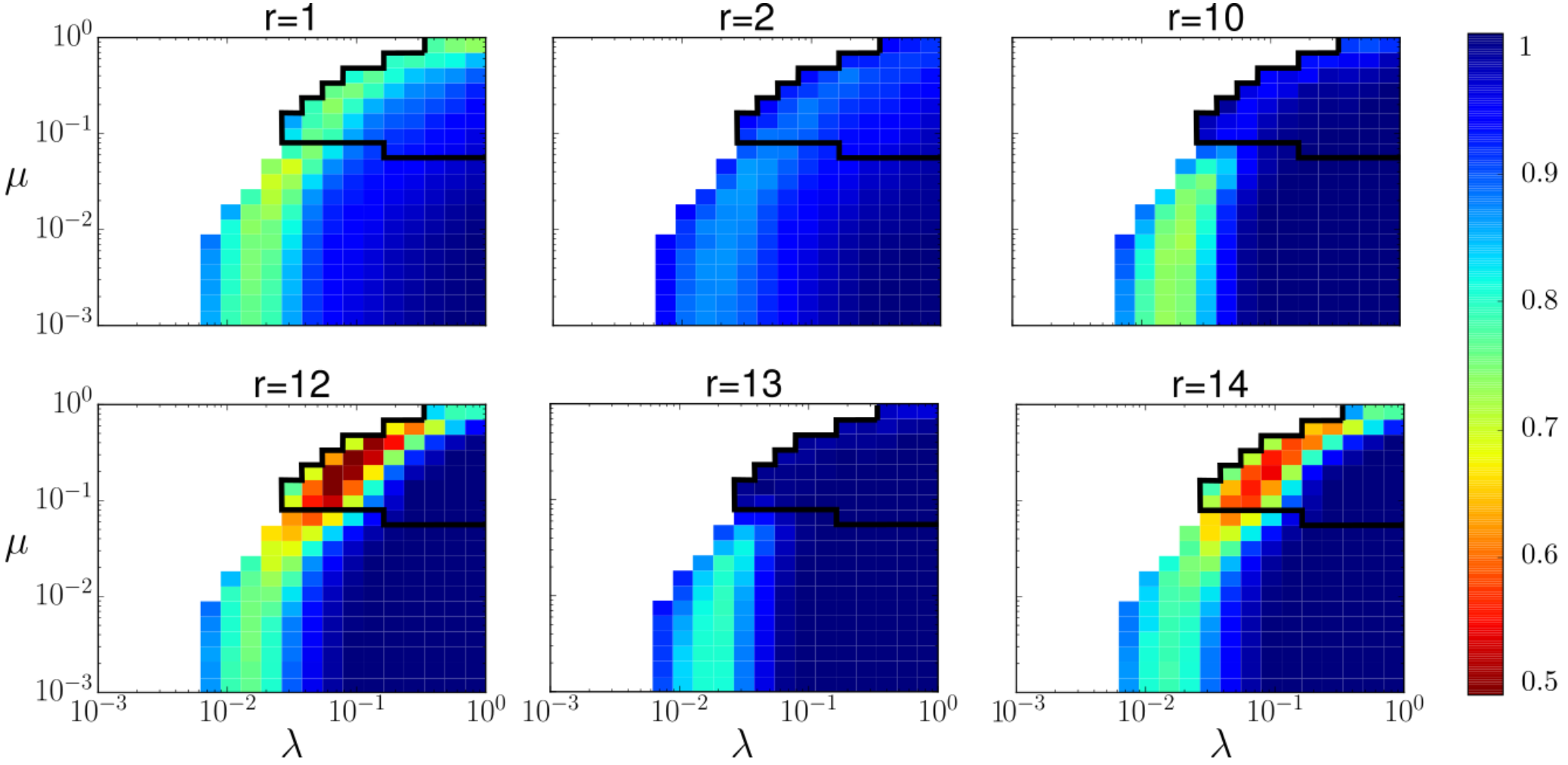
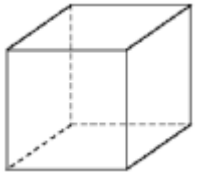


Framework summary

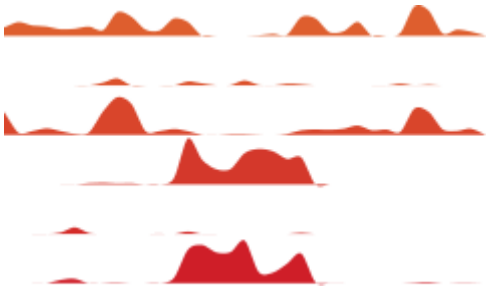
representation of the network as a tensor

factorization into a sum of mesostructures

identification of the « critical » mesostructures



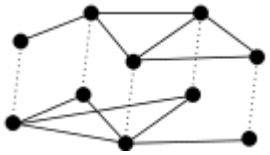
$$\mathcal{T} = \sum_{r=1}^{R_\mathcal{T}} \mathbf{a_r} \circ \mathbf{b_r} \circ \mathbf{c_r}$$

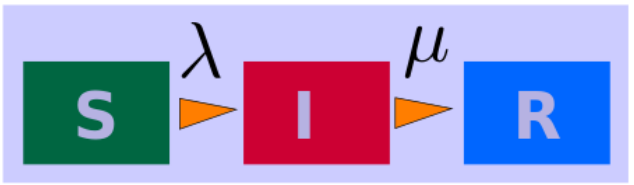


partial reconstruction of the network

spreading process on the altered network

measure of the impact of the alteration of the network





insights for designing intervention strategies

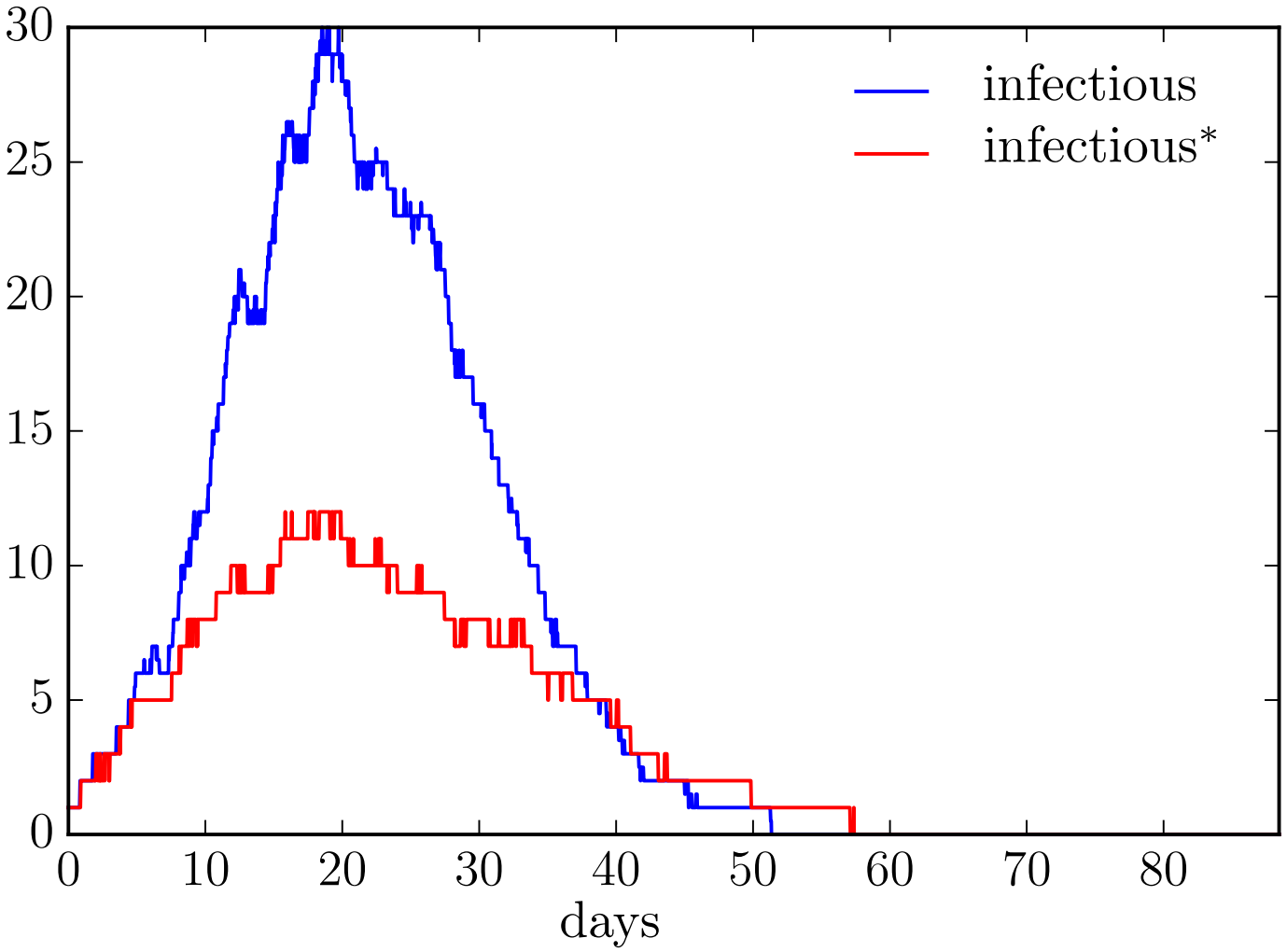
Case study : ILI in a primary school

- Dataset : sequence of typical weeks in the school
- Influenza-like disease : SEIR
- Exposed in the school and outside
- Latent period : 2days
- Recovery : 4 days
- Infectious go home after school
- Reactive intervention : avoid interactions detected as having a strong impact once the spreading started
- Intervention equivalent to limit mix events and replace by class-like events

Case study : ILI in a primary school

Percentage of simulations with an attack rate greater than 10%:

- 54 % in case of an intervention
- 71 % without intervention



Conclusions

- Methodology to uncover mesocale structures in temporal networks and their importance in a spreading process in an unsupervised manner

- Targeted intervention : no need to involve the whole system
  no need to define a ranking of the nodes

- Non trivial mesotructures : complex patterns of correlated activity

- Systematic characterisation and evaluation of mesocale structures in temporal network

- Following the previous framework, we show that a reorganization of the schedule leads to reduction of 42% of infectious cases

- Revealing latent factors of temporal networks for mesoscale intervention in epidemic spread, ArXiv L. Gauvin, A. Panisson, A. Barrat, and C. Cattuto