# Network Based Perspectives on Vibrations in Complex Systems

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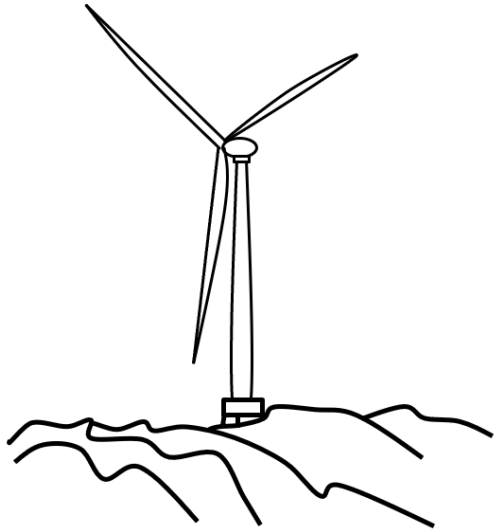
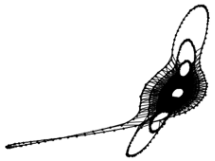
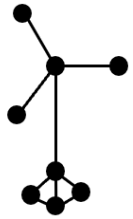
# Three network-based perspectives



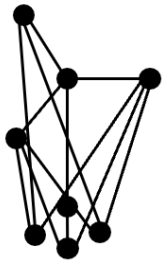
*dynamics* as topology



*geometrical* structure as topology

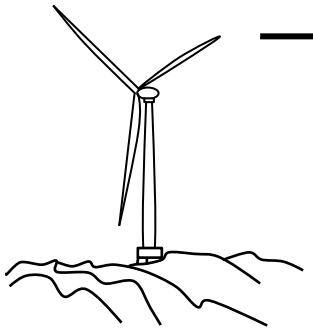


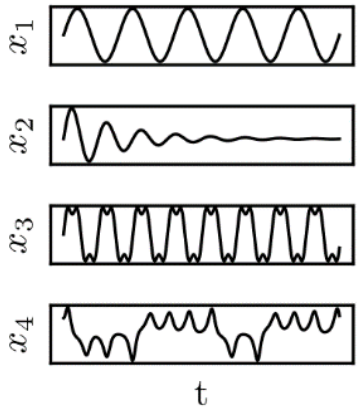
*functional* structure as topology

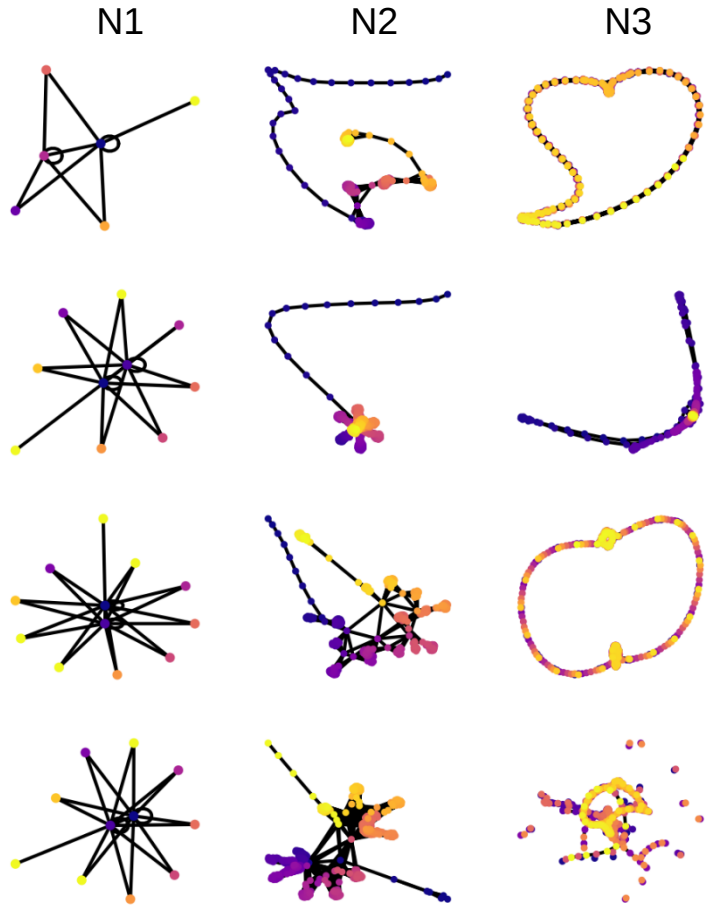


… maybe more?

# Dynamics as topology






- Study transitions / emergent phenomena / bifurcations
- Distinguish stochastic from chaotic behaviour
- Dynamic invariants

N1: temporal succession of partitions
N2: mutual visibility criteria
N3: proximity measures

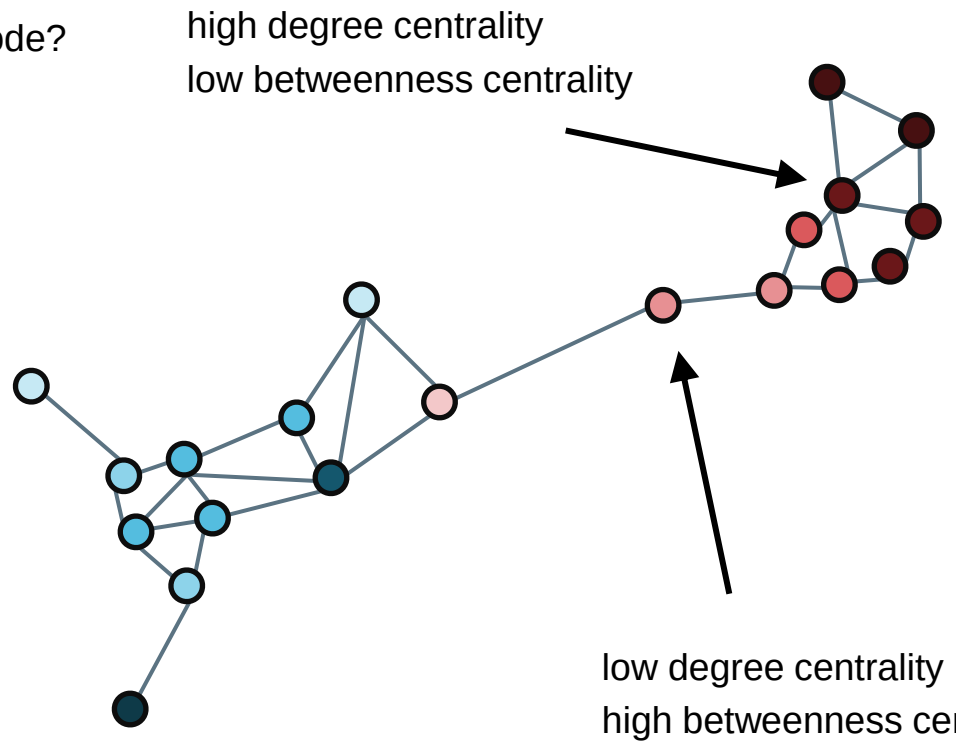
# *Geometrical* structure as topology

Network metrics can define (structural) importance of components

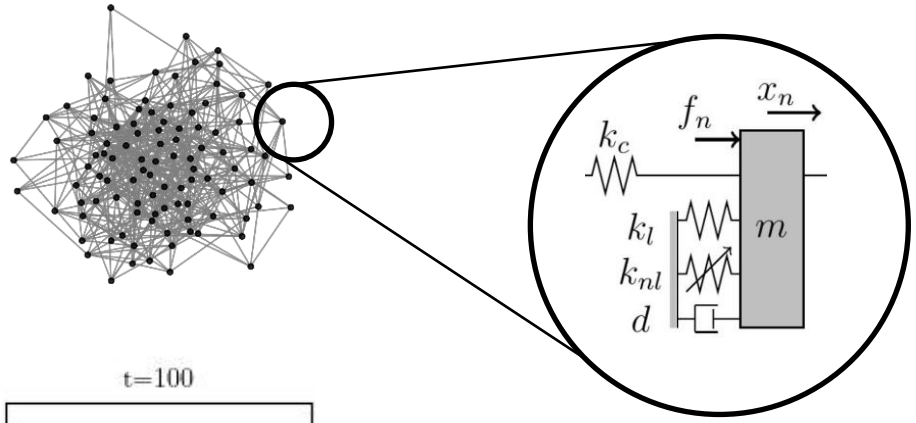
e.g. centrality measures:

- Degree centrality: how many nodes is a node connected to?
- Betweenness centrality: how many shortest paths go through a node?

- ➢ Analysis of structural properties
- ➢ Cluster formation
- ➢ Vulnerability / robustness against attacks

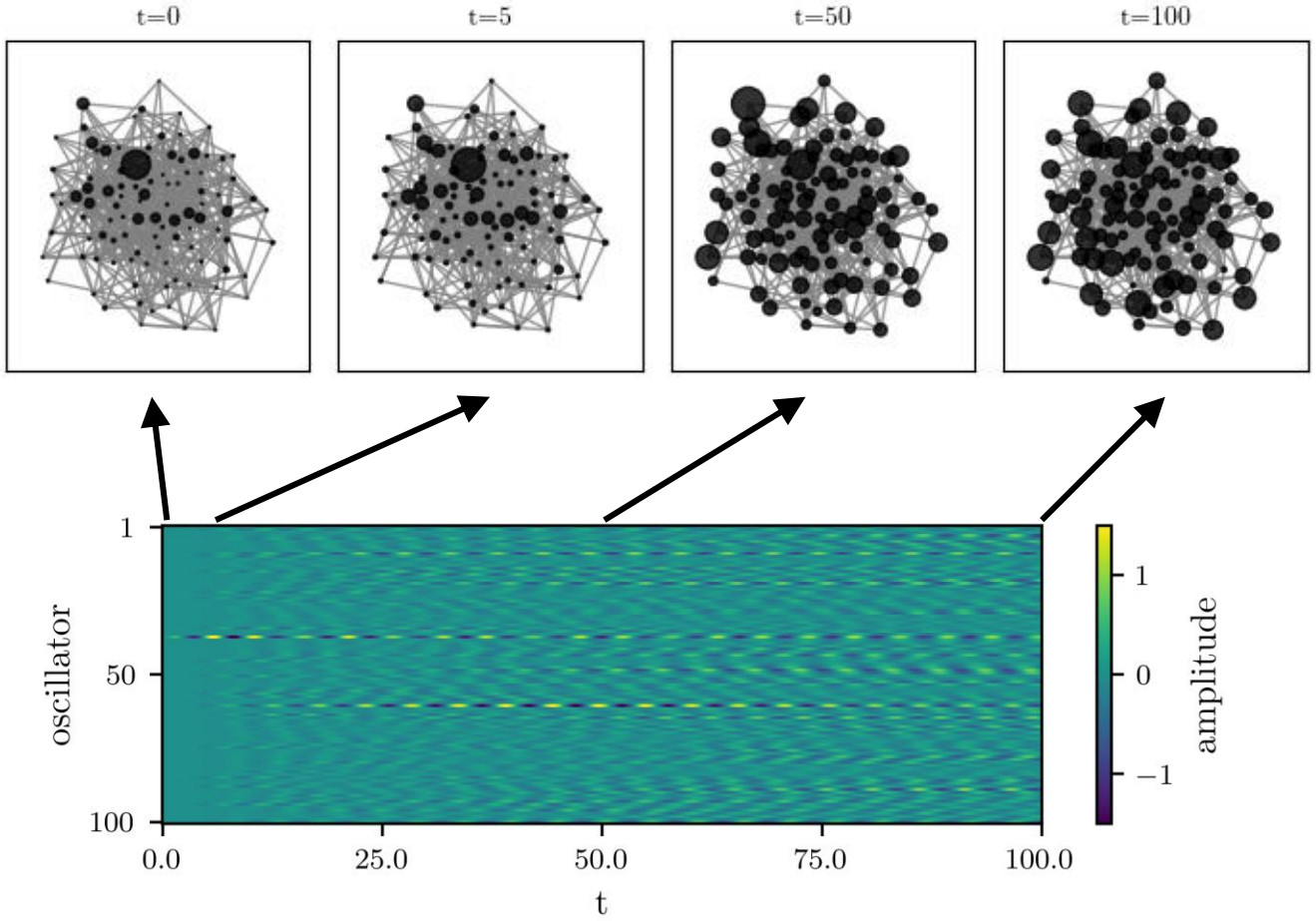


# Dynamics on networks




So far: structure

Now: add dynamics

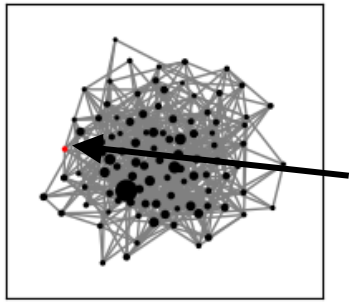



- Flow patterns
- Most important components
- Global dynamics from local interactions

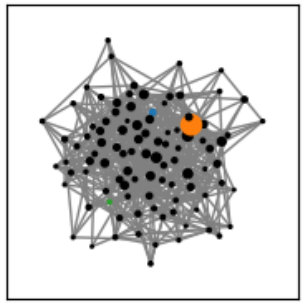
➢ Prediction and Control

➢ Focus of design efforts

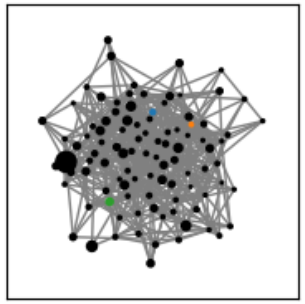
# Assessing the role of individual nodes for global dynamics



network with 100 nodes
remove red node

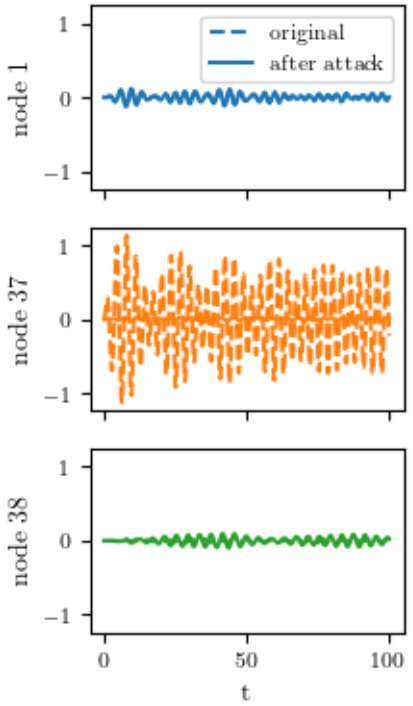


dynamics of original network

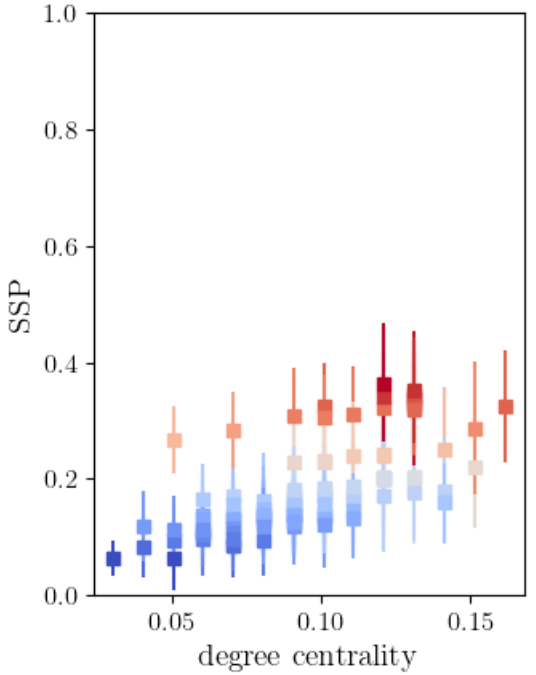


dynamics after node is removed

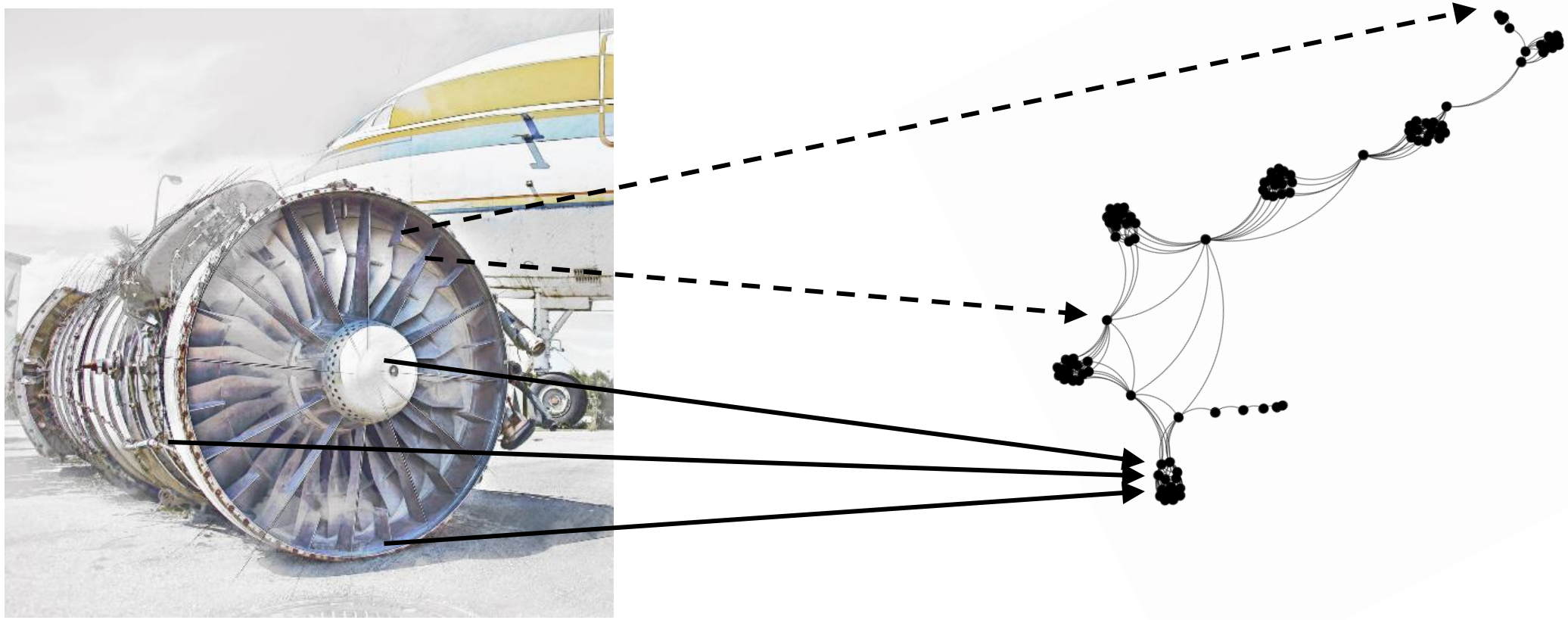
compare time series




repeat for every node



# *Functional* structure as topology



Turbine: By K. Aainsqatsi - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=4008470/

# Building a functional network

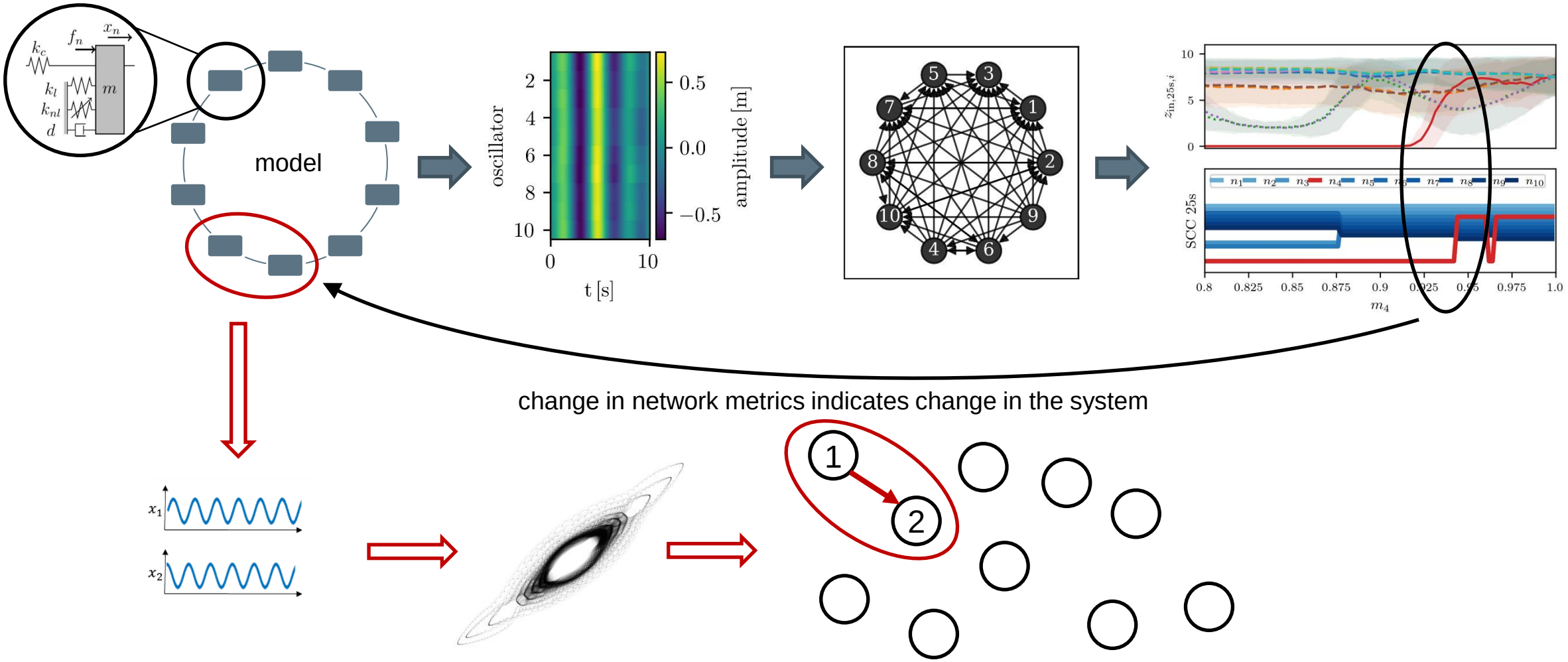



Figure: C. Geier and N. Hoffmann, Exploring localization in nonlinear oscillator systems through network-based predictions. Preprint available at https://arxiv.org/abs/2407.05497.

# Tracking disturbances

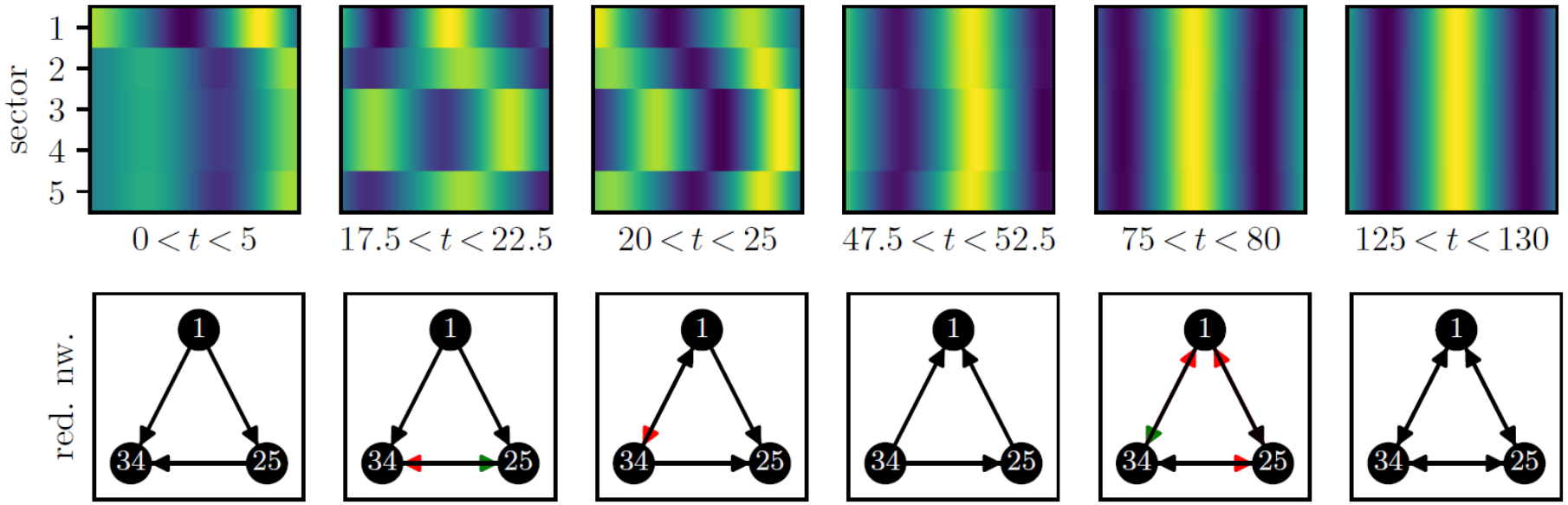
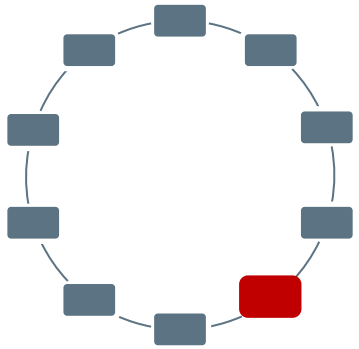



Figure: C. Geier, M. Stender and N. Hoffmann, Building functional networks for complex response analysis in systems of coupled nonlinear oscillators. Journal of Sound and Vibration 590 (2024) 118544

# Studying localized vibrations



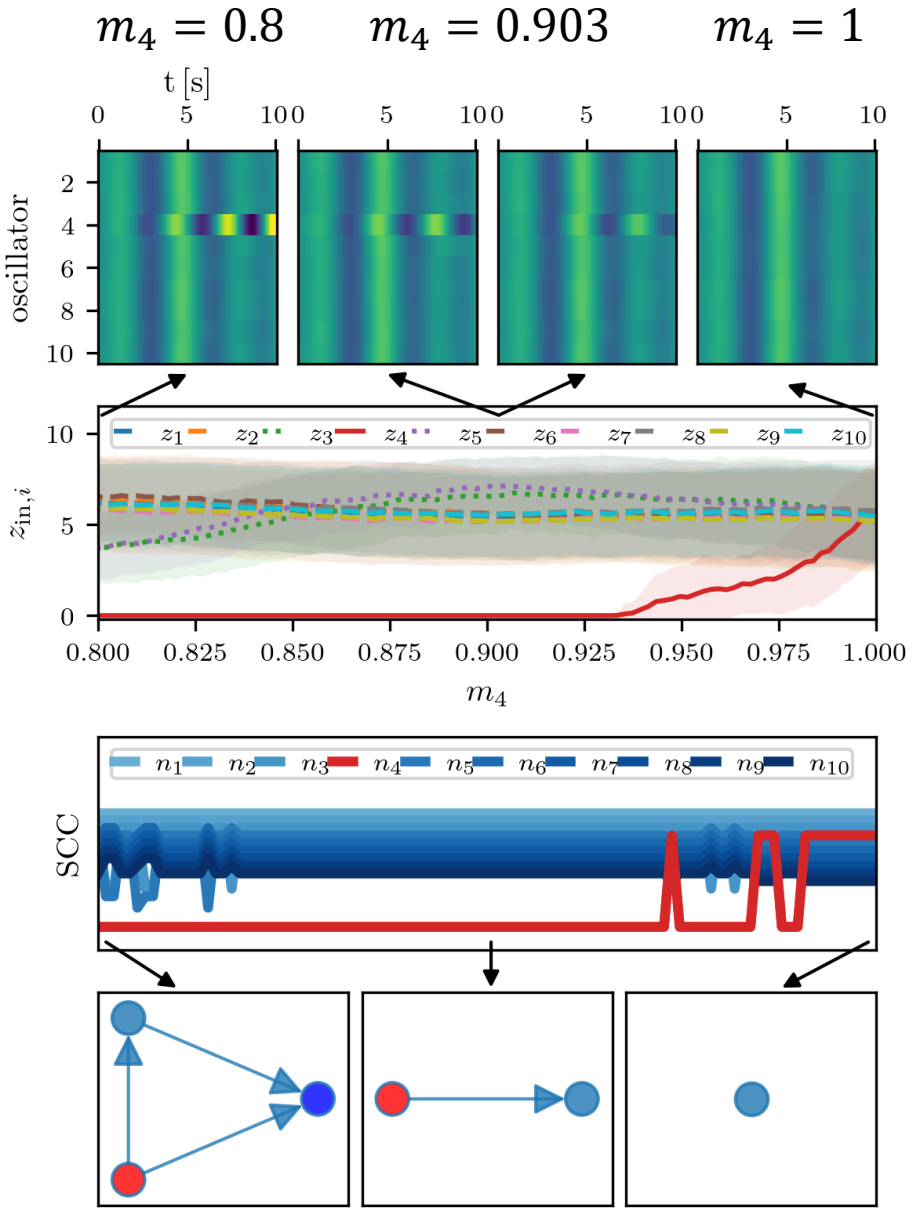


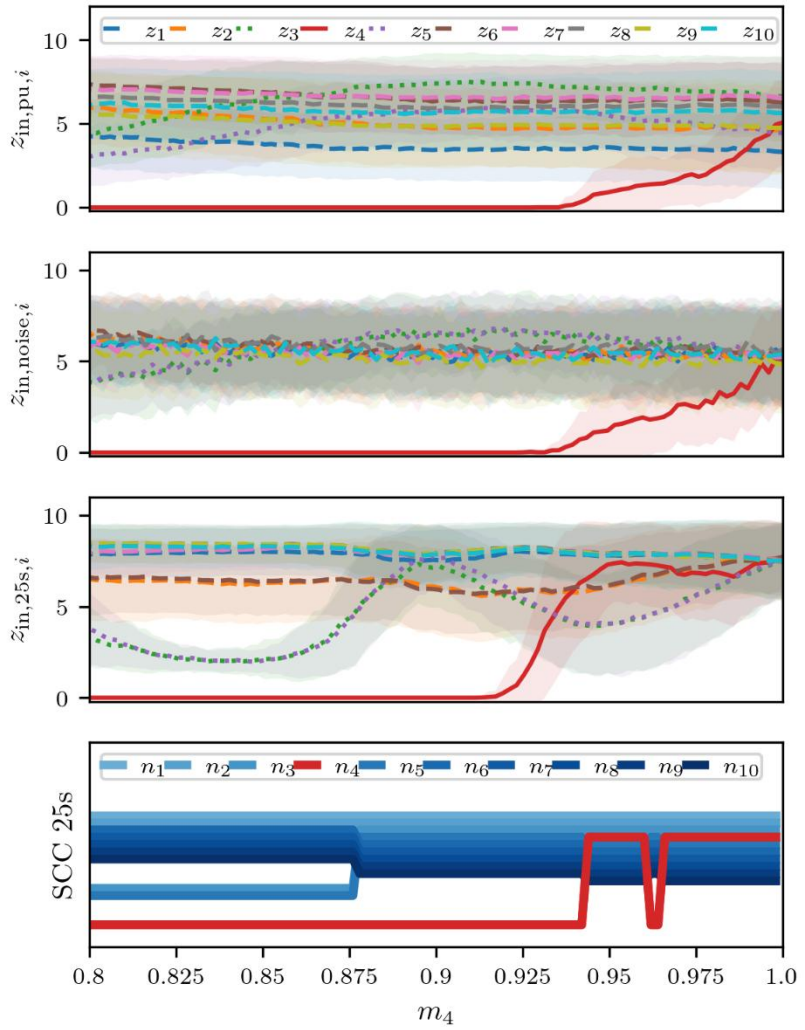

Figure: C. Geier and N. Hoffmann, Exploring localization in nonlinear oscillator systems through network-based predictions. Preprint available at https://arxiv.org/abs/2407.05497

# Robustness?

parameter uncertainties

noise

input data length



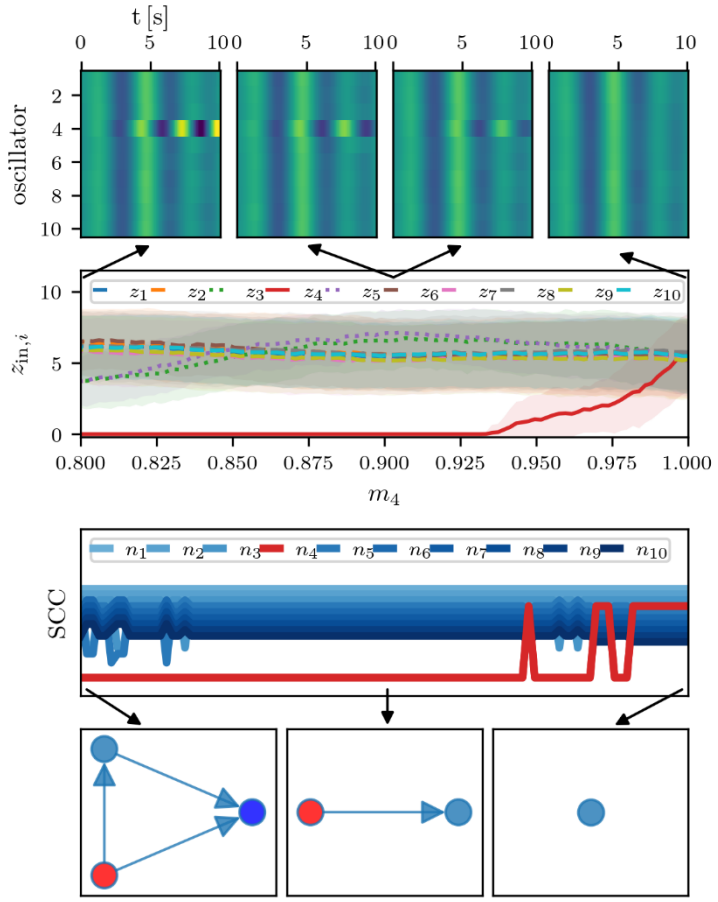
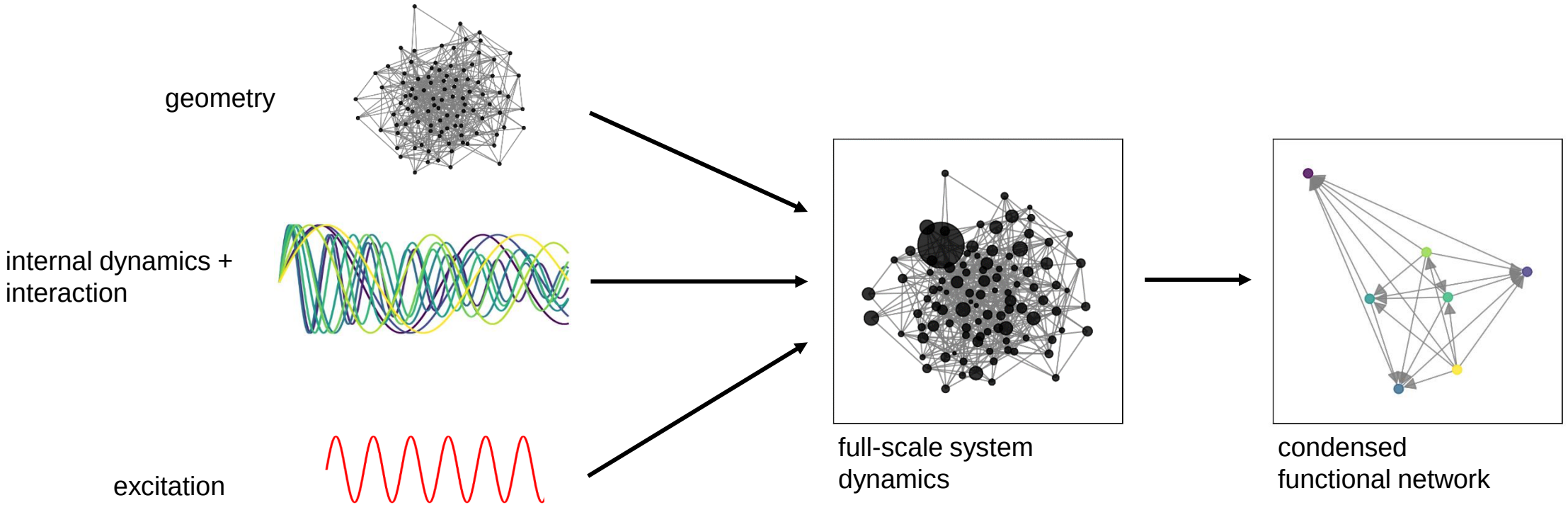




Figure: C. Geier and N. Hoffmann, Exploring localization in nonlinear oscillator systems through network-based predictions. Preprint available at https://arxiv.org/abs/2407.05497

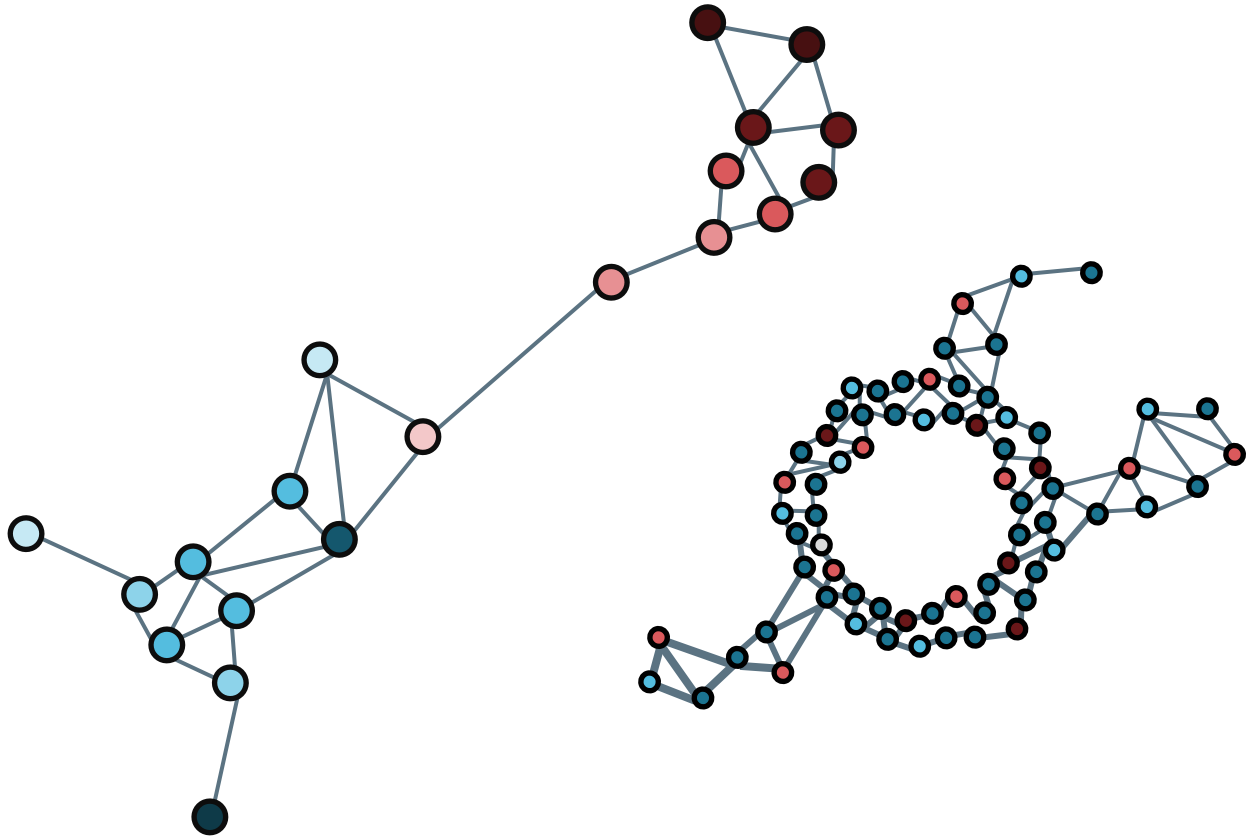
# Larger systems and more complex interactions




- study how the interplay of these components gives rise to the entire system dynamics
- patterns and stability
- focus design and control efforts on most relevant contributor

Figure: C. Geier and N. Hoffmann, Embedding complex dynamics into network topology. Poster at NetSci 2024, Quebec City, Canada.

# Thank you!



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