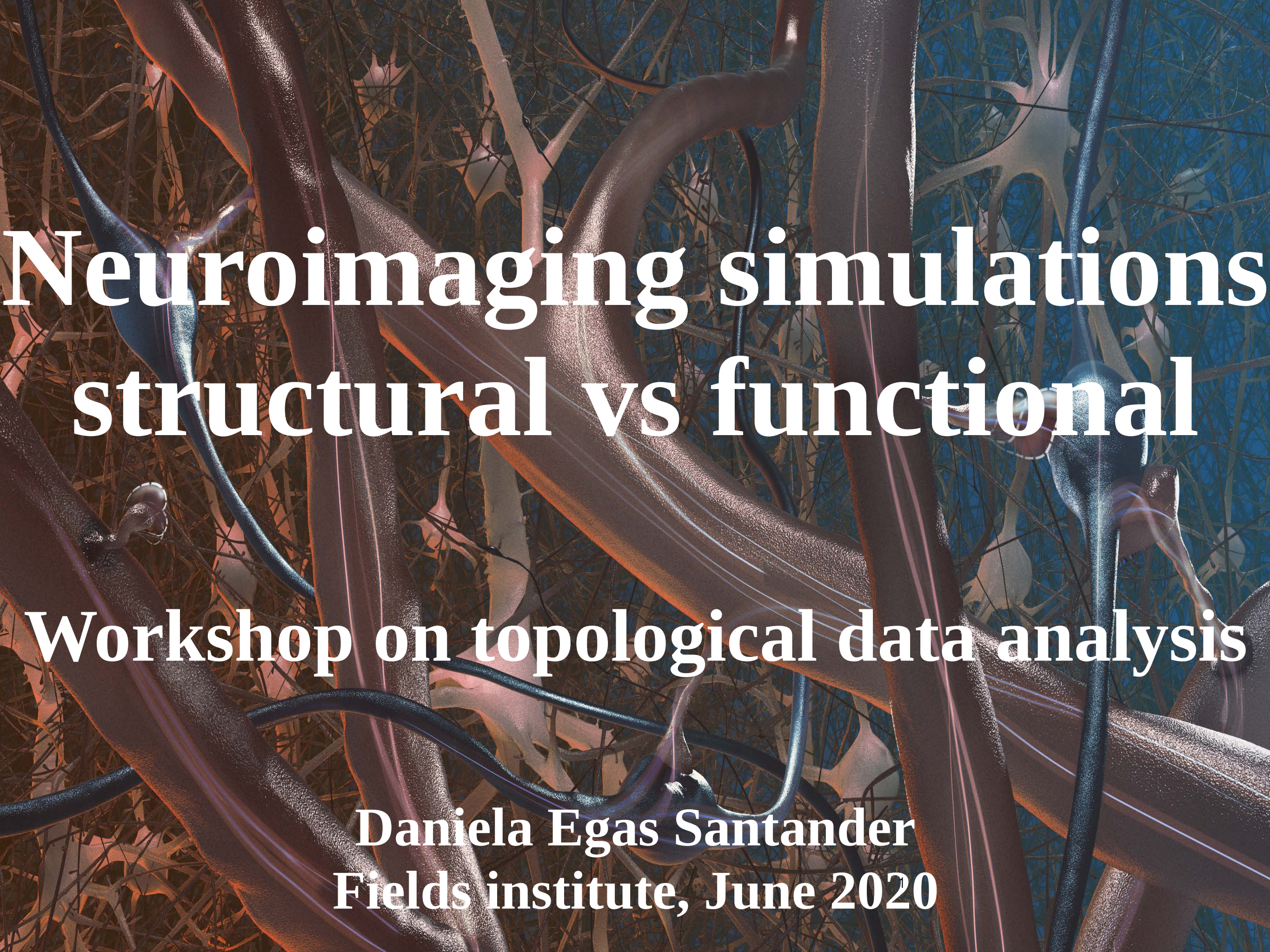




Neuroimaging simulations structural vs functional

Workshop on topological data analysis

Daniela Egas Santander
Fields institute, June 2020

Collaborators

Henry Markram, Taylor Newton, Max Nolte, and Michael Reimann
(Blue Brain Project, EPFL)

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Smith (Aberdeen)

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Spreeman (Laboratory for Topology and Neuroscience, EPFL)

Nicolas Antille and Jonas Karlsson (visualization)

Biological neural networks

Neural systems



Networks



Structural networks

Physical/material

Functional networks

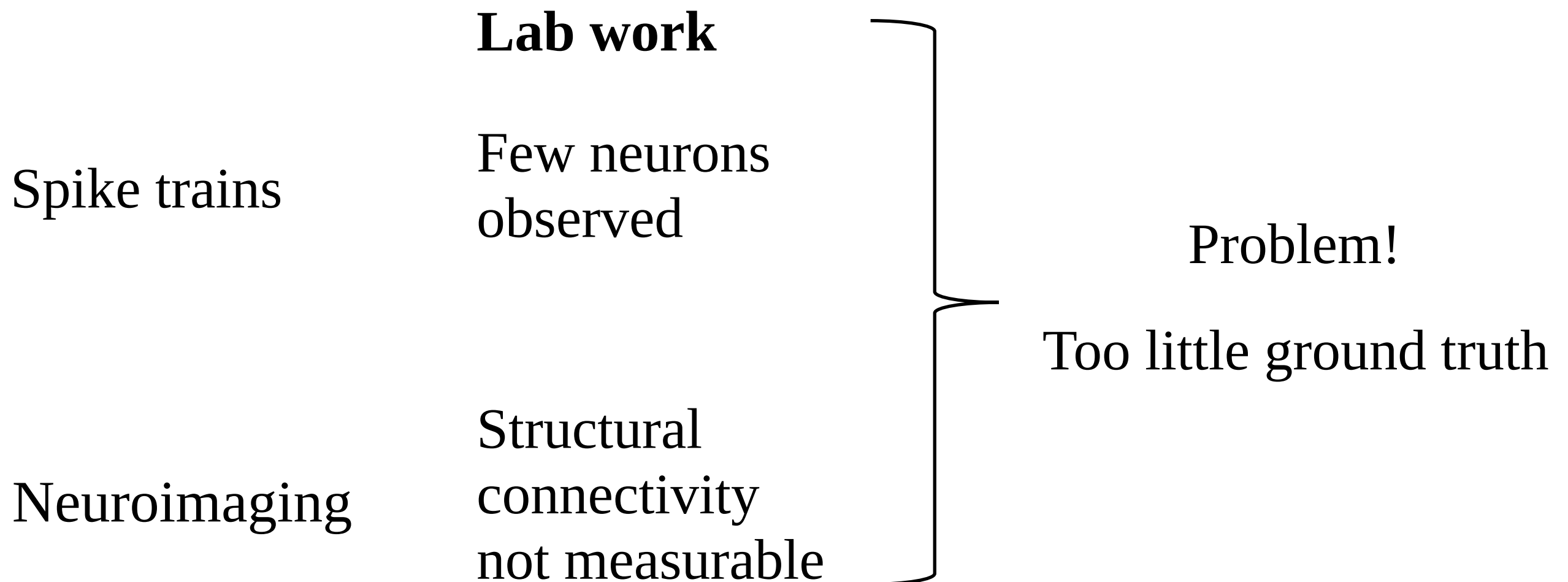
Statistical: (generalized)
correlations between time series

- Spike trains
- Neuroimaging (fMRI, VSD, calcium imaging)

Today → **explore connections**

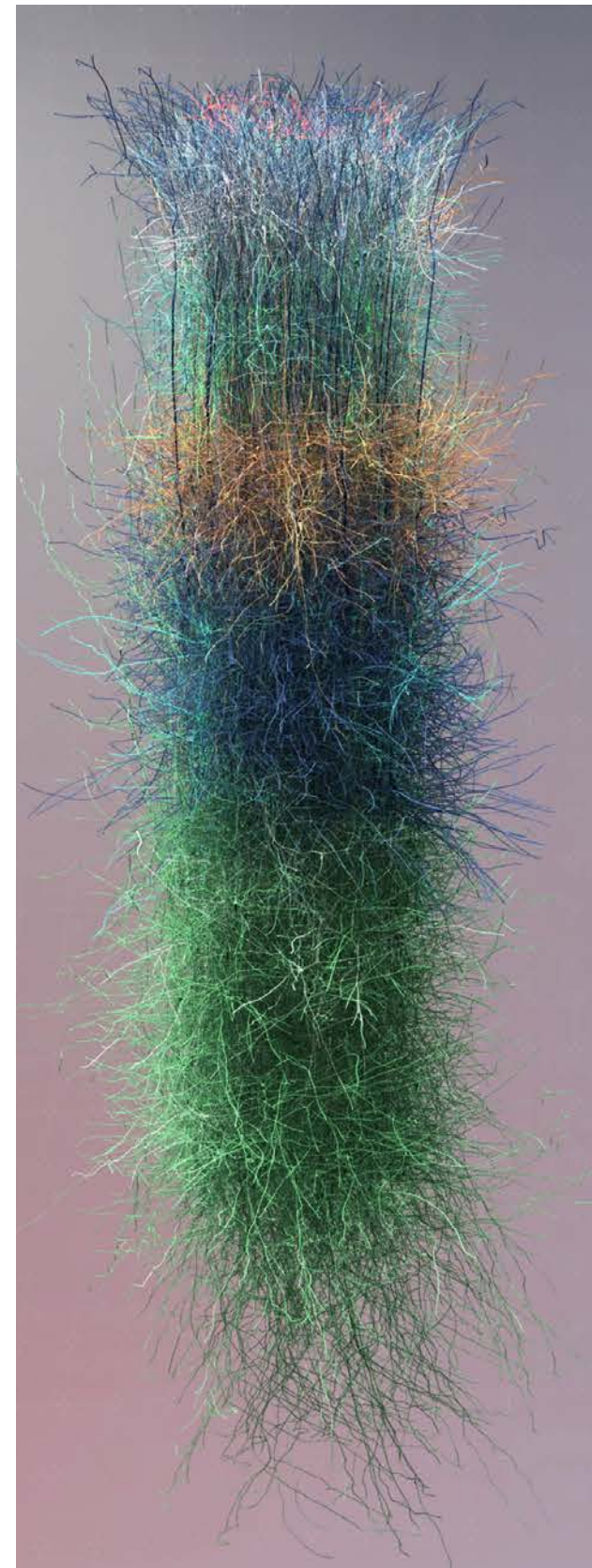
Estimated connectivity

- Functional connectivity $\longrightarrow$ increasingly popular
- Question: High correlations $\longrightarrow$ neural communication?
- “ **Structure shapes function**” $\longrightarrow$ **how?**



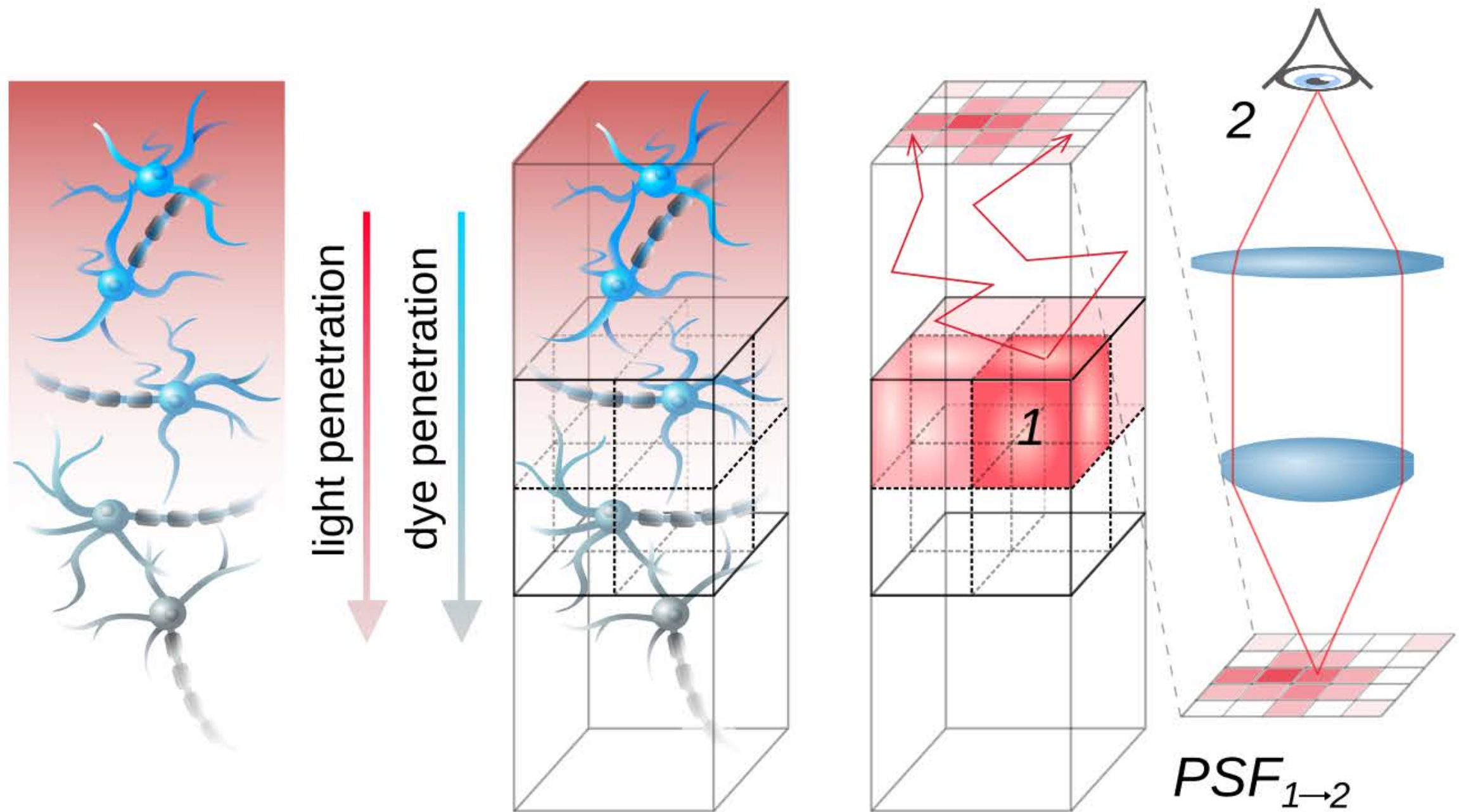
The Blue Brain Microcircuit

- Digital reconstruction of the somatosensory cortex of a rat
- ~ 31 000 neurons
- ~ 8 million synaptic connections
- Numerous experiments in the lab digitally reproduced, without parameter tuning



Voltage Sensitive Dye (VSD)

Taylor Newton (BBP)

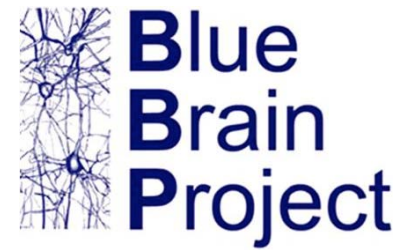


microcircuit

voxelization

point spread

The Blue Brain as a digital laboratory



Lab work

Spike trains

Few neurons
observed

Neuroimaging

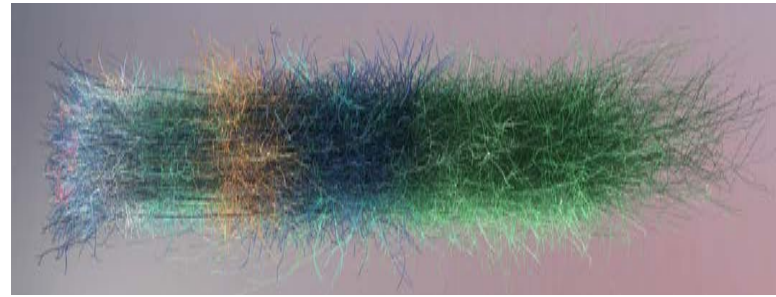
Structural
connectivity
not measurable

BBP

~30K neurons
observed

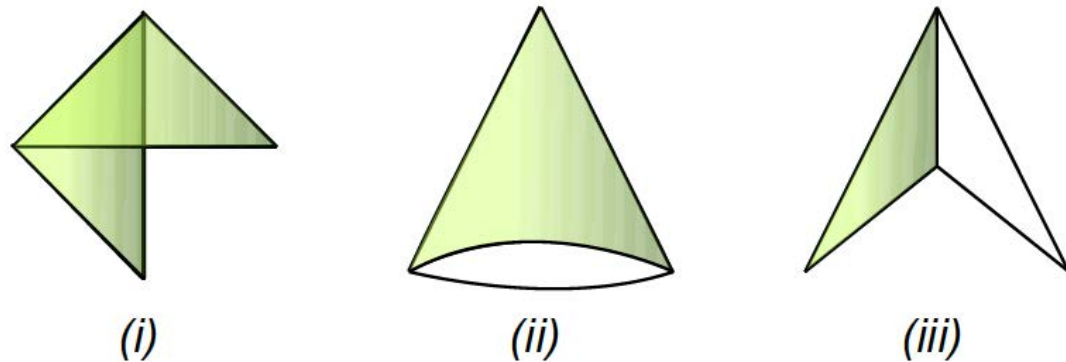
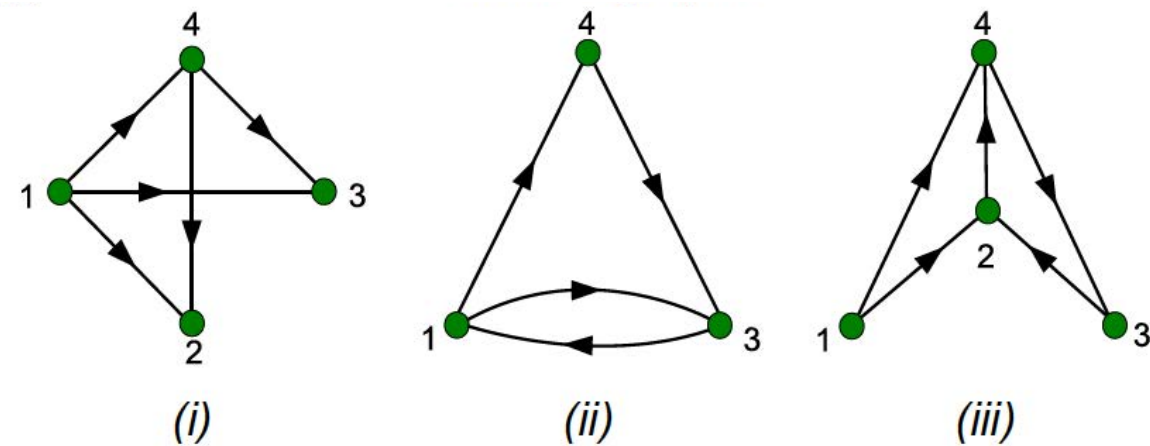
Structural
network is
known

From microcircuits to topology

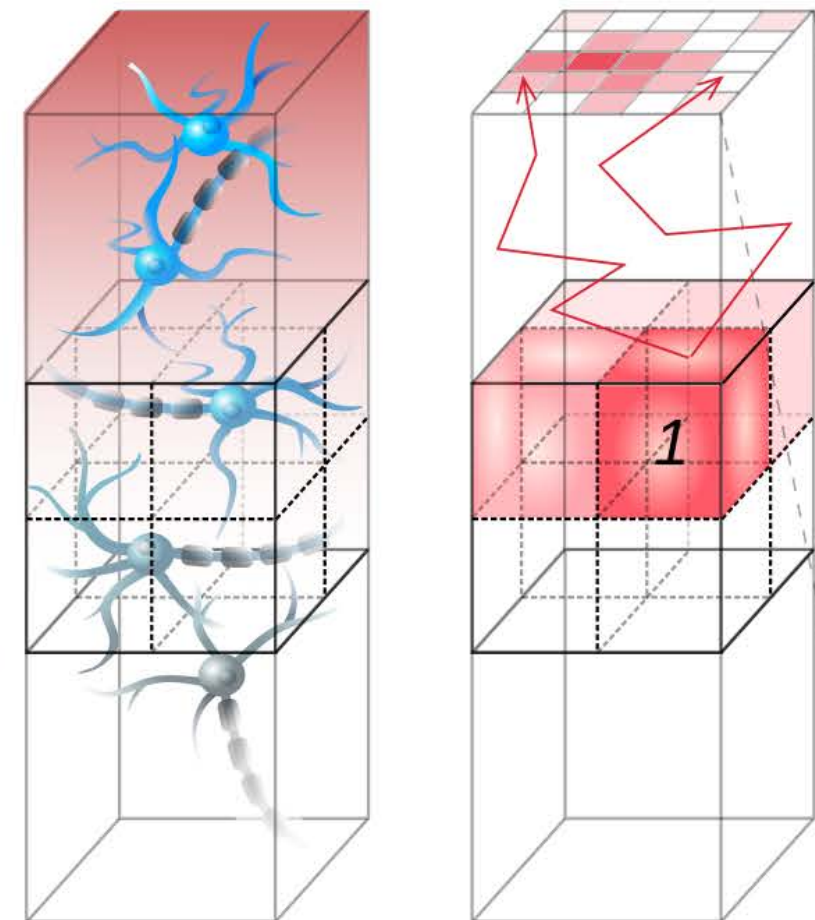


Structural
microcircuit

Functional
VSD



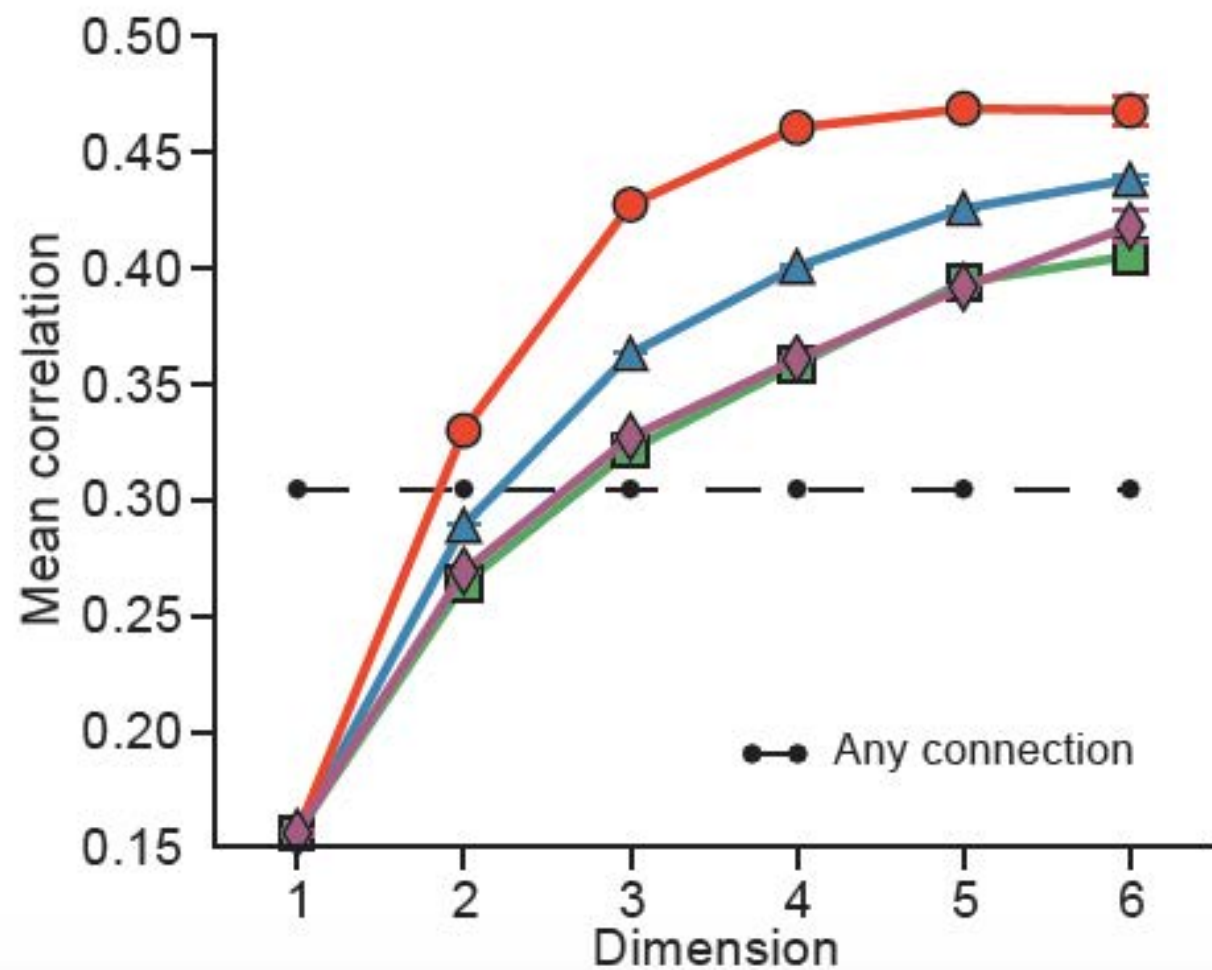
Directed Flag Complex



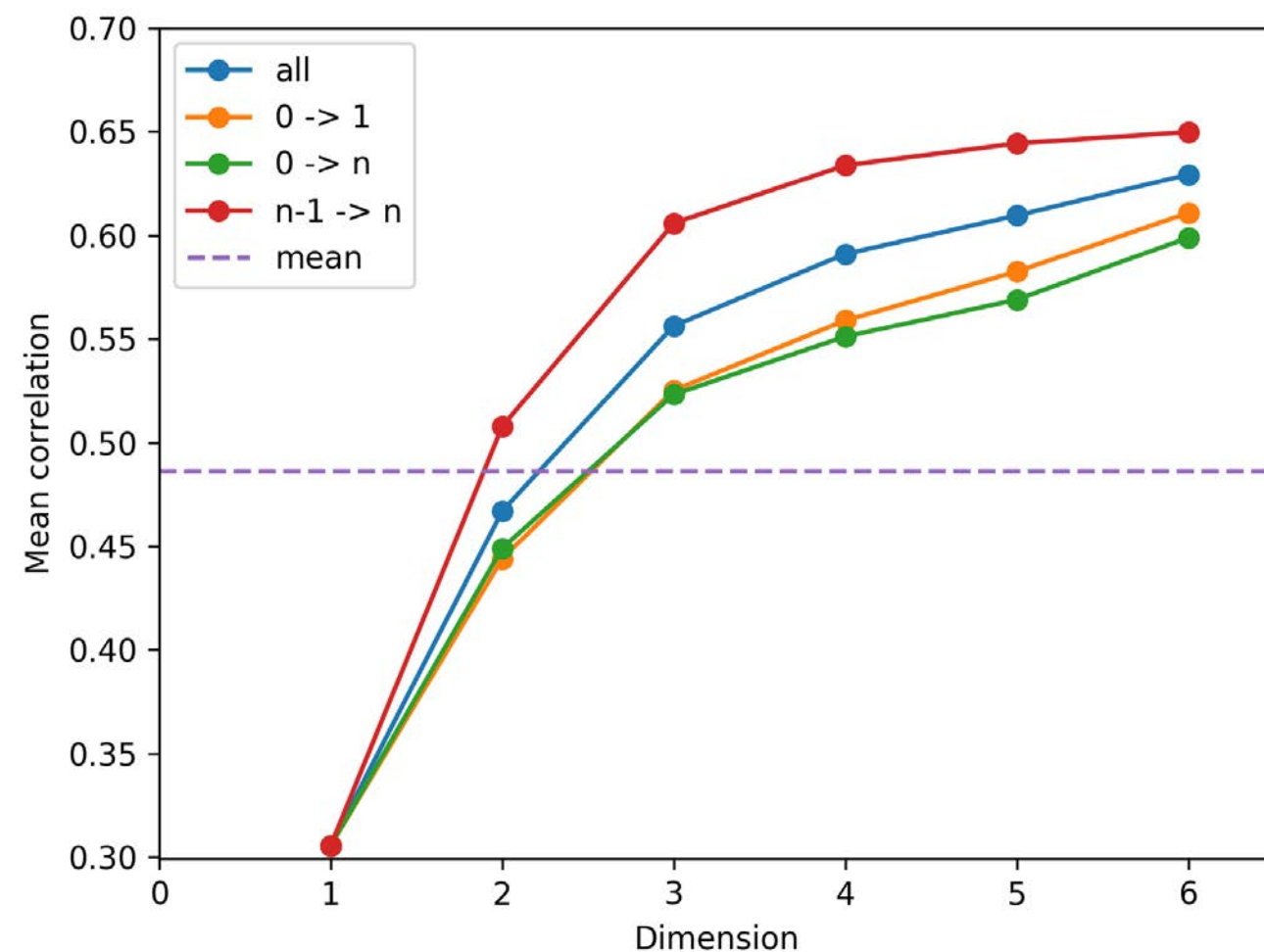
2D/3D -Filtered cubical complex ₈

Structure shapes function

Neurons belonging to high dimensional simplices have:

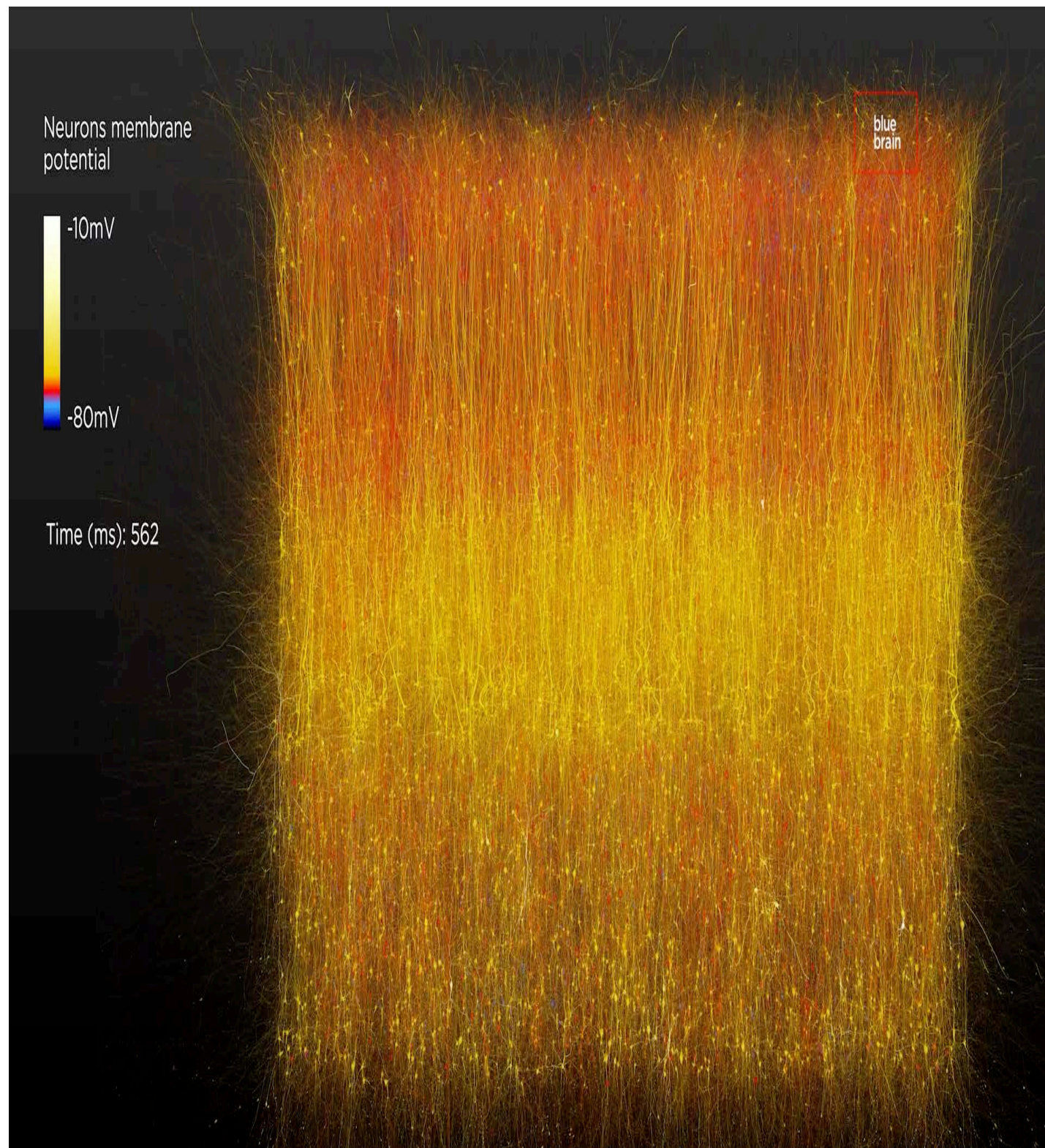


high spiking correlation



high VSD correlation

Studying activity



Transmission-response
graphs



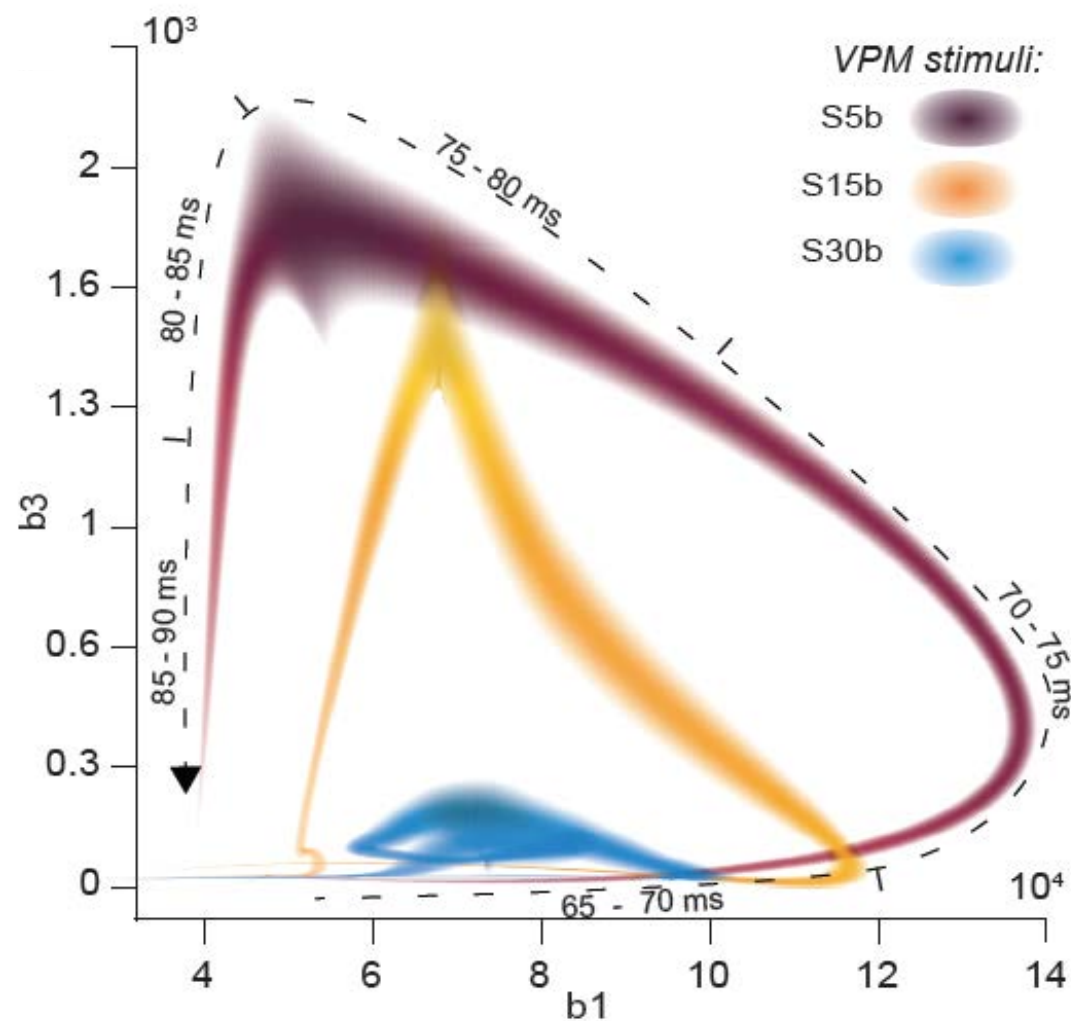
Time series



Filtrations of a
cubical complex

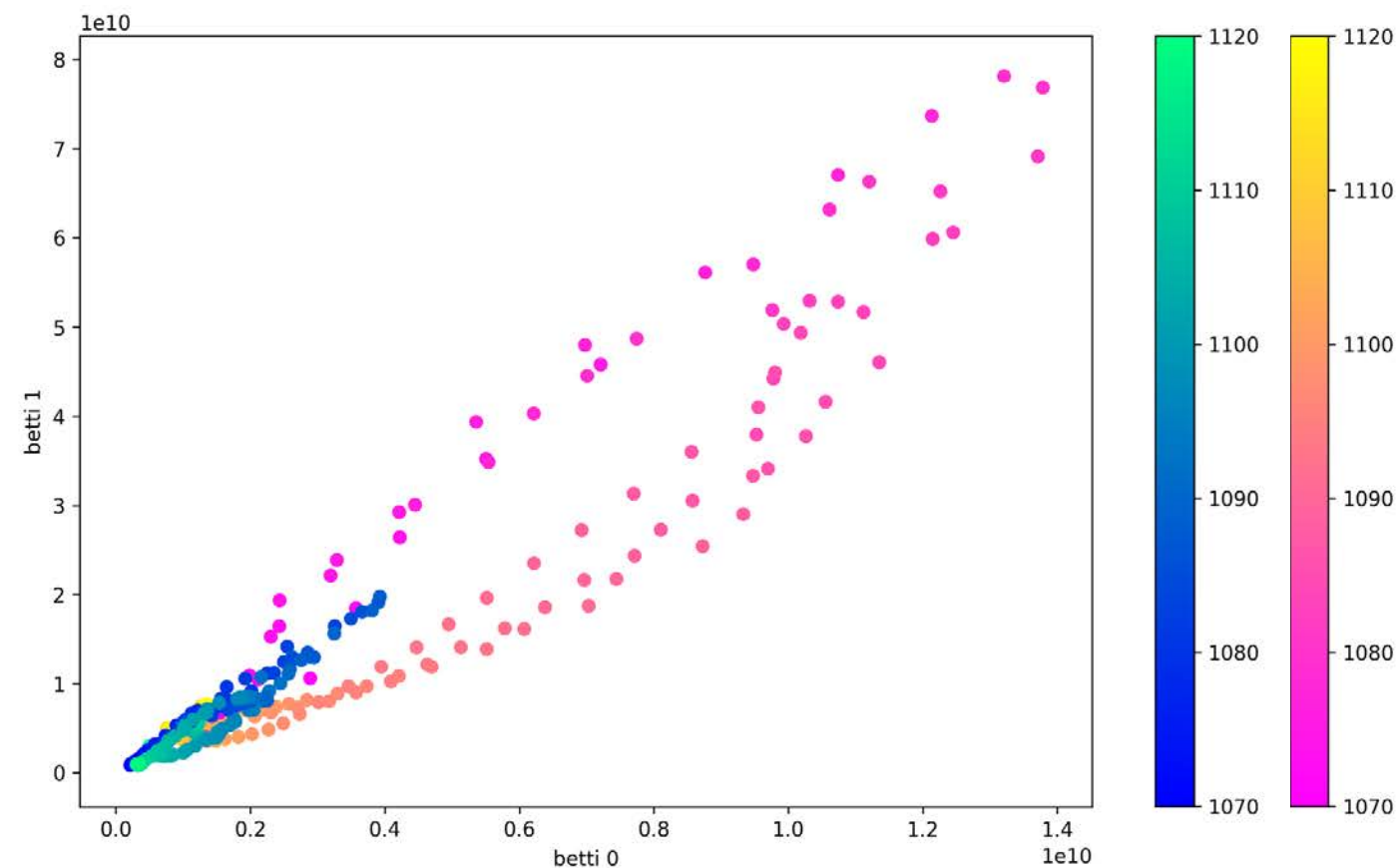
Topological signatures of activity

Structural



Homological signature
of spiking activity

Functional



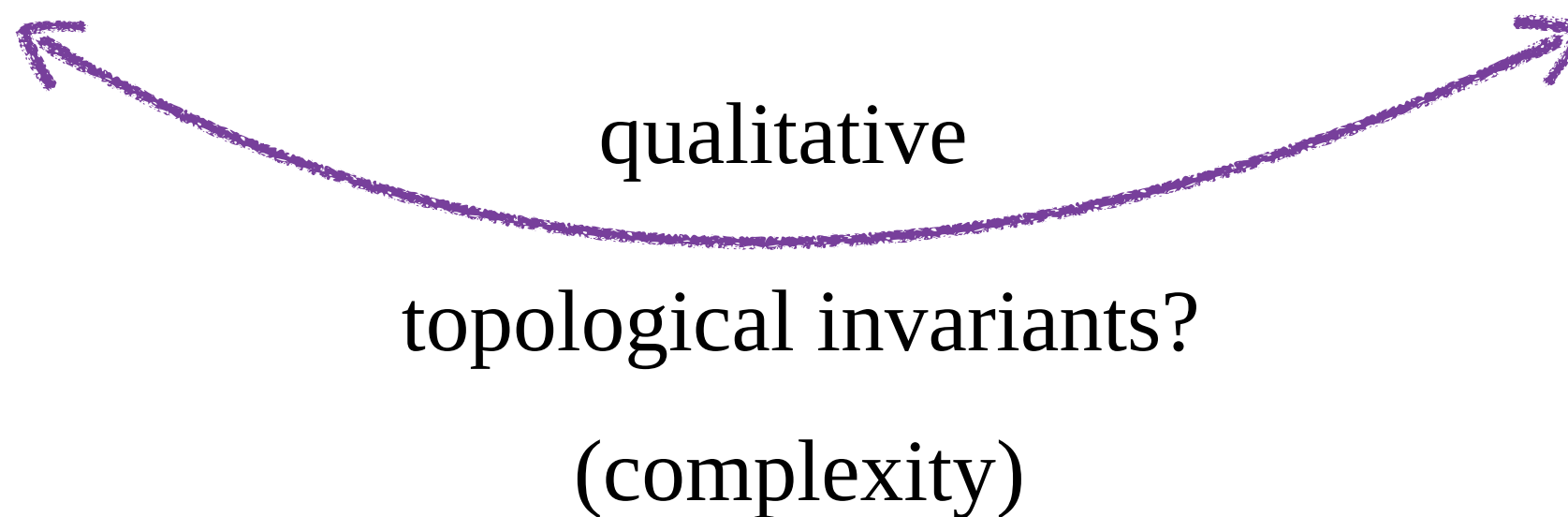
Persistence signature of
imaging activity

Functional and structural connectivity

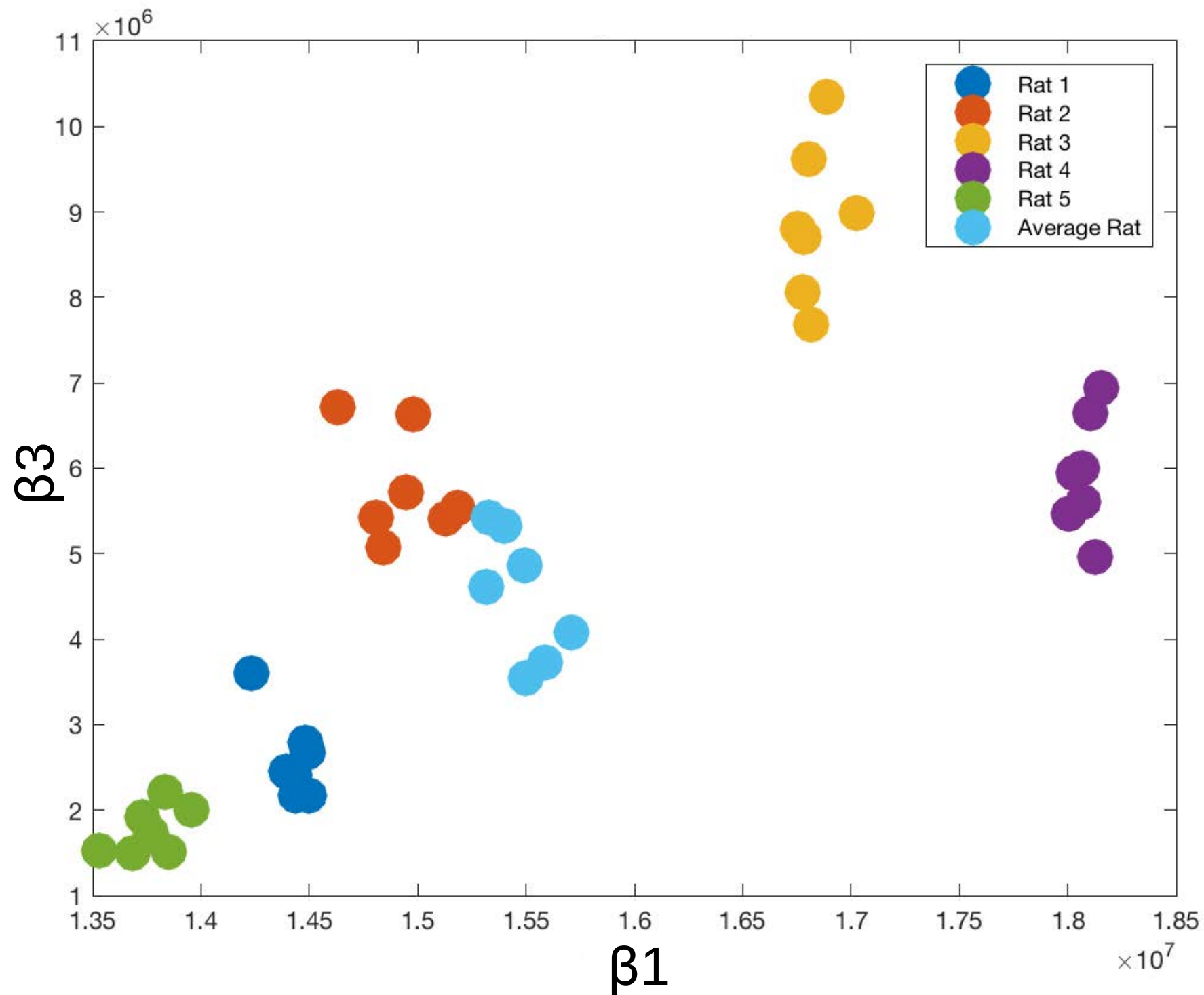
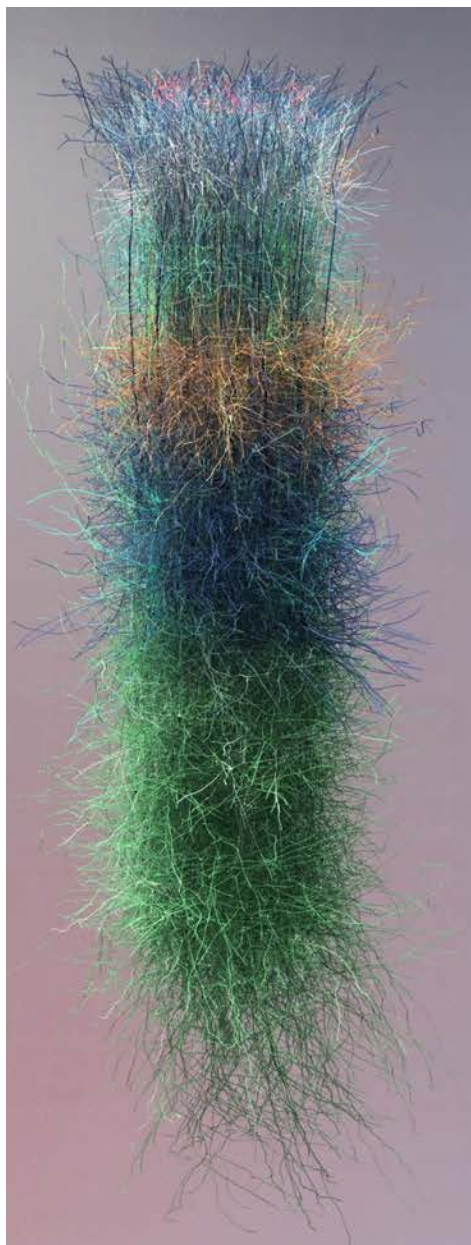
- Functional connectivity $\neq$ neural communication

- “Structure shapes function”
 - Spike trains
 - VSD data

- Structural microcircuit Functional microcircuit

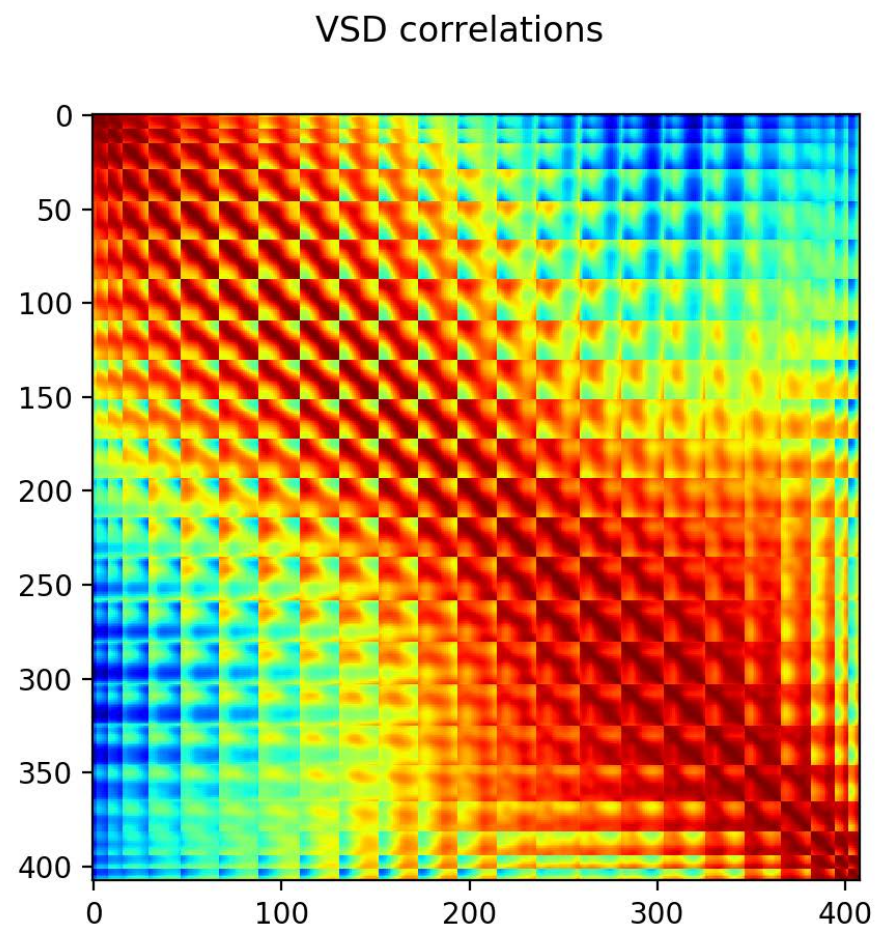


Structure of the brain



<https://github.com/luetge/flagser>

Functional connectomes and smoothness



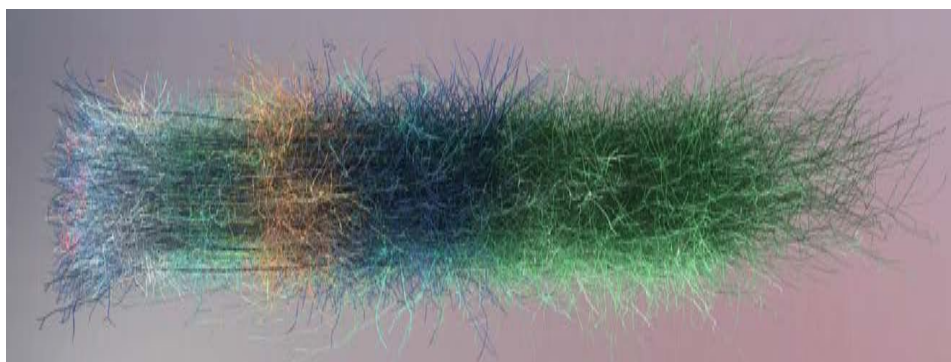
Thresholding
→
Persistence

Functional
connectome

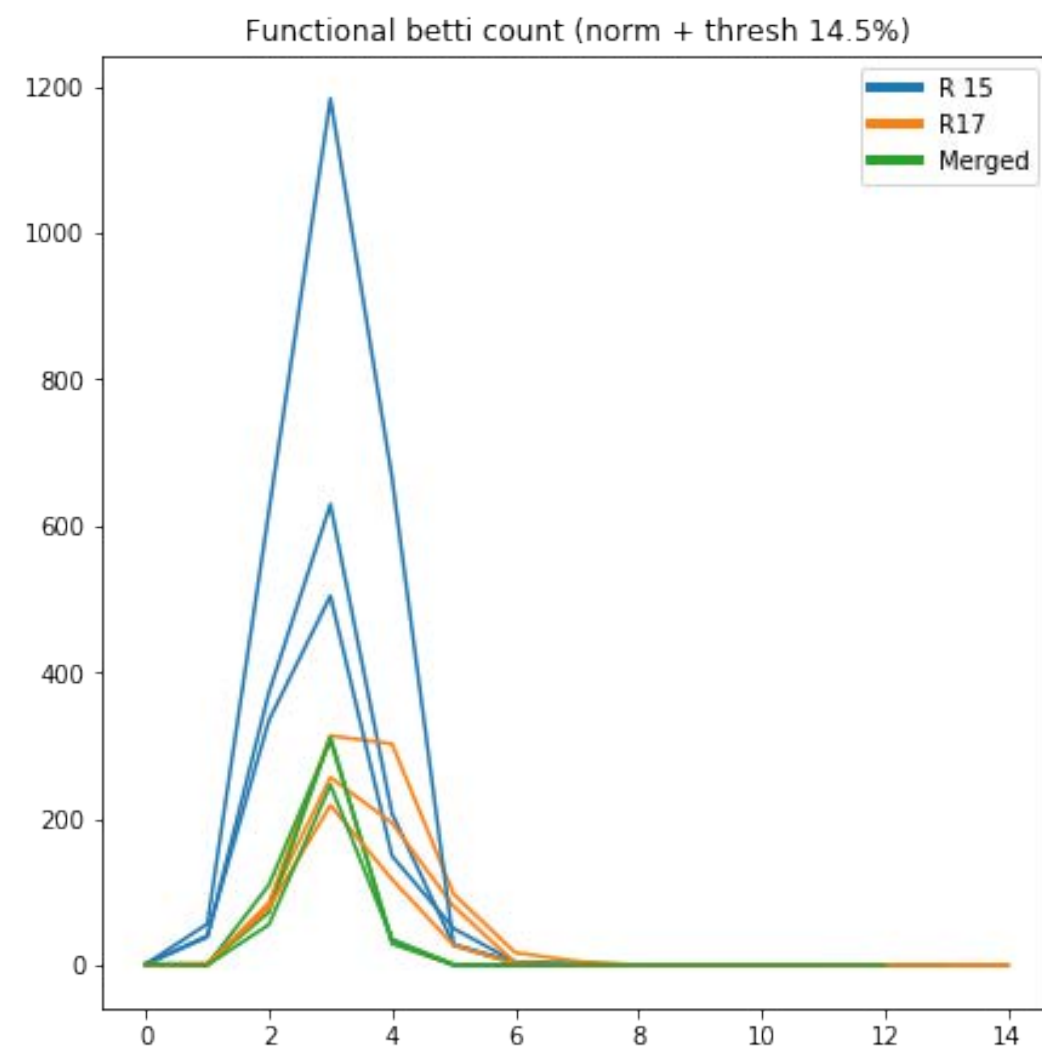
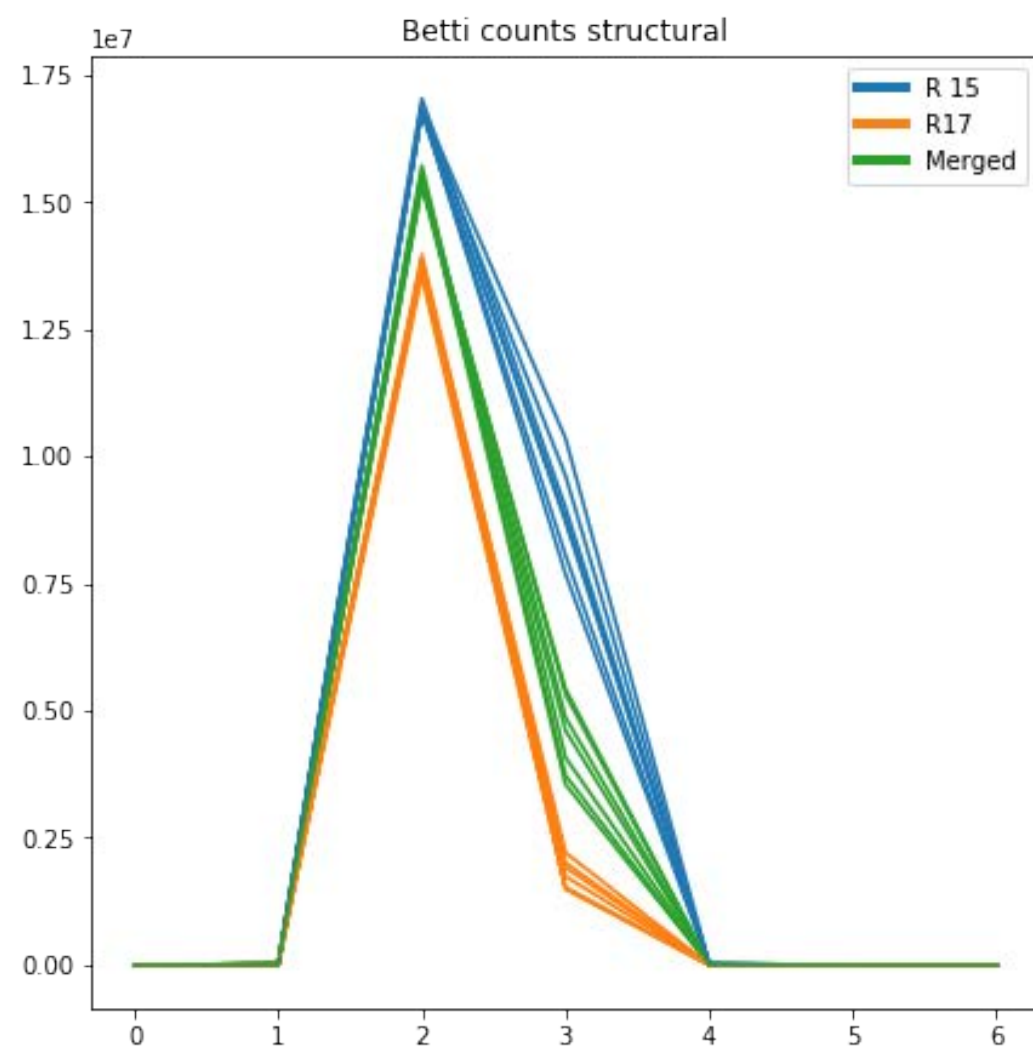
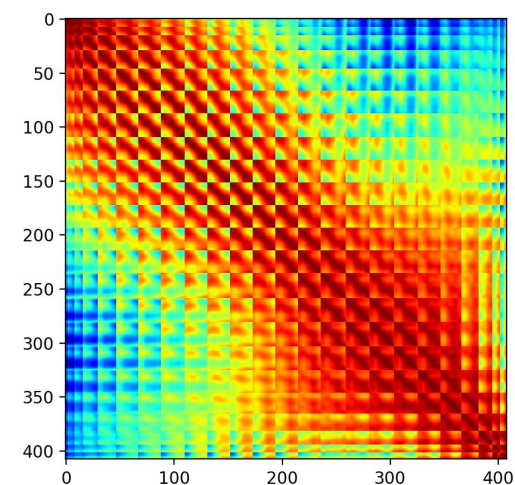
- How to see more than just close neighbours?
- How to detect surprisingly high correlations?

Semi-naive thresholding

Structural



Functional



Summary

- Structure shapes function:
 1. Correlations and structural graph
 2. Structural and functional swooshes
 3. Functional and structural microcircuits (in progress)

Perspectives

- Robust methods for thresholding or correcting distance dependence
- Finite cubical complexes with random filtration
- Statistical methods for the construction of random directed graphs with fixed simplex counts