

Lecture 2.4

Connectome spectral analysis

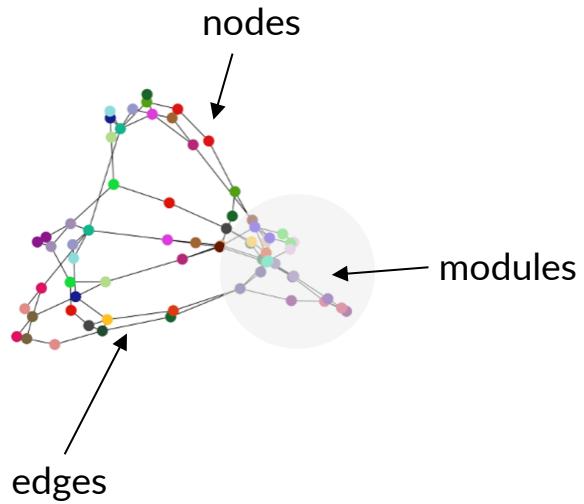
Katharina Glomb

Postdoc, Section Brain Simulation
Charite, Berlin

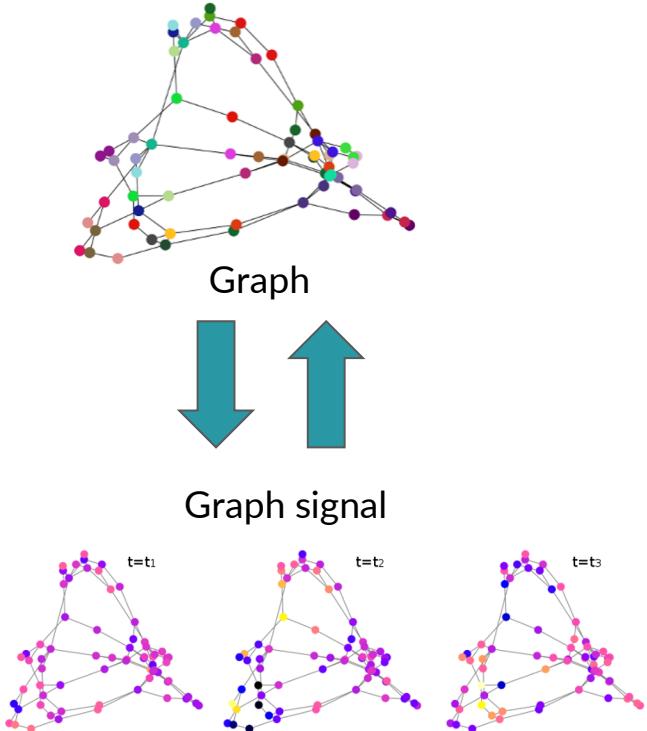


Brain Communication Pathways
Sinergia Consortium
Swiss National Science Foundation

Graph signal processing

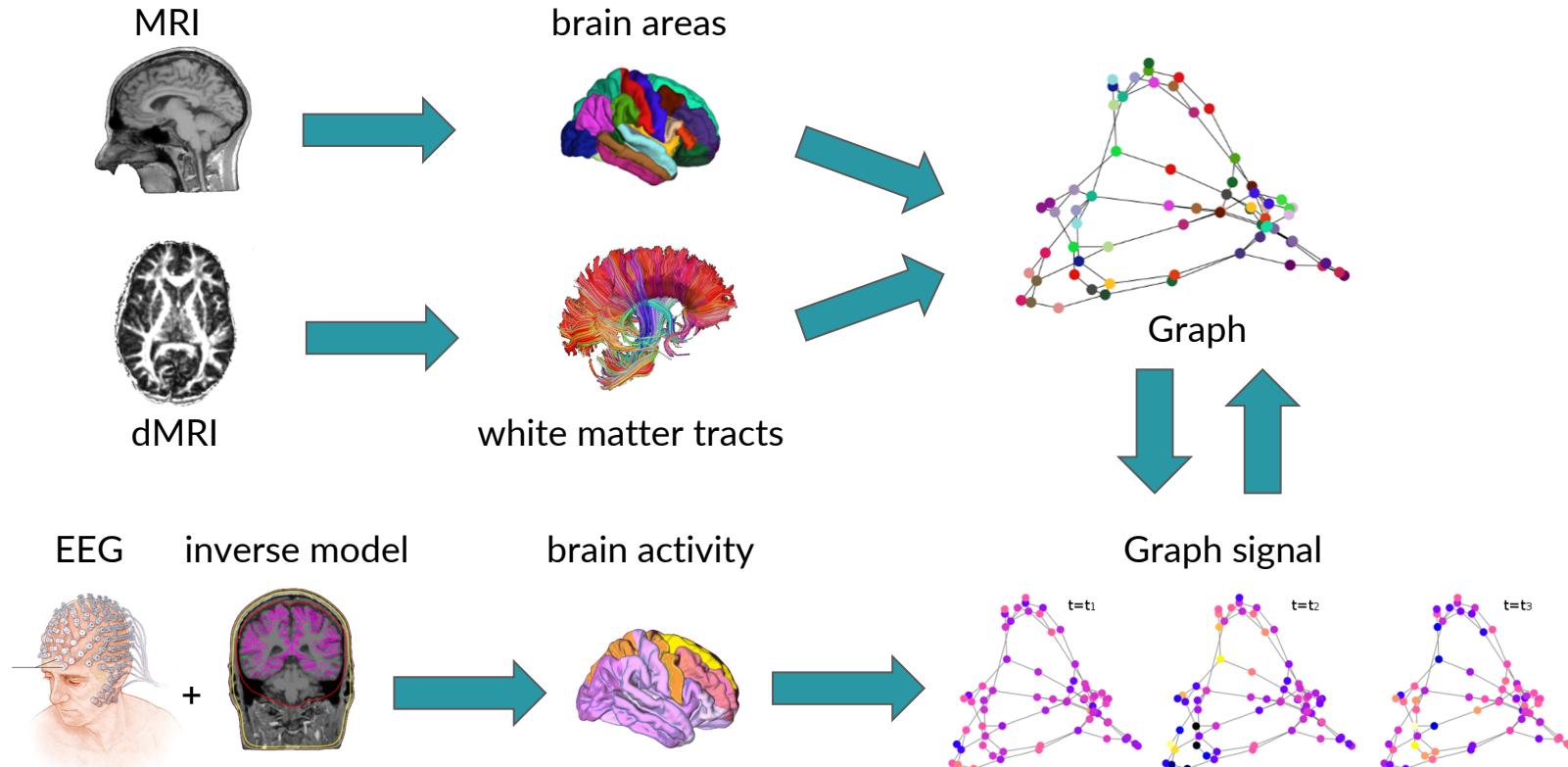


Graph signal processing

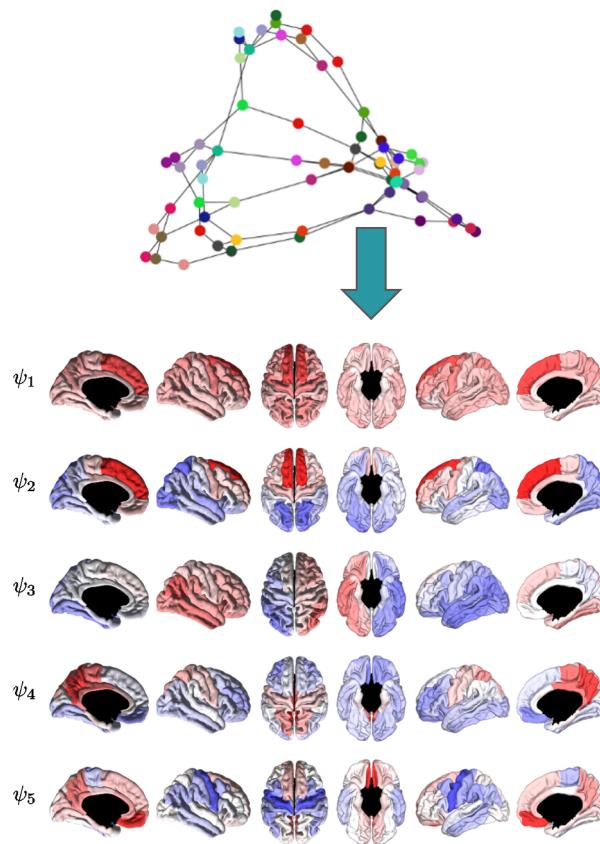
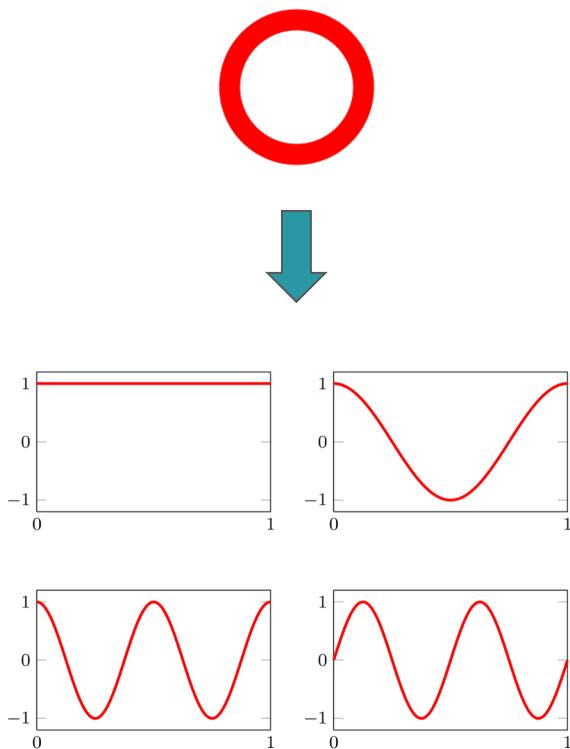


→ signal processing on the graph:
Graph Signal Processing

Graph signal processing



Graph signal processing



Fourier basis
functions =
“harmonic modes”
(a.k.a. *connectome harmonics*)

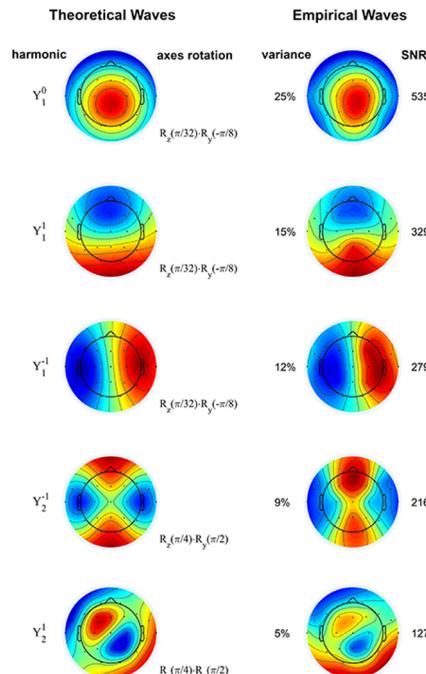
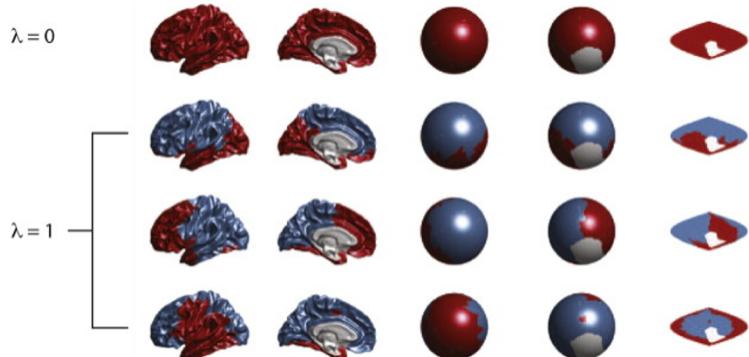
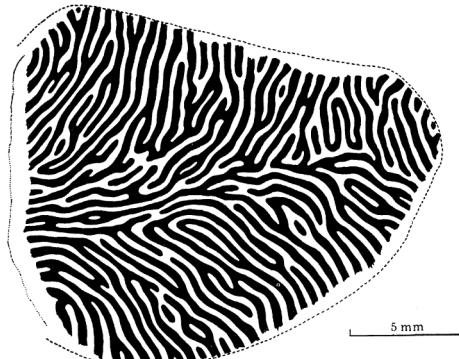


Harmonic modes - ubiquitous in nature



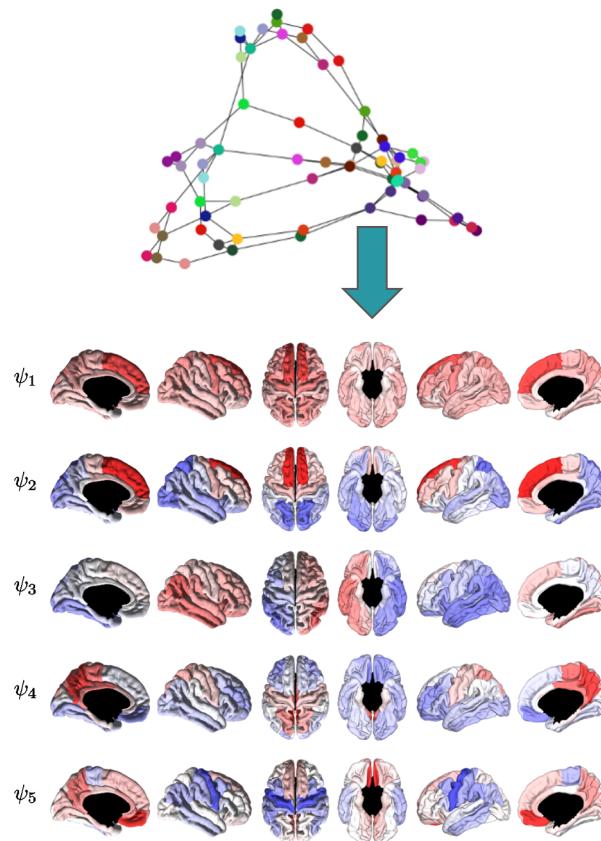
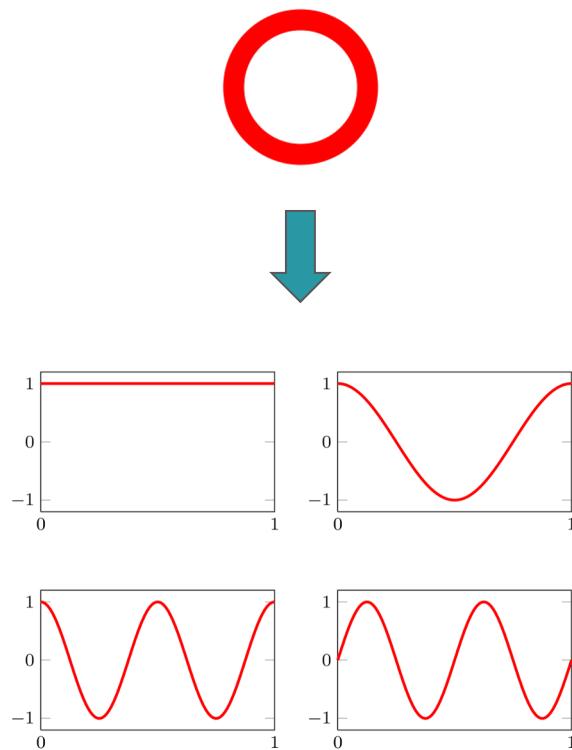
- 1 Liu, ysjournal, 2017
- 2 Matemateca (IME/USP)/Rodrigo Tetsuo Argenton
- 3 Murray et al., Sci Am, 1988

Harmonic modes - ubiquitous in nature



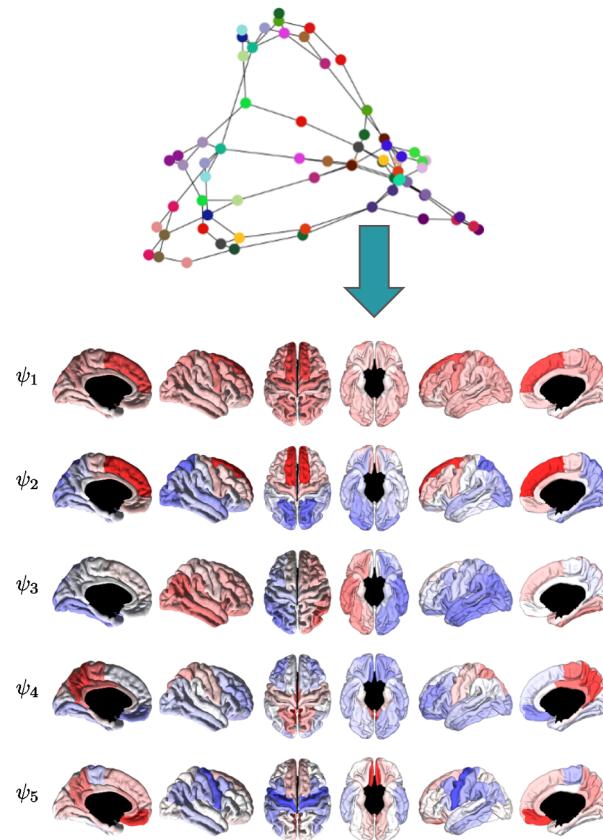
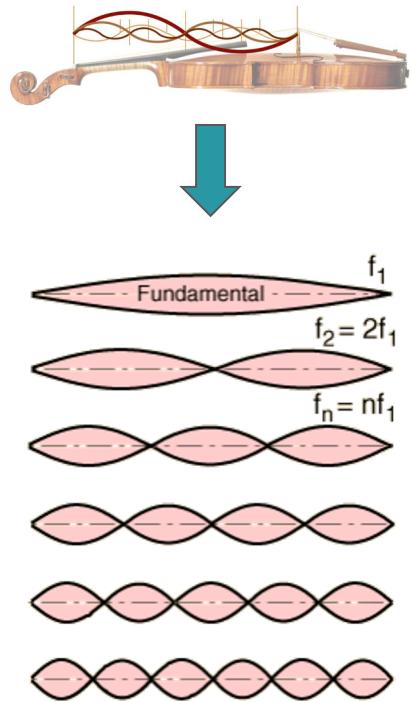
1 Swindale, Proc Roy Soc B, 1980
2 Robinson et al., NIMG, 2016
3 Sivamuktar et al., Front Comp Neurosci, 2016

Harmonic modes - ubiquitous in nature



harmonic modes
are a tool...

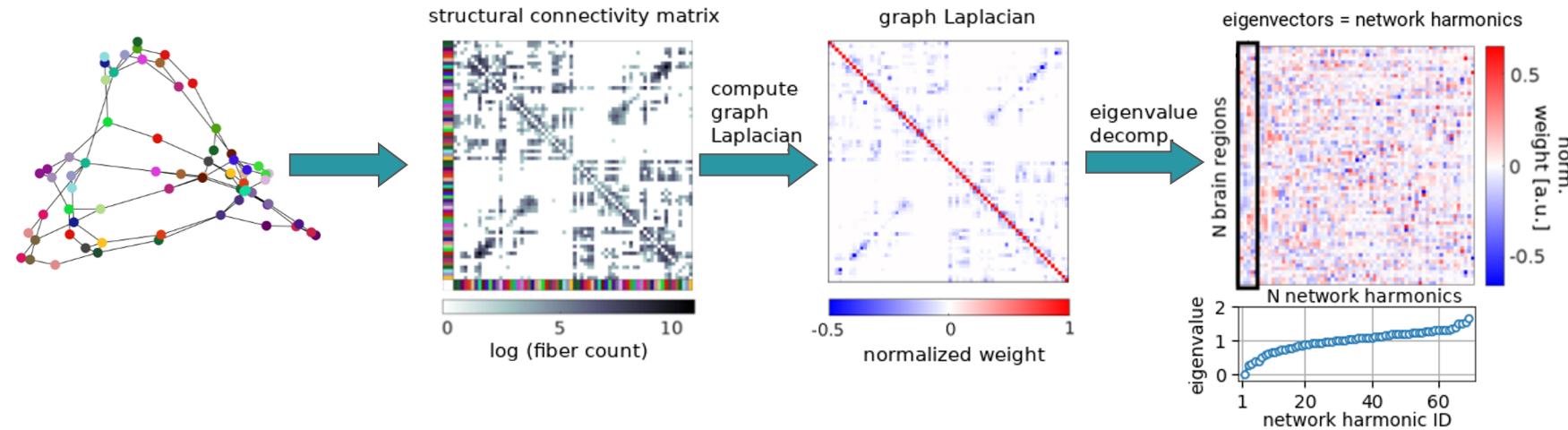
Harmonic modes - ubiquitous in nature



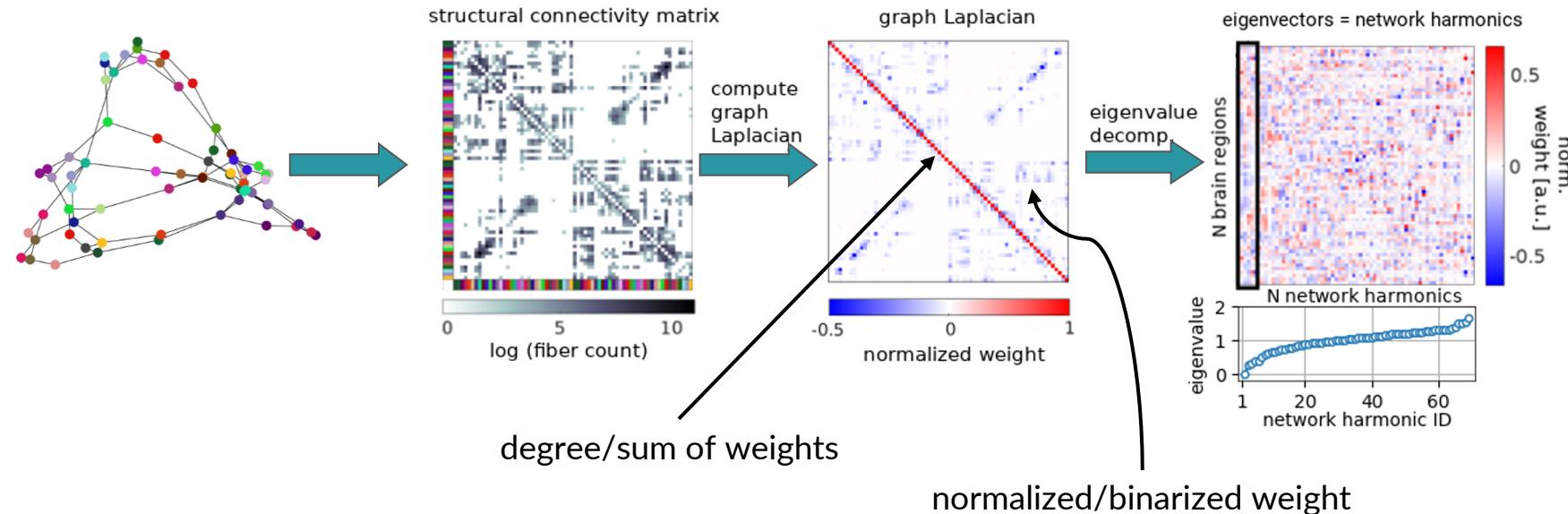
...but harmonic modes also link the brain with other phenomena in nature



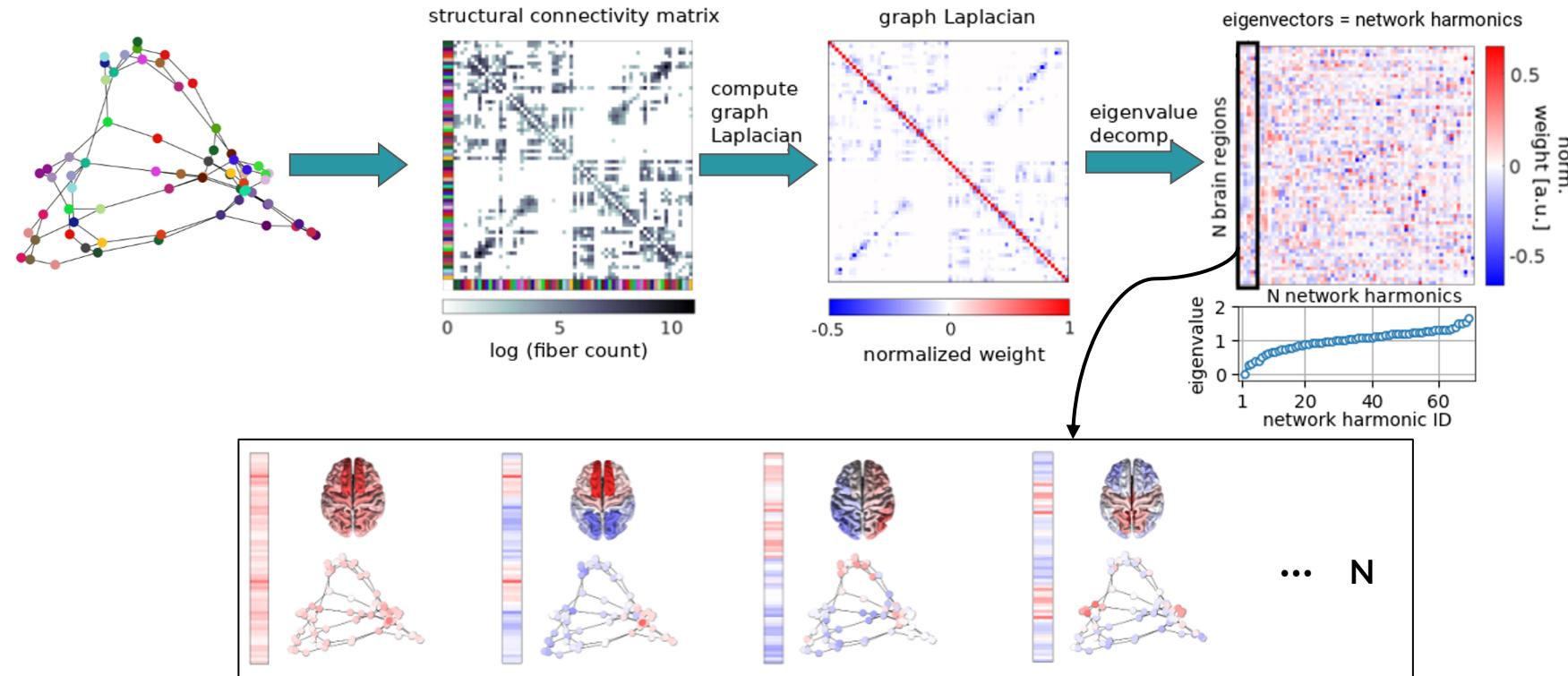
Spectral analysis on the graph



Spectral analysis on the graph



Spectral analysis on the graph



Spectral analysis on the graph

- each graph has its own set of harmonic modes

Spectral analysis on the graph

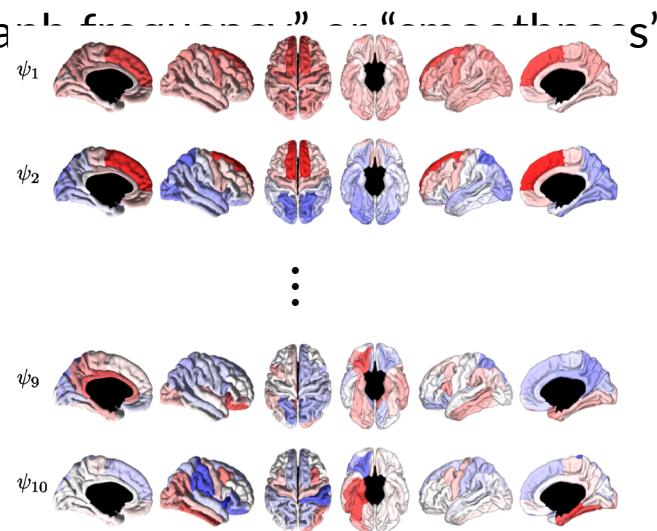
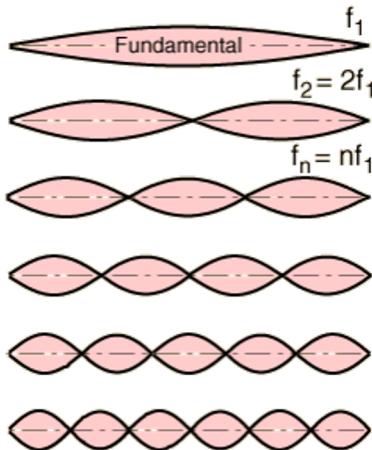
- each graph has its own set of harmonic modes
- there are as many harmonic modes as there are brain regions
(→eigendecomp.)

Spectral analysis on the graph

- each graph has its own set of harmonic modes
- there are as many harmonic modes as there are brain regions
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- they are ordered by “graph frequency” or “smoothness”

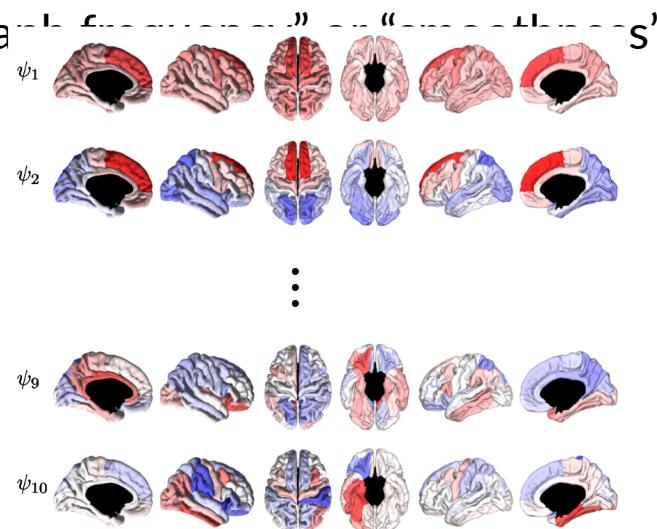
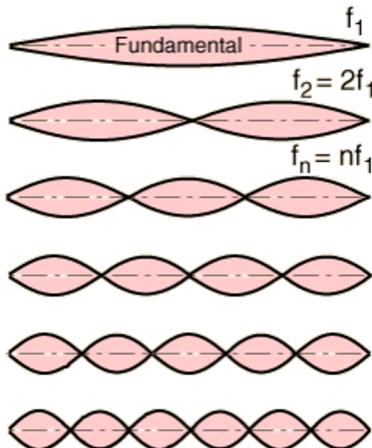
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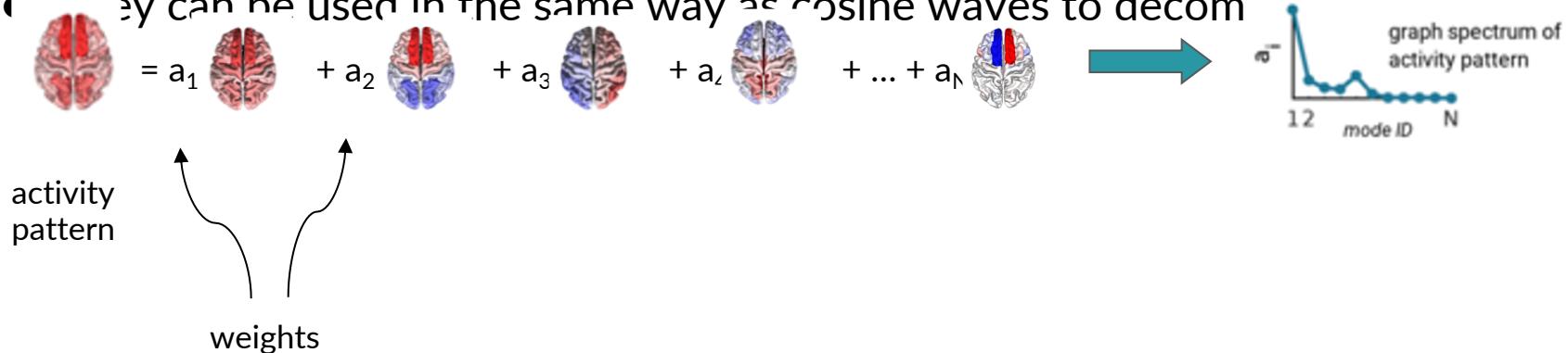
→ hierarchical
and multiscale
networks!

Spectral analysis on the graph

- each graph has its own set of harmonic modes
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- they are ordered by “graph frequency” or “smoothness”
- they can be used in the same way as cosine waves to decompose a signal

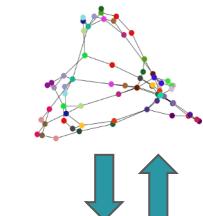
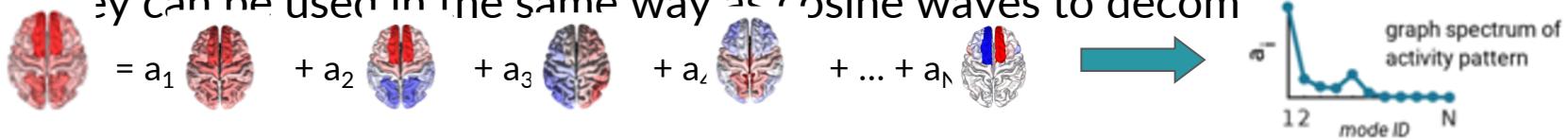
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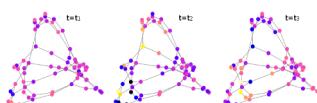


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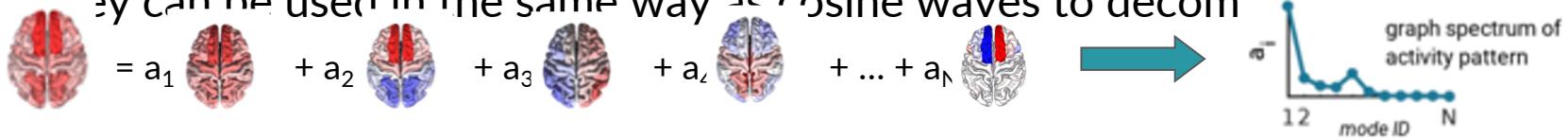


- activity pattern = graph signal
- harmonic modes = building blocks from graph



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→ multimodal



Summary

1. Brain data can be seen as a signal evolving on a graph and can be analyzed with graph signal processing
2. Harmonic modes explain self-organized pattern formation in many contexts
3. Harmonic modes are the graph-equivalent to cosine waves in Fourier analysis and are:
 - a. hierarchical
 - b. multiscale
 - c. multimodal

Thank you!!

Here are some references:

1. Rué-Queralt, Joan, et al. "The connectome spectrum as a canonical basis for a sparse representation of fast brain activity." *NeuroImage* 244 (2021): 118611.
2. Glomb, Katharina, et al. "Functional harmonics reveal multi-dimensional basis functions underlying cortical organization." *Cell Reports* 36.8 (2021): 109554.
3. Glomb, Katharina, et al. "Connectome spectral analysis to track EEG task dynamics on a subsecond scale." *NeuroImage* 221 (2020): 117137.
4. Atasoy, Selen, Isaac Donnelly, and Joel Pearson. "Human brain networks function in connectome-specific harmonic waves." *Nature communications* 7.1 (2016): 1-10.