Kiel University
Christian-Albrechts-Universität zu Kiel

A DATA-DRIVEN METHOD TO IDENTIFY FREQUENCY BOUNDARIES IN MULTICHANNEL ELECTROPHYSIOLOGY DATA

| Cohen, Journal of Neuroscience Methods, 2021

StepUp Journal Club

15th February 2023

UNIVERSITÄTSKLINIKUM
Schleswig-Holstein

AUTHOR

Kiel University
Christian-Albrechts-Universität zu Kiel

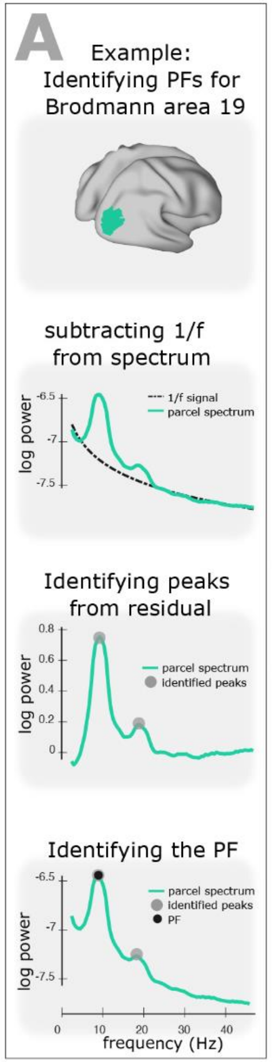
Location	Research Area	H-Index
PI Donders Neuroinformatics	-Theta and cognitive control - LFP & single unit	119 Analyzing neural time series data: theory and practice (~2100)

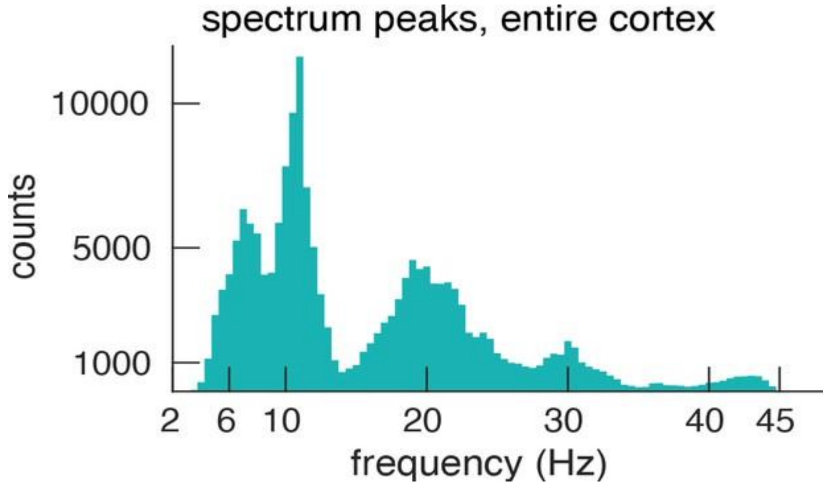
INTRO

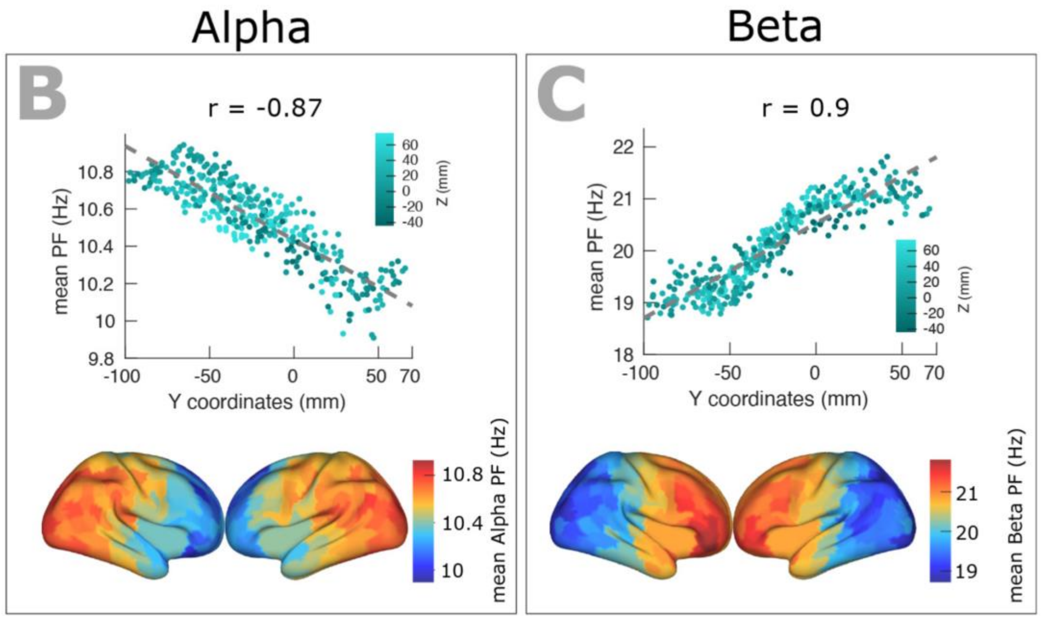
- Methods focused paper
- Define boundaries of frequency bands in multichannel electrophysiological data (e.g. beta)
- Works on individual data

Not covered today:
- Regularization methods
- Clustering in depth

FREQUENCY BANDS



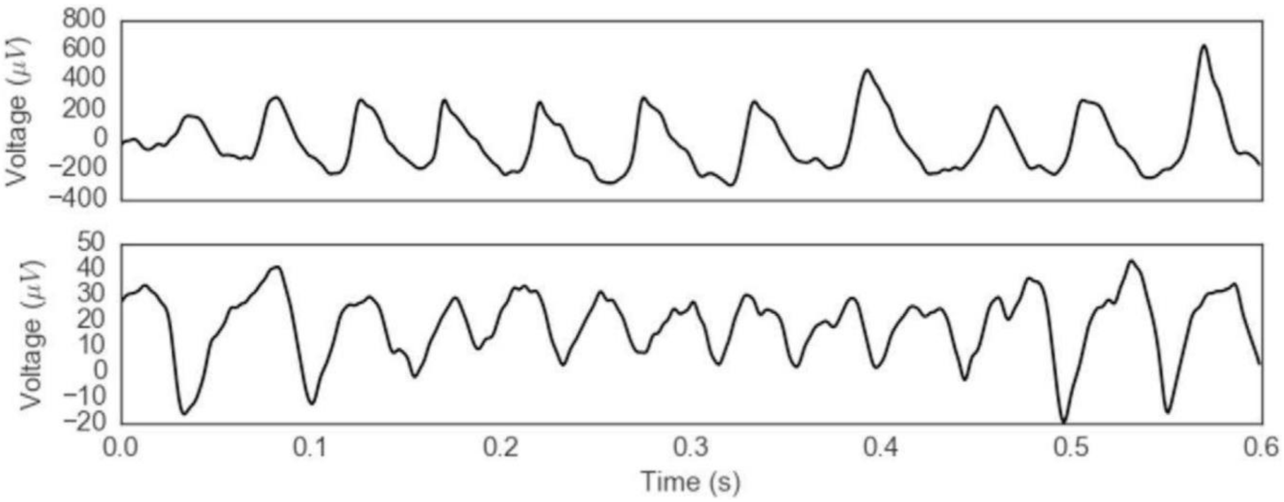




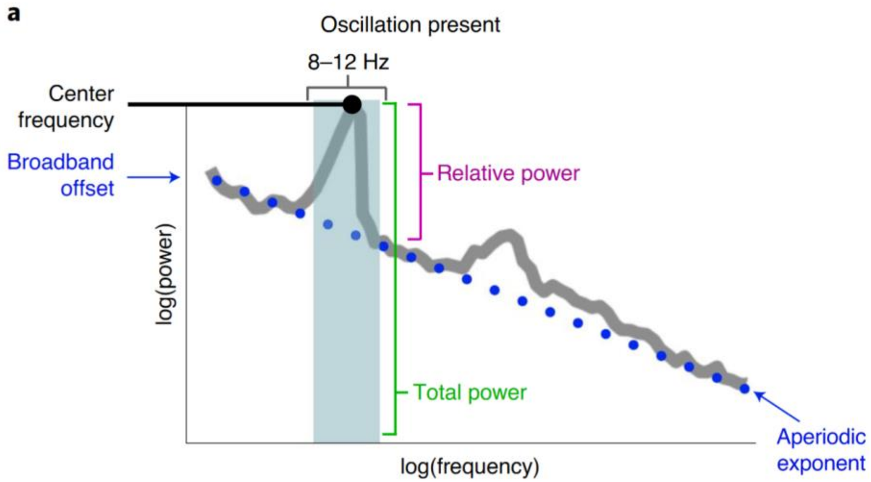
Mahjoory ea., *eLife*, 2020

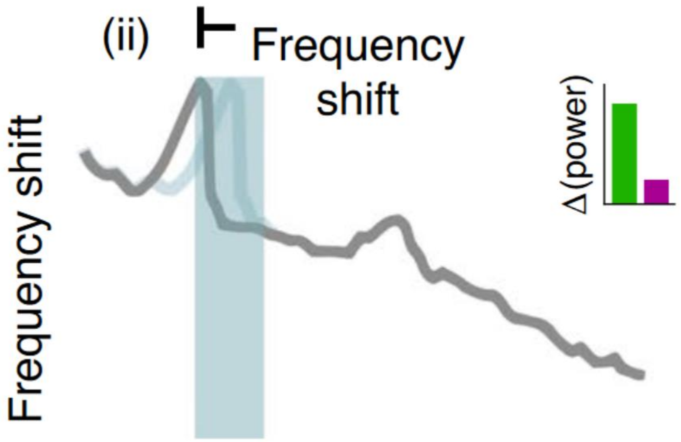
MOTIVATION

"[...] existing methods of empirically detecting frequencies rely on the peaks, typically from individual channels [...]"



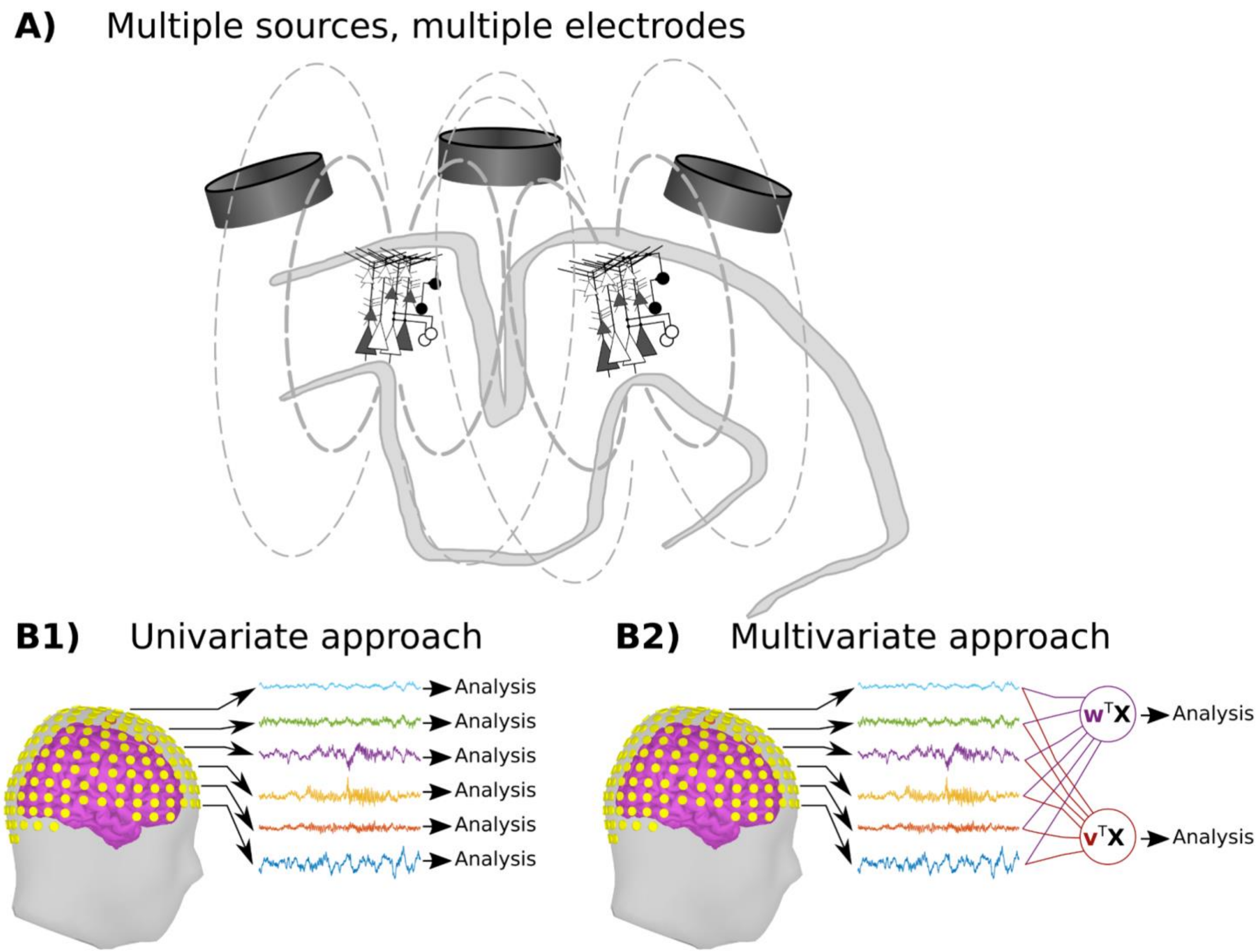
https://bycycle-tools.github.io/bycycle/index.html





Cole ea., J.Neuroscience, 2017; Donoghue ea., *Nature Neuroscience*, 2020

MOTIVATION

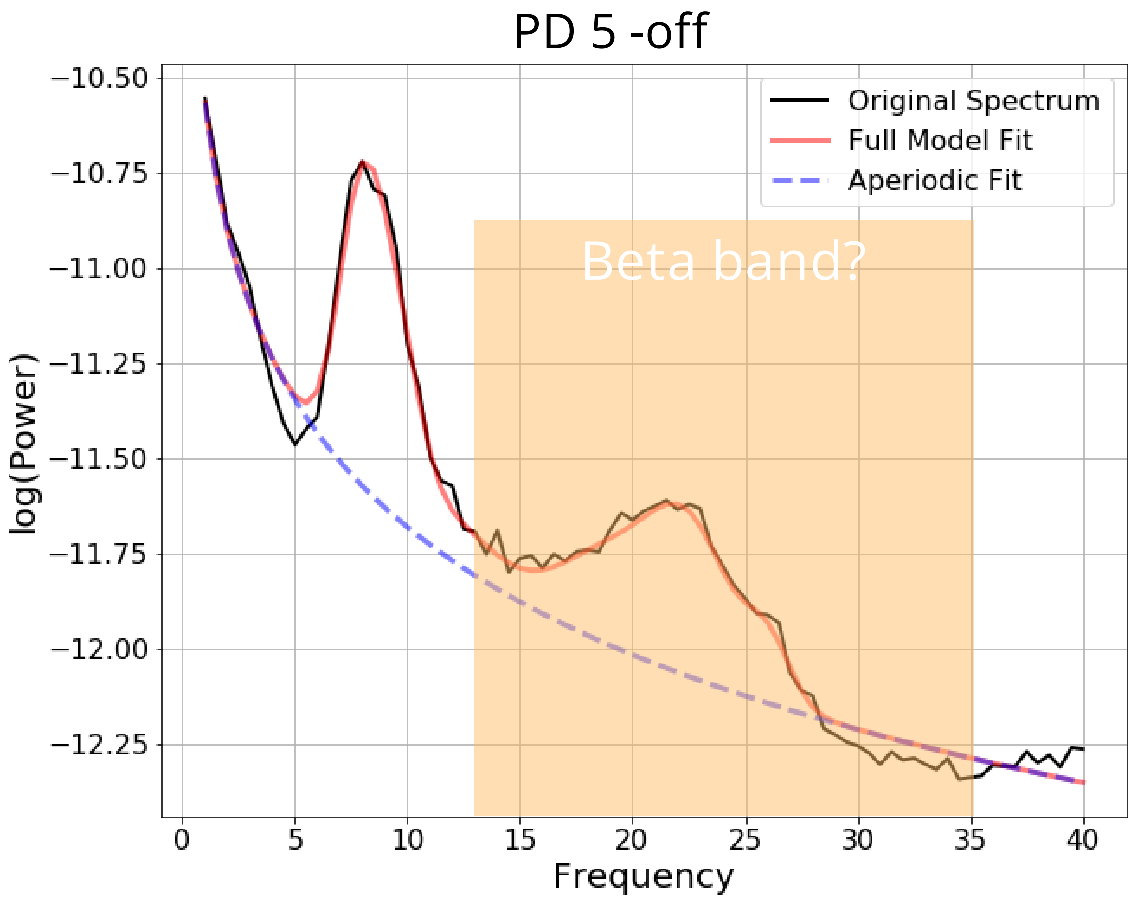


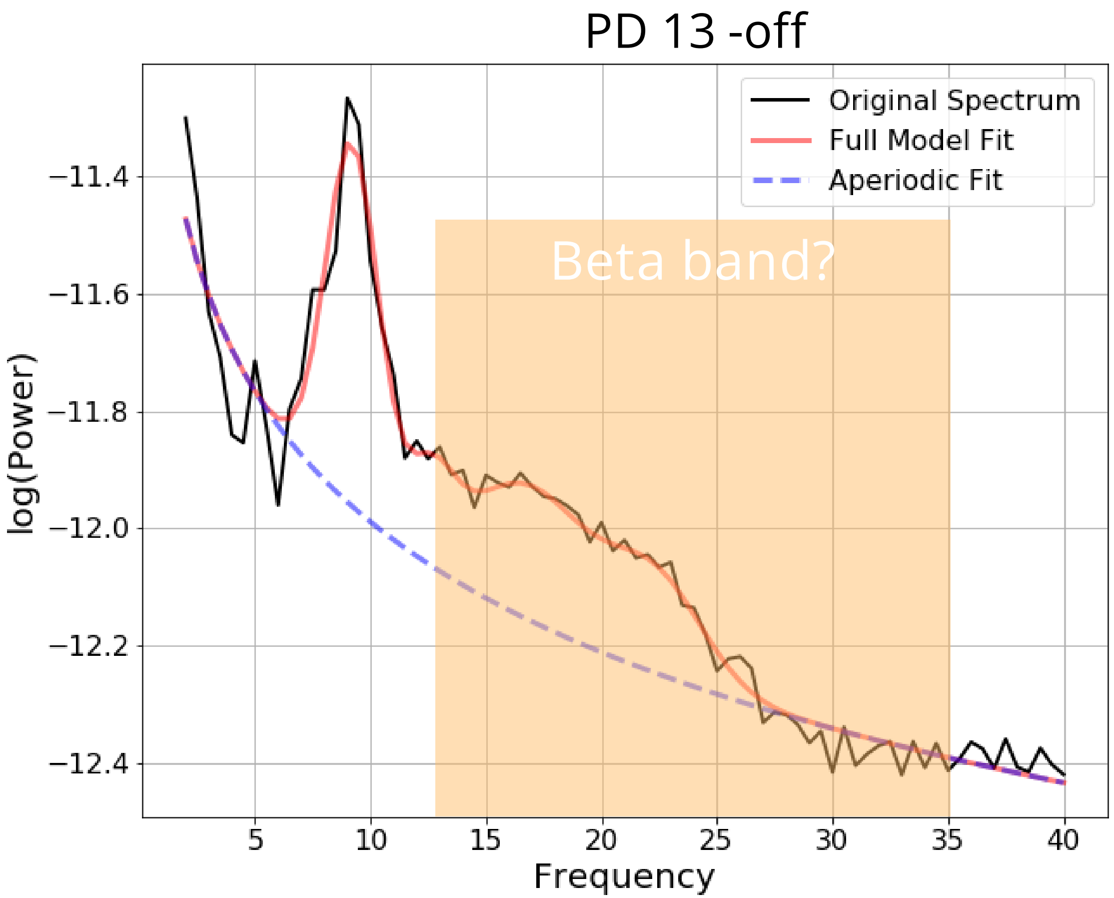
Cohen, 2022

BUT …

"[…] these arbitrary (and nearly always integer-based) cut-offs probably do fairly little damage to the final conclusions of each individual publication […]"

GOAL | individual beta band





UC San Diego Resting State EEG Data from Patients with Parkinson's Disease, *OpenNeuro*, 2020 (v. 1.0.3)

GET BOUNDS

Kiel University
Christian-Albrechts-Universität zu Kiel

Assumptions

1. "Frequency bands" have similar spatiotemporal characteristics

2. Boundaries between bands can be defined as changes in those similarities

3. Signal with narrowband activity is expected

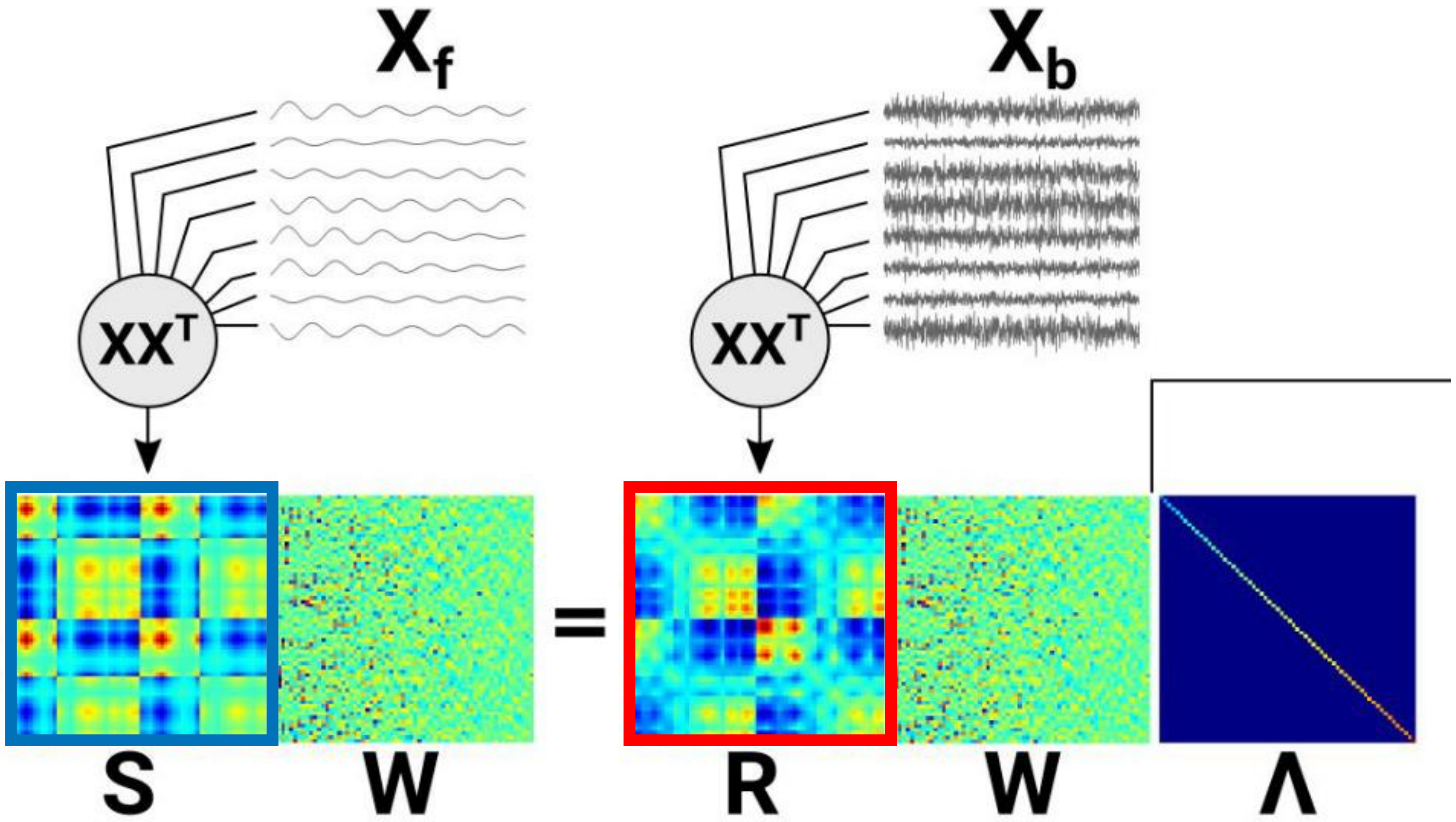
METHOD | 5 steps

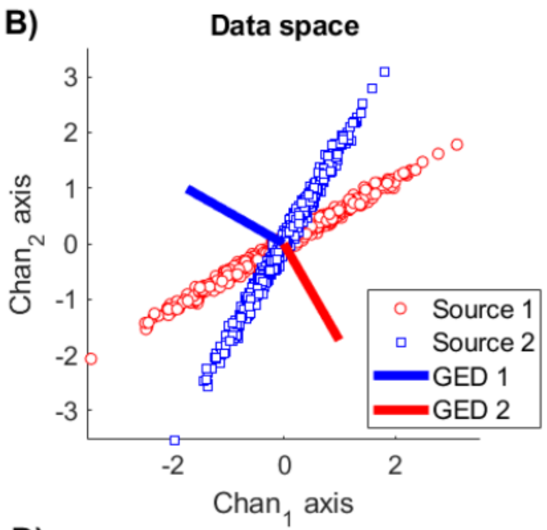
1. Create a channel covariance matrix using broadband data. (R)
2. In desired frequency range (e.g. 13-35 Hz) create channel covariance (S) per frequency bin
3. Compute generalized eigendecomposition (GED) on R&S -> spatial filter, maximally separates S from R
4. Compute pairwise squared correlations across "best" eigenvectors from all frequencies → matrix of eigenvector similarities
5. Apply cluster analysis to this matrix to identify "blocks" on the diagonal that have high similarities

MatLab code available: https://github.com/JuliusWelzel/StepUp-jc

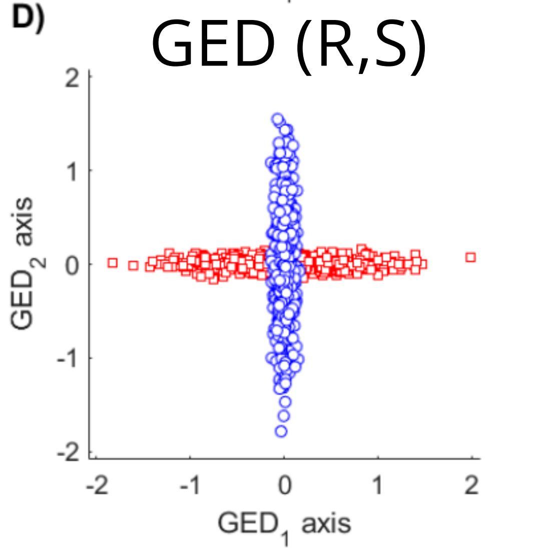
PIPELINE 1

Kiel University
Christian-Albrechts-Universität zu Kiel

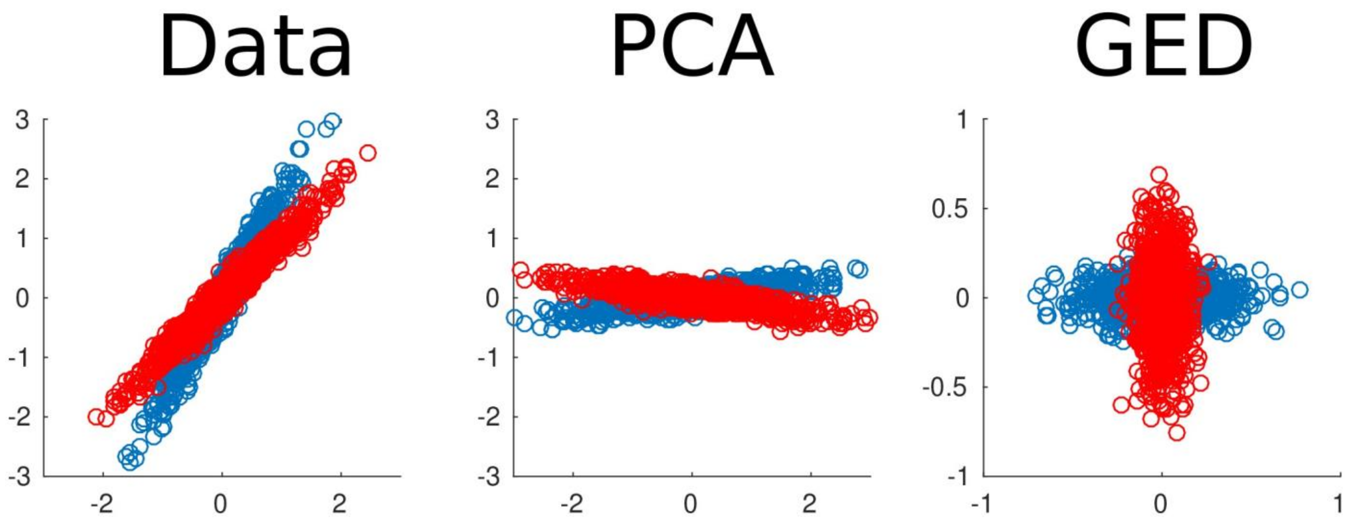


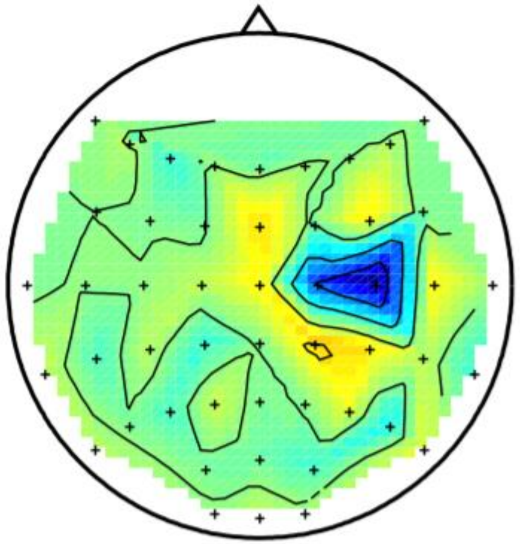


GED (R,S)



GED | a spatial filter?

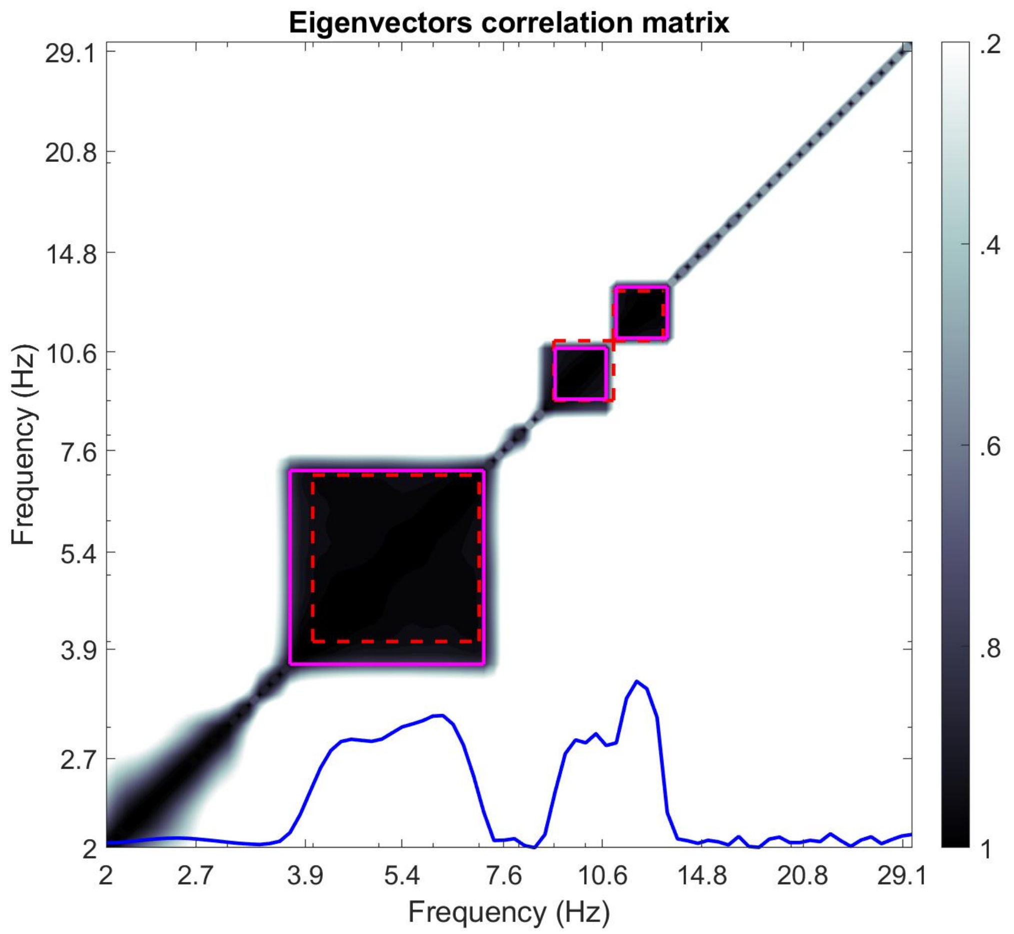




filter

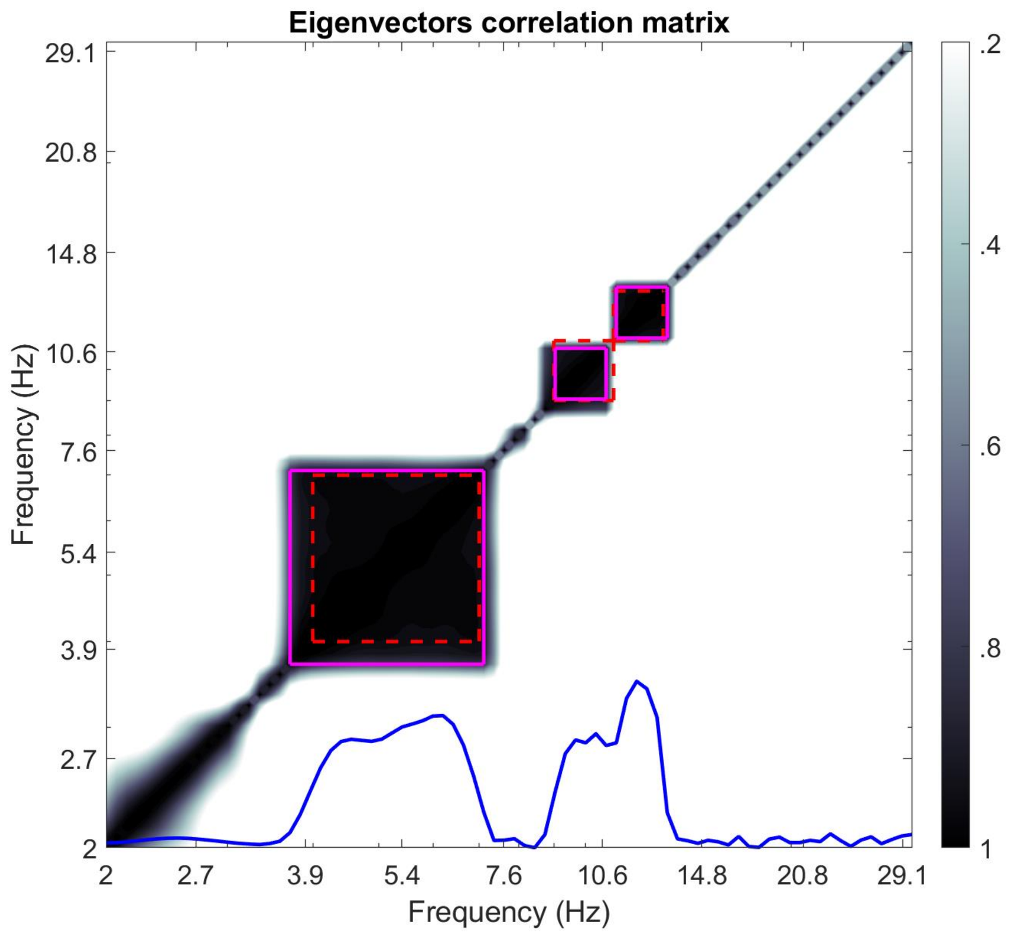
Cohen, *eLife*, 2017; Blankertz, *eLife*, 2007

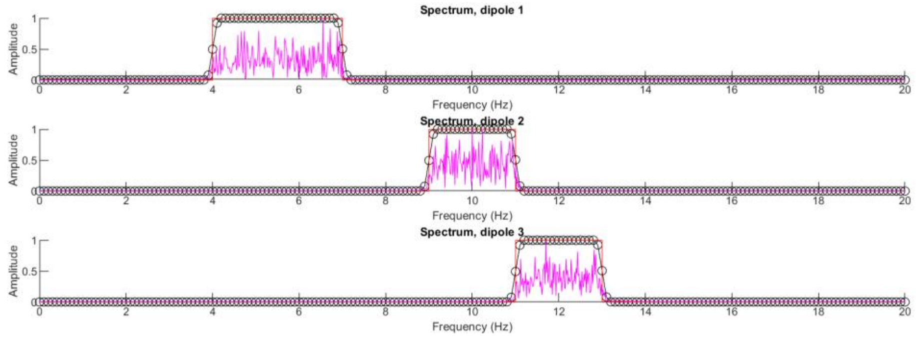
PIPELINE 2

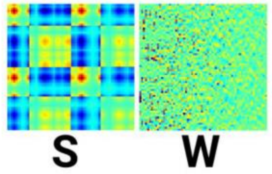


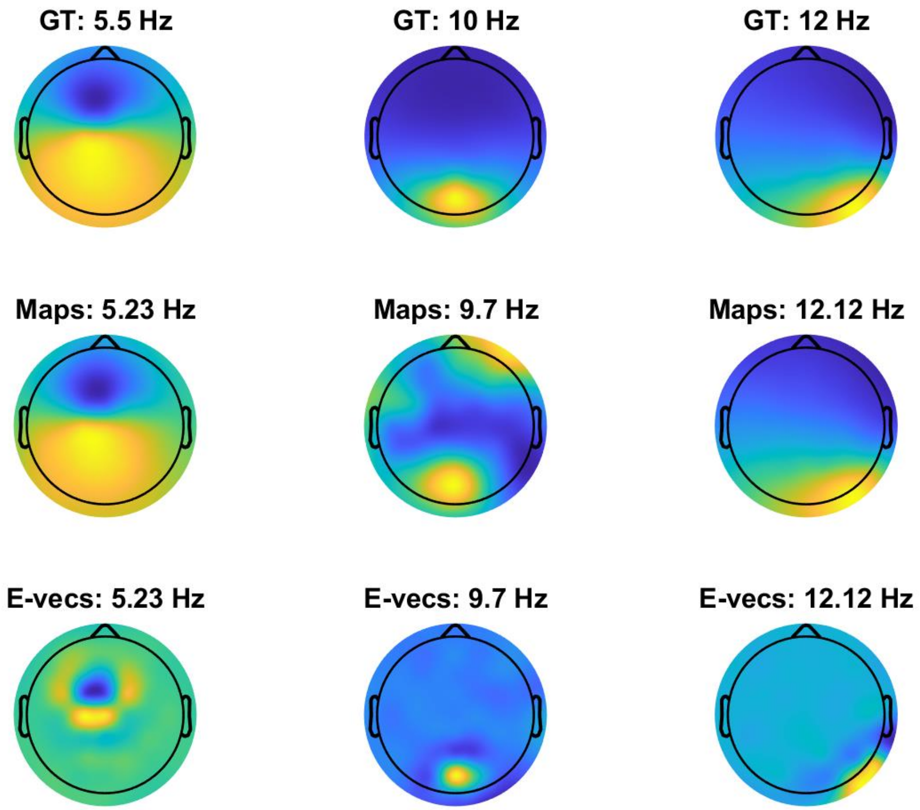
- Eigenvector correlation matrix
  - Using top eigenvector from each frequency in [S] -> best separator
- Clustering into frequency bins
  - Dbscan (density-based spatial clustering)
  - … a lot of tuning possibilities

INTERPRETATION

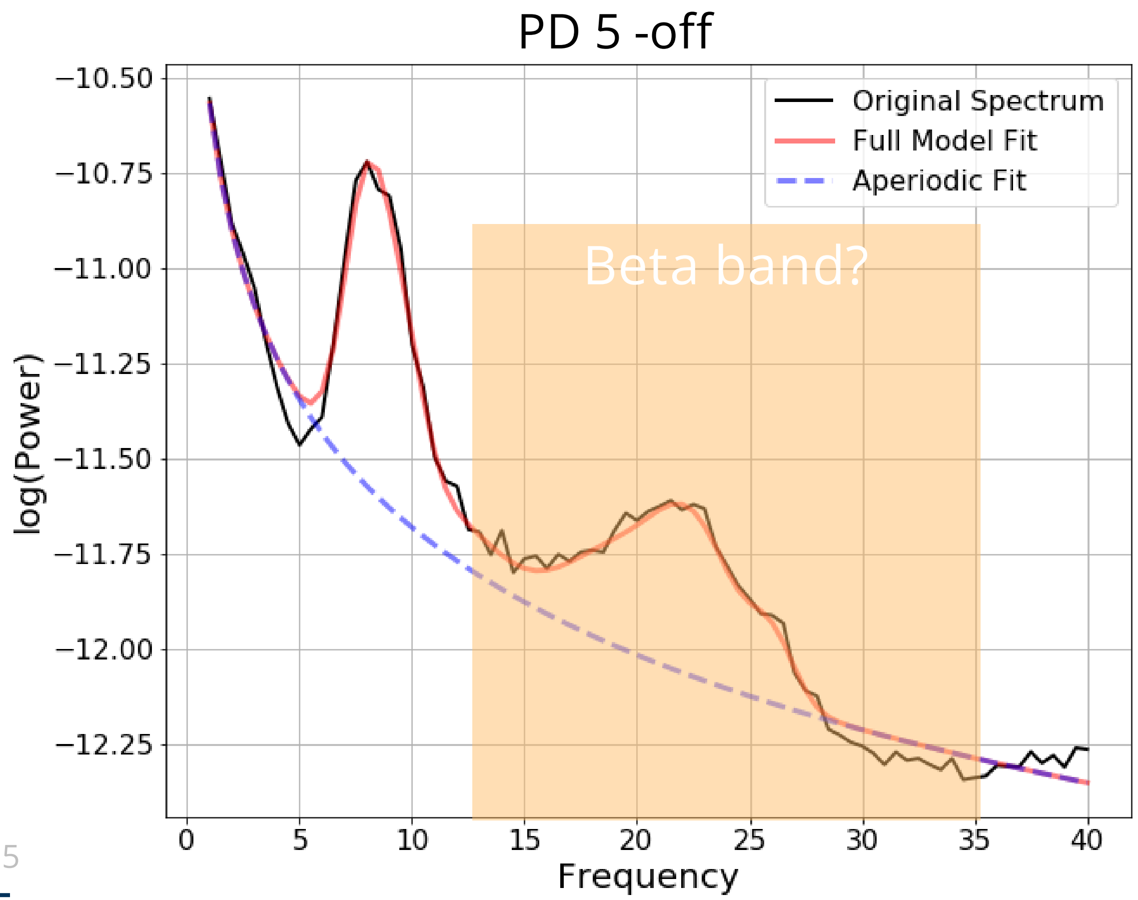


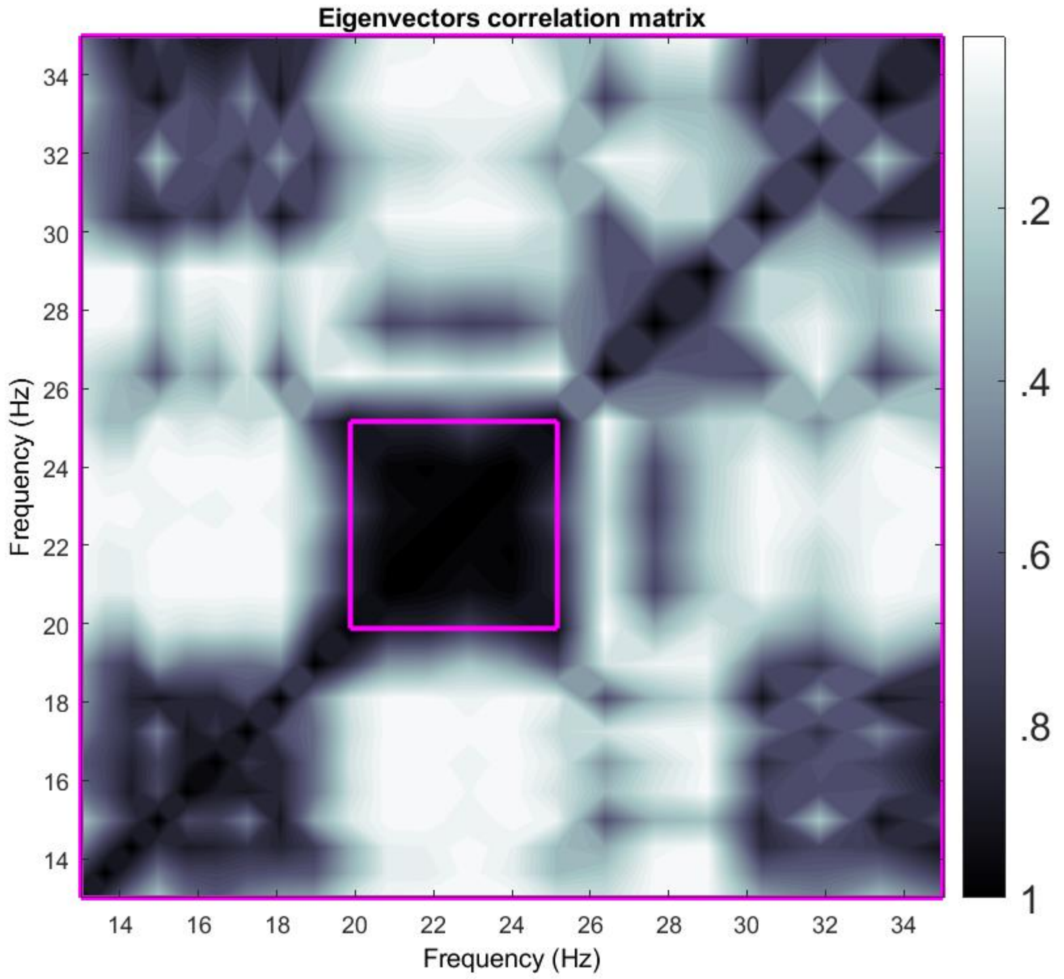




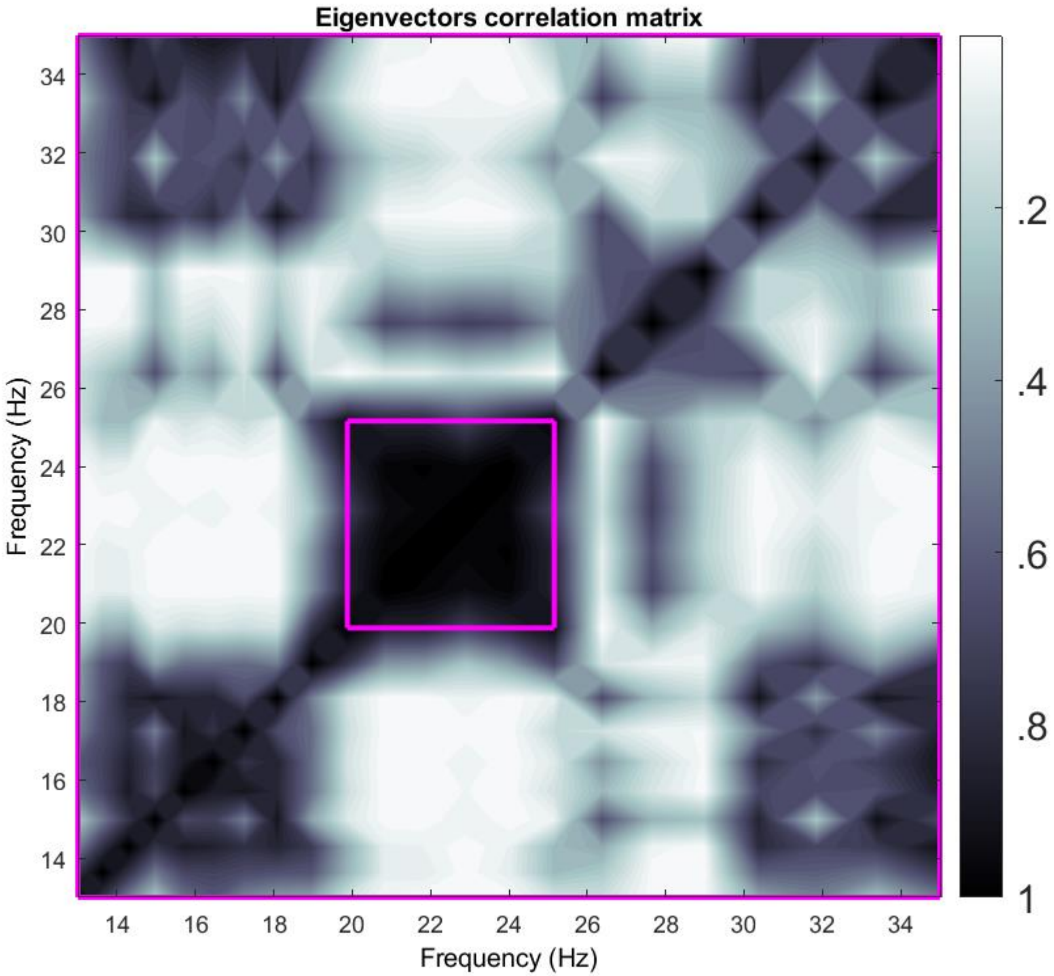


DOES IT WORK?


PD 5 -off
Original Spectrum
Full Model Fit
Aperiodic Fit
Beta band?
log(Power)
−10.50
−10.75
−11.00
−11.25
−11.50
−11.75
−12.00
−12.25
0
5
10
15
20
25
30
35
40
Frequency


Eigenvectors correlation matrix
Frequency (Hz)
34
32
30
28
26
24
22
20
18
16
14
Frequency (Hz)
.2
.4
.6
.8
1

DOES IT WORK?



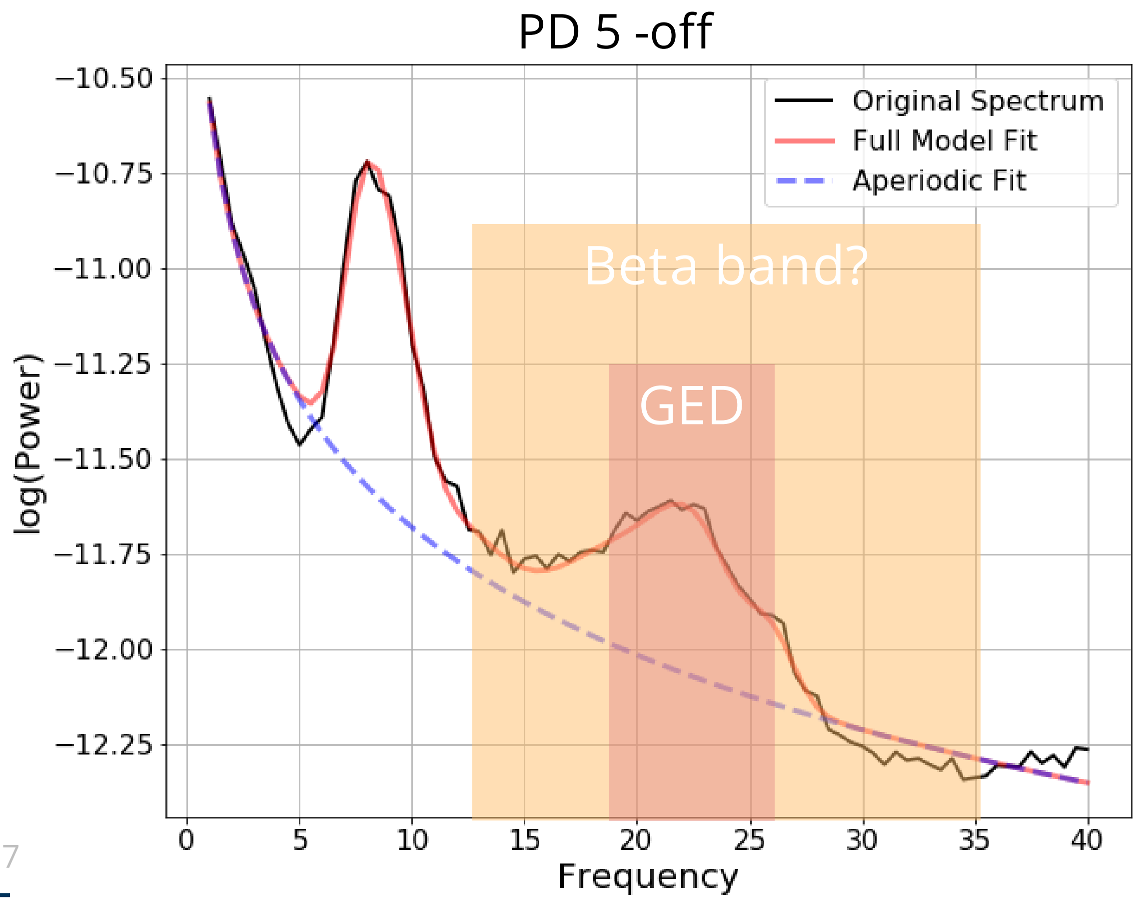
Correlation matrix of Eigenvectors at each Frequency

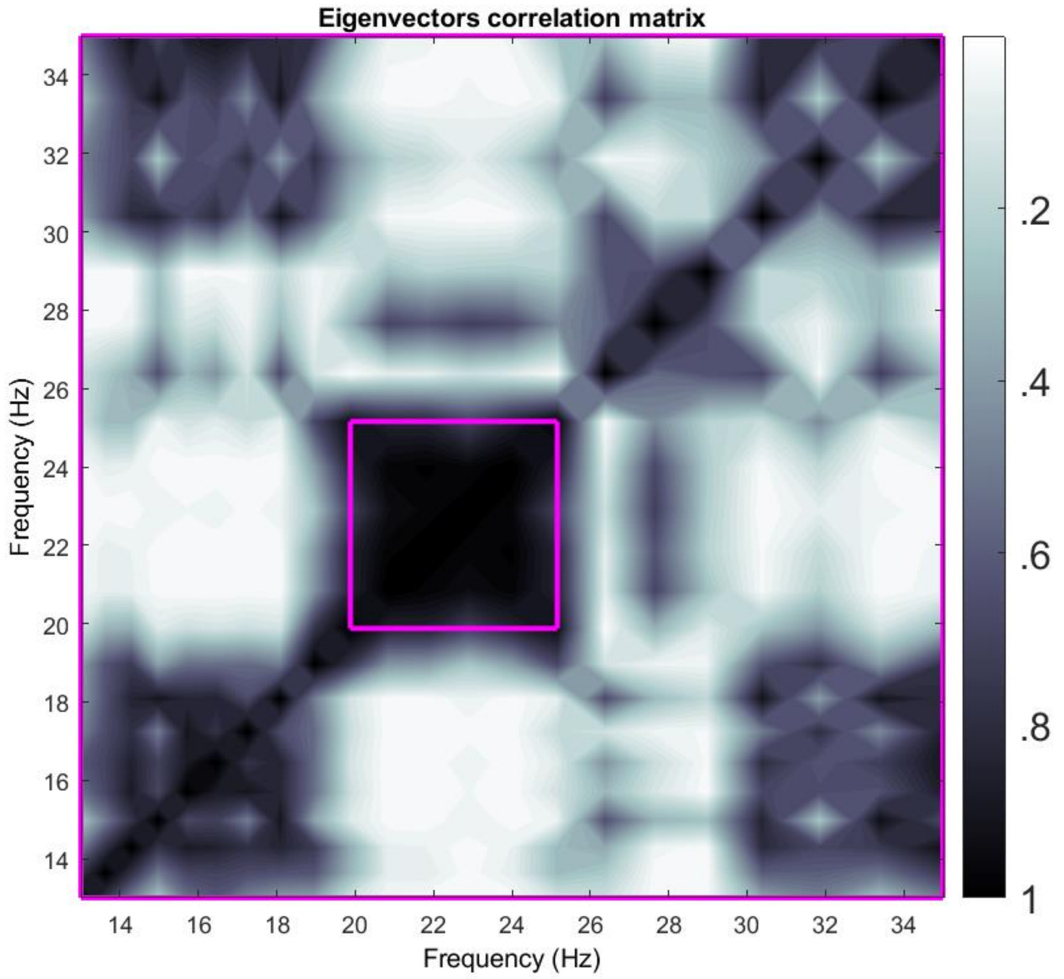
- Maximal separates what exactly?
- ✓ Narrowband from Broadband data!

- In what regard?
- ✓ Spatial characteristics

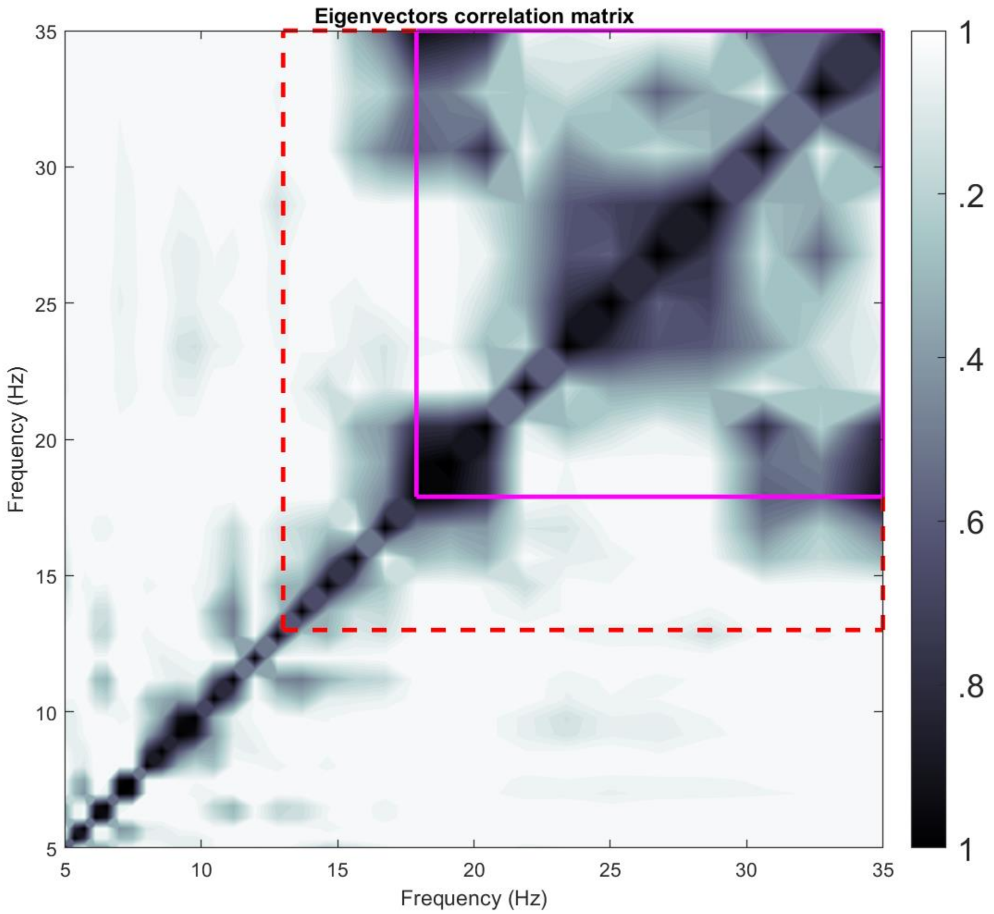
→ When two spectral bands have different anatomical origins , GED will decouple the spectral features

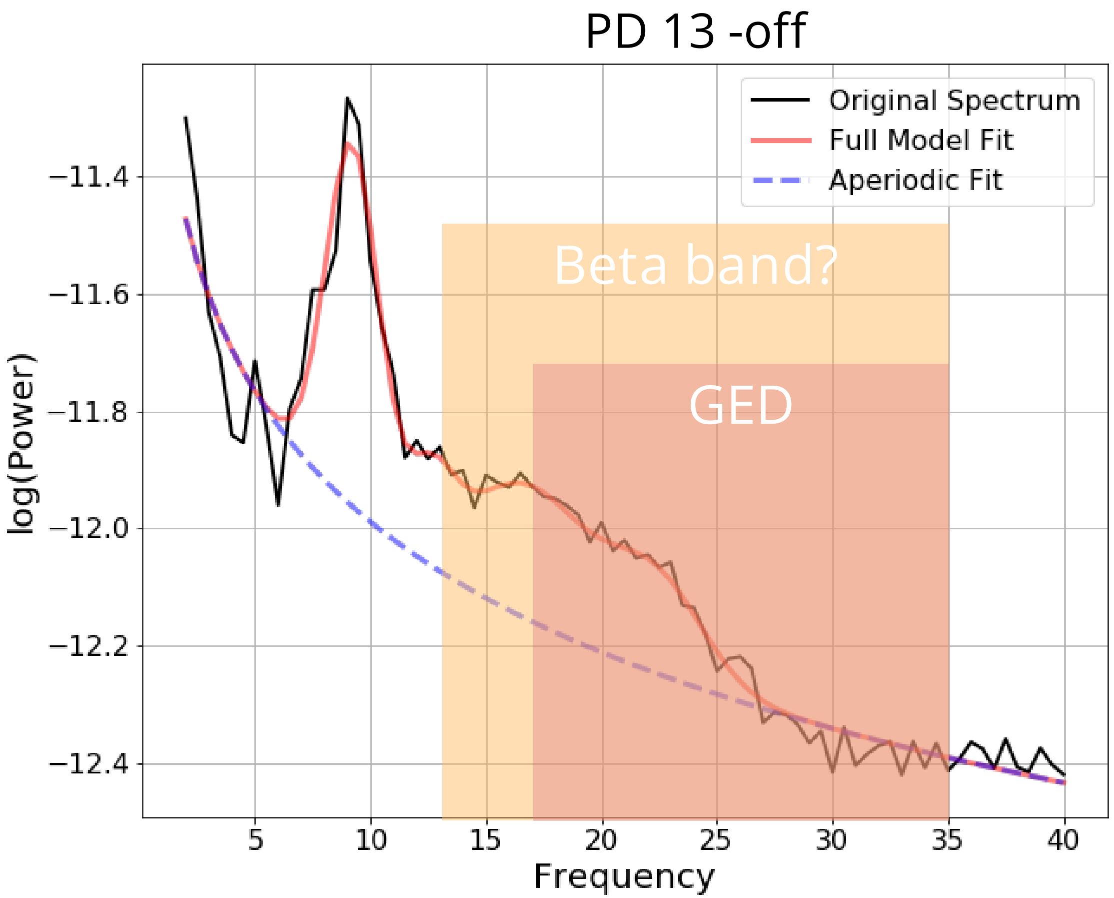
DOES IT WORK? | sometimes yes





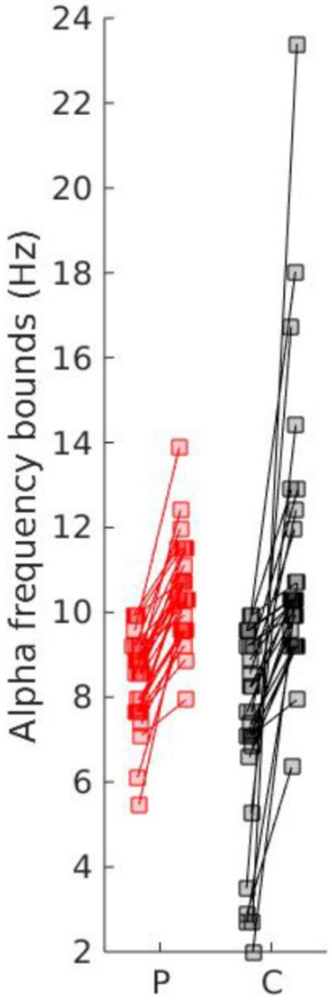
DOES IT WORK? | sometimes no

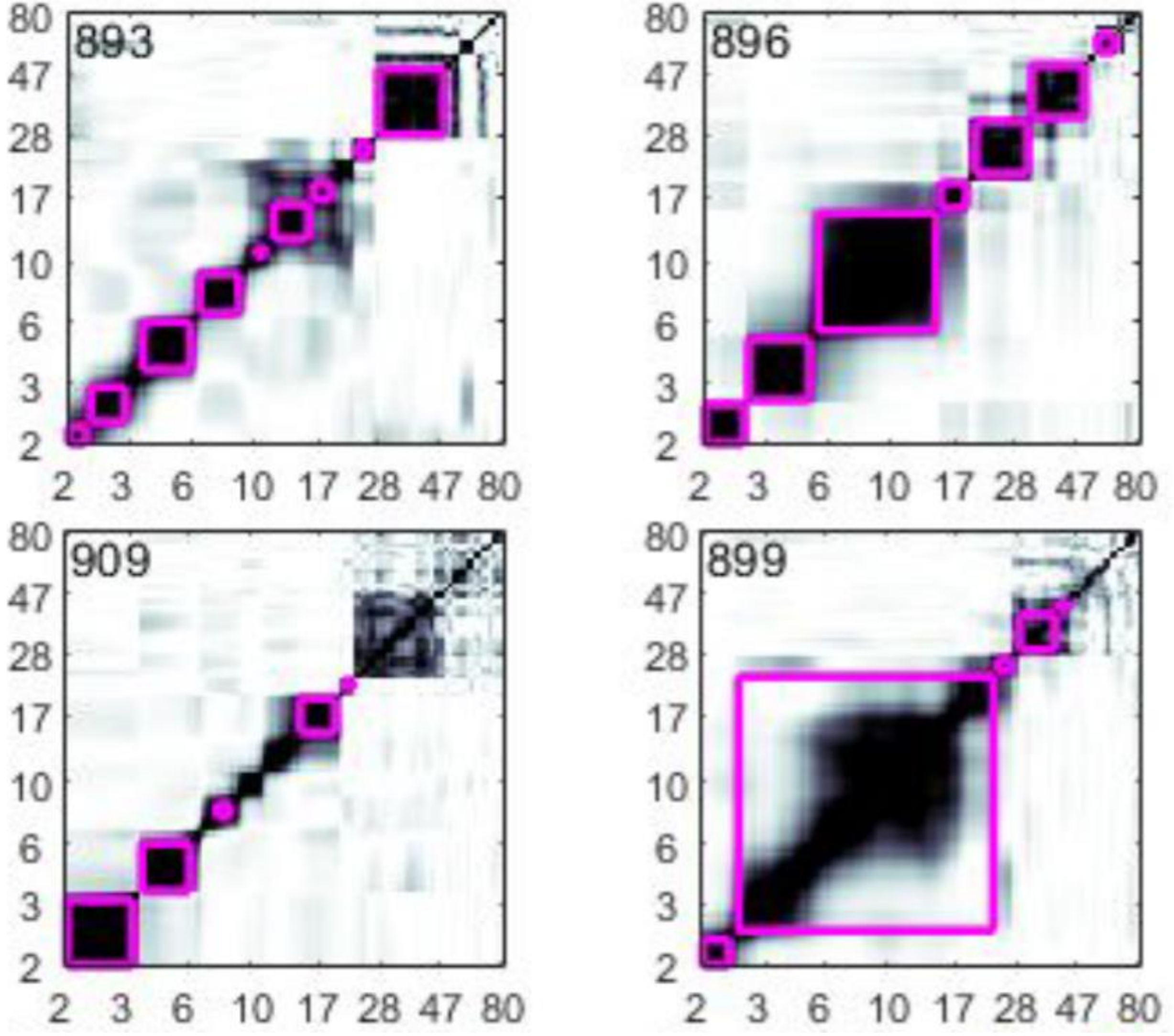




UC San Diego Resting State EEG Data from Patients with Parkinson's Disease, *OpenNeuro*, 2020 (v. 1.0.3)

MORE PD DATA | alpha band





TAKE HOME

- GED can be used for the detection of individual frequency boundaries
- Depending on spatial characteristics, the results can vary a lot
- Clustering of eigenvector correlations seems unstable if correlation between different frequency bands

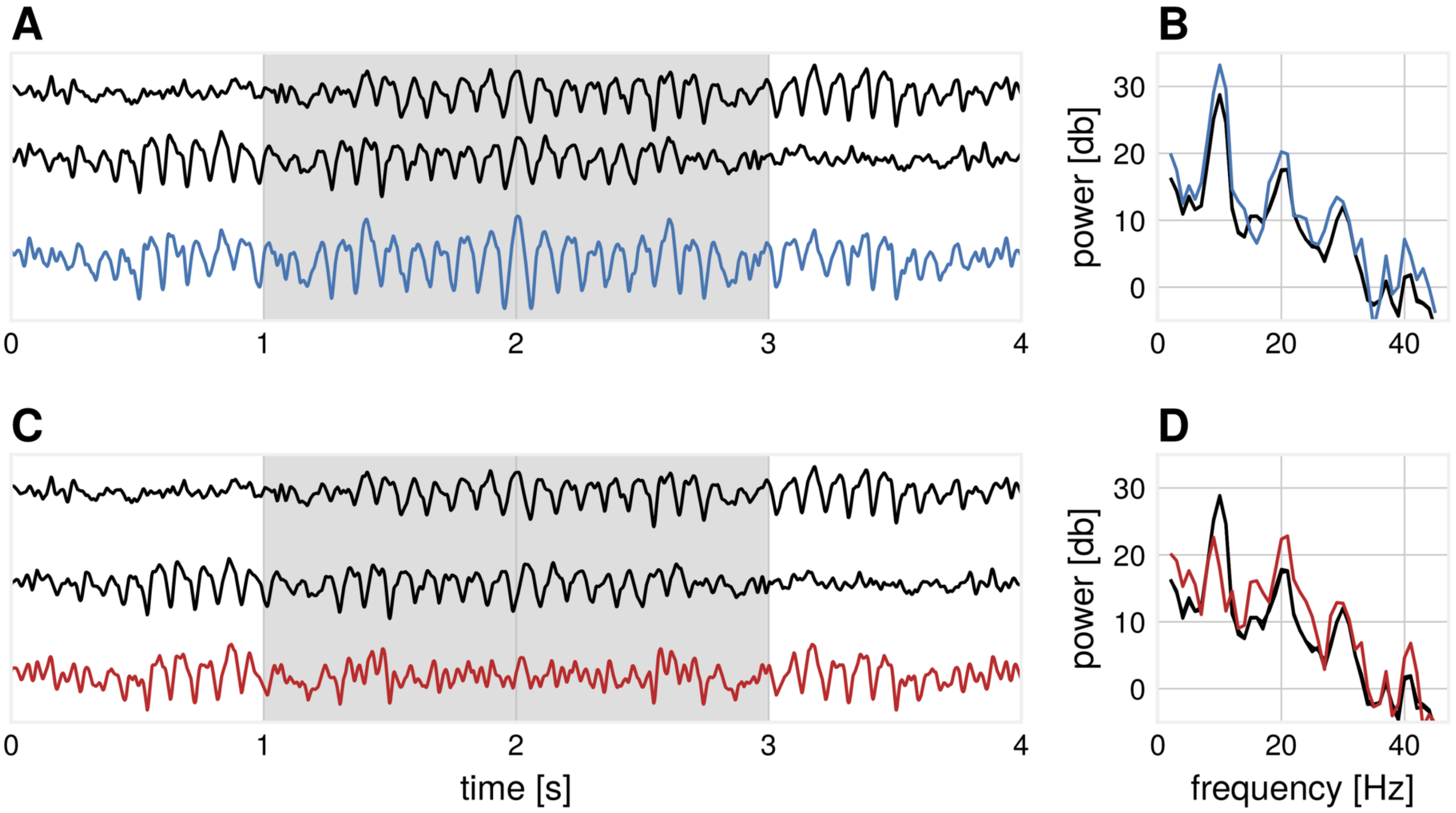
THANKS FOR LISTENING CAREFULLY

NEXT JC

- Next journal club:
  - 15.03.23 10am (UTC+1)
  - Topics: Beta in PD, EEG & Gait, …
- Slides and code
  - https://github.com/JuliusWelzel/StepUp-jc

NON SINUSOIDAL WAVEFORMS

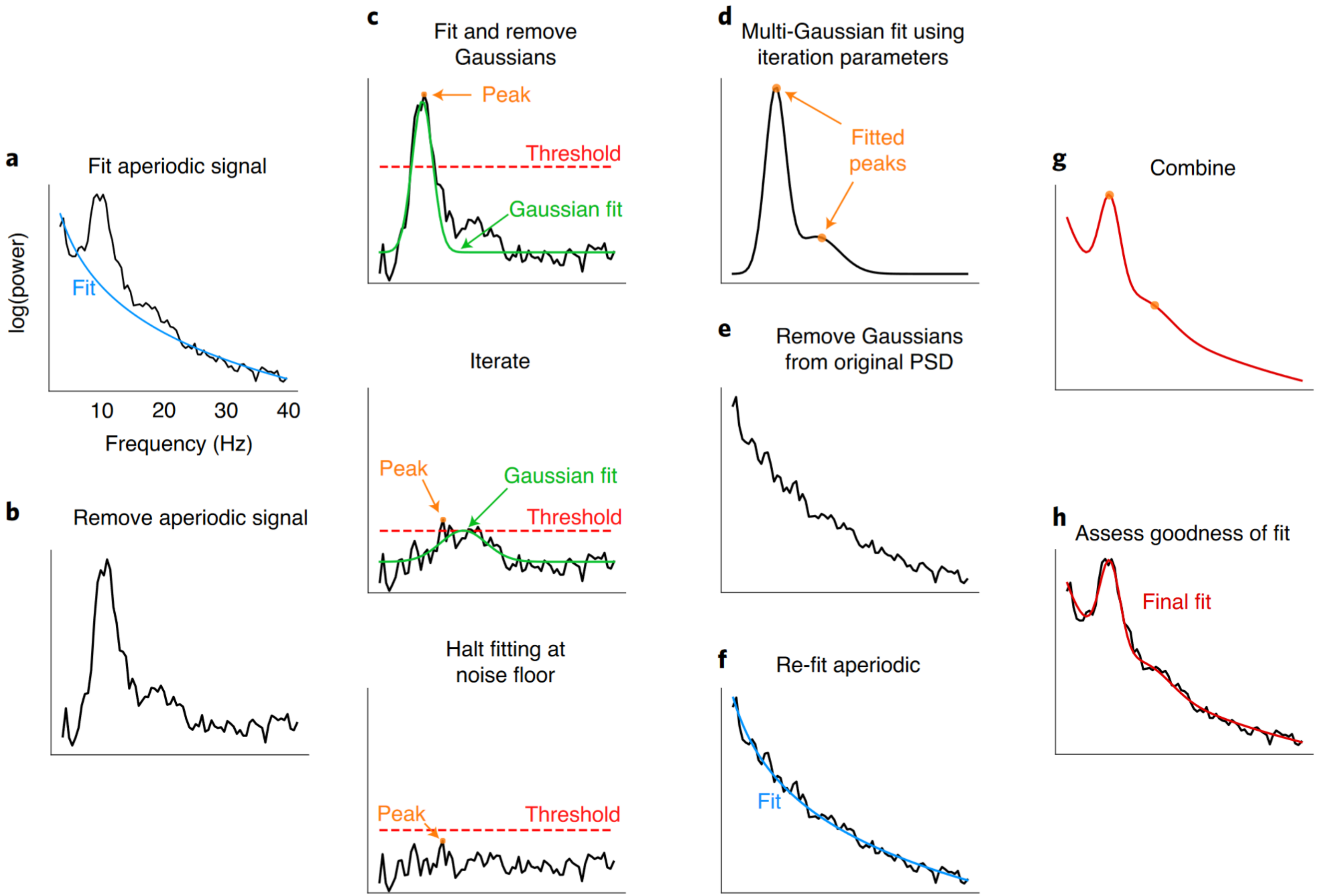
C | A | U
Kiel University
Christian-Albrechts-Universität zu Kiel



Schaworonkow & Nikulin, *PLOS Comp. Bio.*, 2019

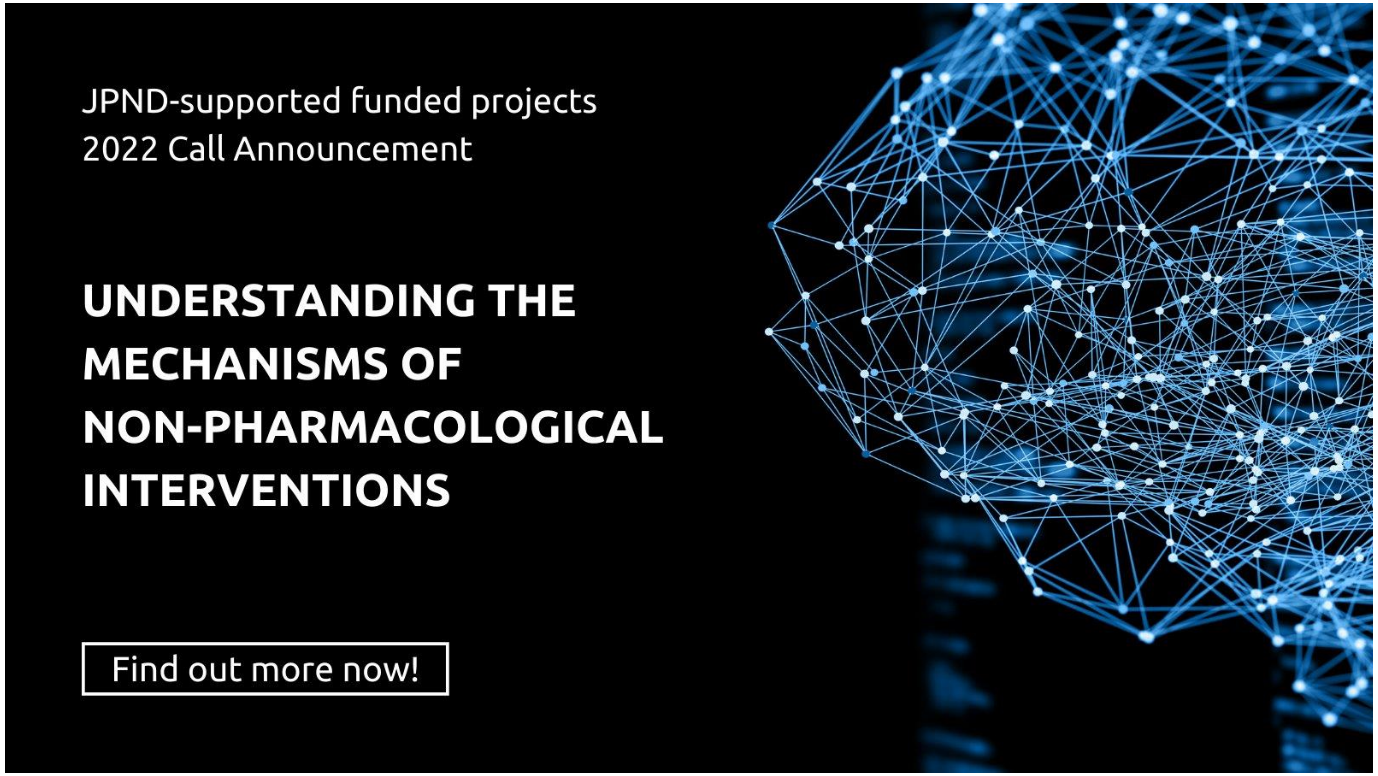
FOOOF

C | A | U
Kiel University
Christian-Albrechts-Universität zu Kiel



JPND CALL

Kiel University
Christian-Albrechts-Universität zu Kiel



A three year project:

Steps against the burden of Parkinson’s Disease (StepuP)