Intro to source reconstruction

CuttingEEGX workshop

Dr. Britta Westner
Teaching fellow and researcher
Donders Institute & Radboudumc

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Source reconstruction of M/EEG data

Goal: Estimate the source activity underlying our channel-level measurements.

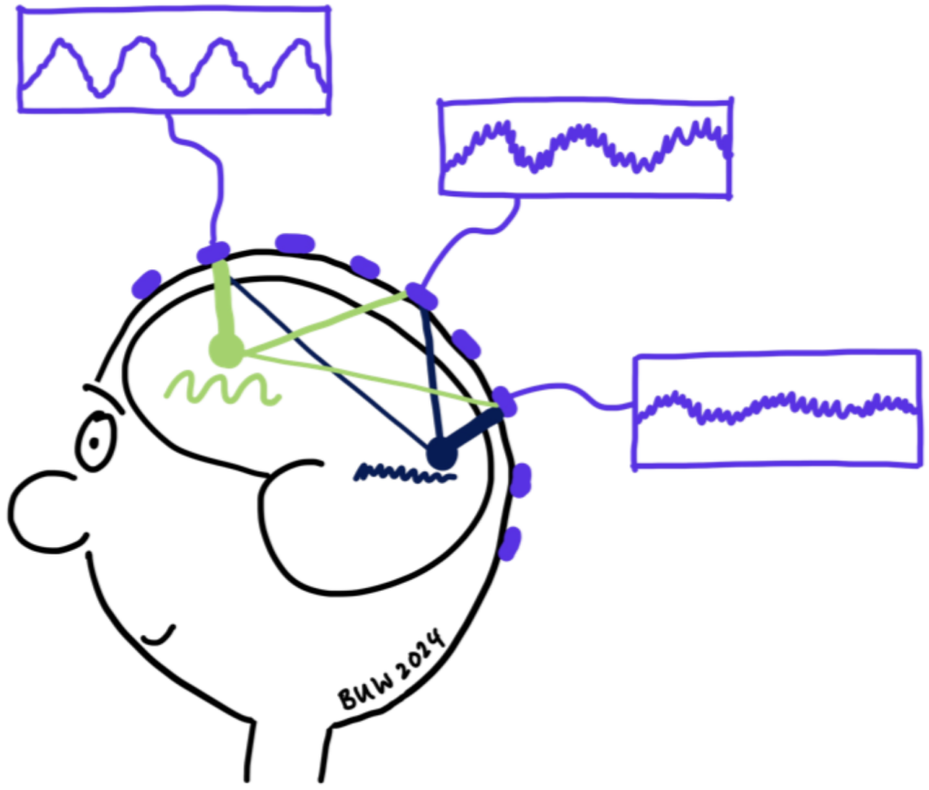


Fig.: original figure

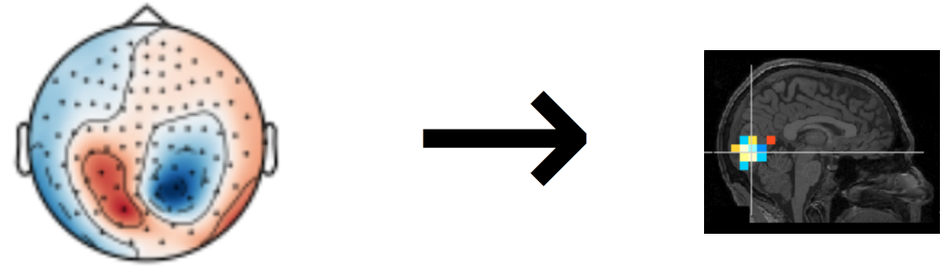
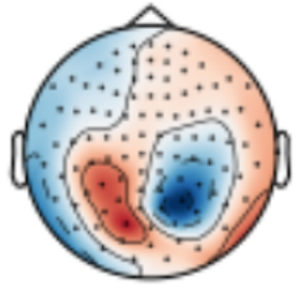


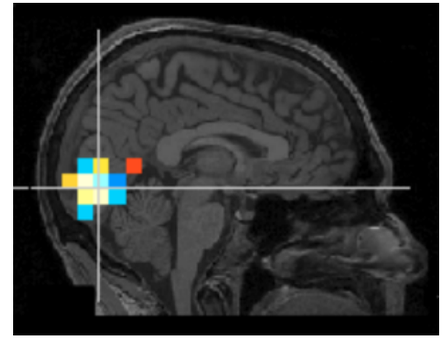
Fig.: parts from MNE-Python

- Disentangle measured source activity
- Increase spatial resolution of M/EEG data

Forward and inverse solution

forward solution





inverse solution

The inverse problem

Ill-posed problem:
many more source points (thousands)
than sensors (hundreds).

- infinite number of solutions
- use **constraints** to make solvable:
  - biophysical constraints: **forward model**
  - additional mathematical constraints in the **inverse solution**

Shadow art example for dimensionality / ill-posedness:

`http://timnobleandsuewebster.com/dirty_white_trash_1998.html`

Biophysical constraints: the forward model

The **forward solution** describes the relation between *known* sources and the channel-level activity they produce.

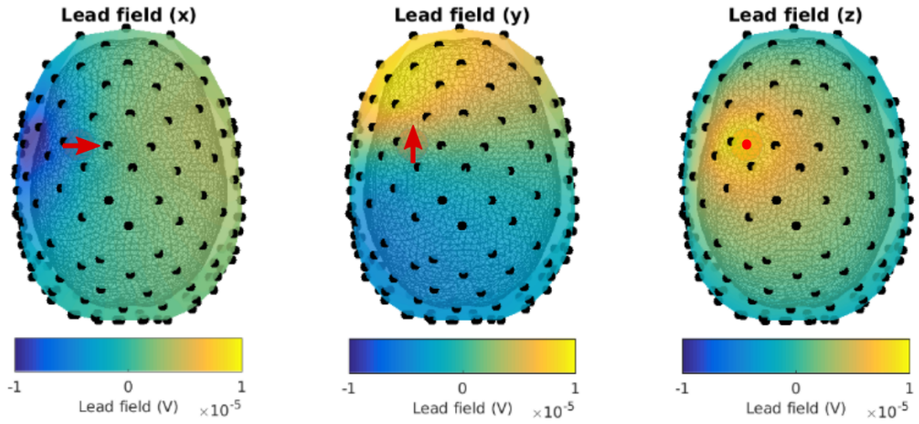


Fig.: modified from FieldTrip

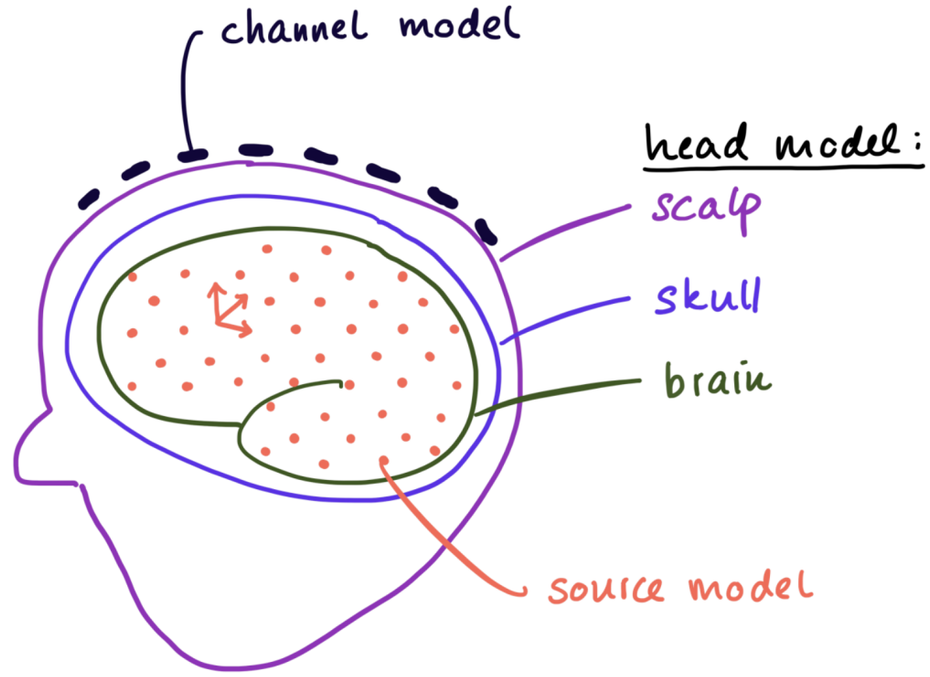


Fig.: original figure

A forward model incorporates:

1. source model
2. head model
3. channel properties

Minimum norm estimation

Idea: Estimate **source strength** at pre-defined positions all across cortex.

Set up a source space on **cortical surface**

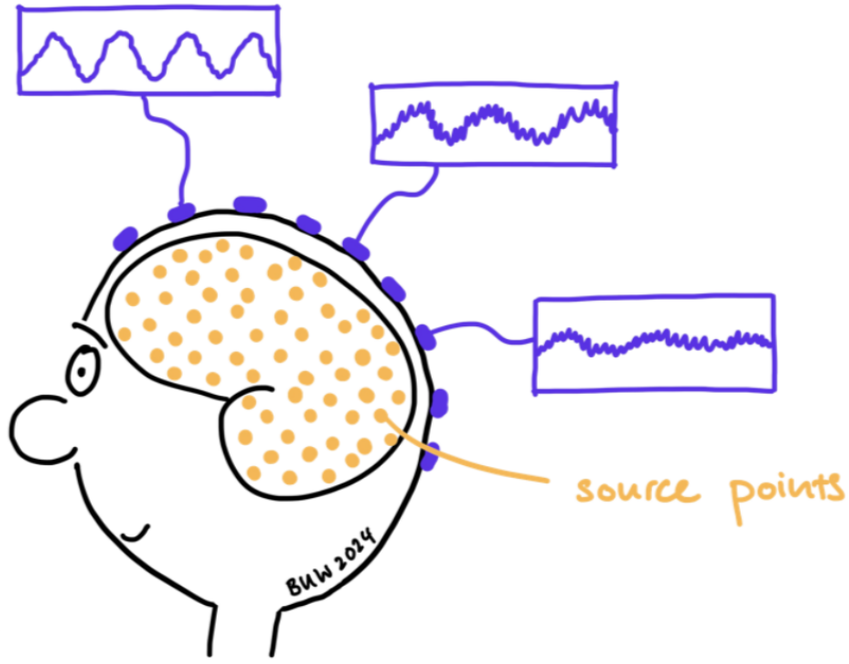


Fig.: original figure

Minimum norm estimation

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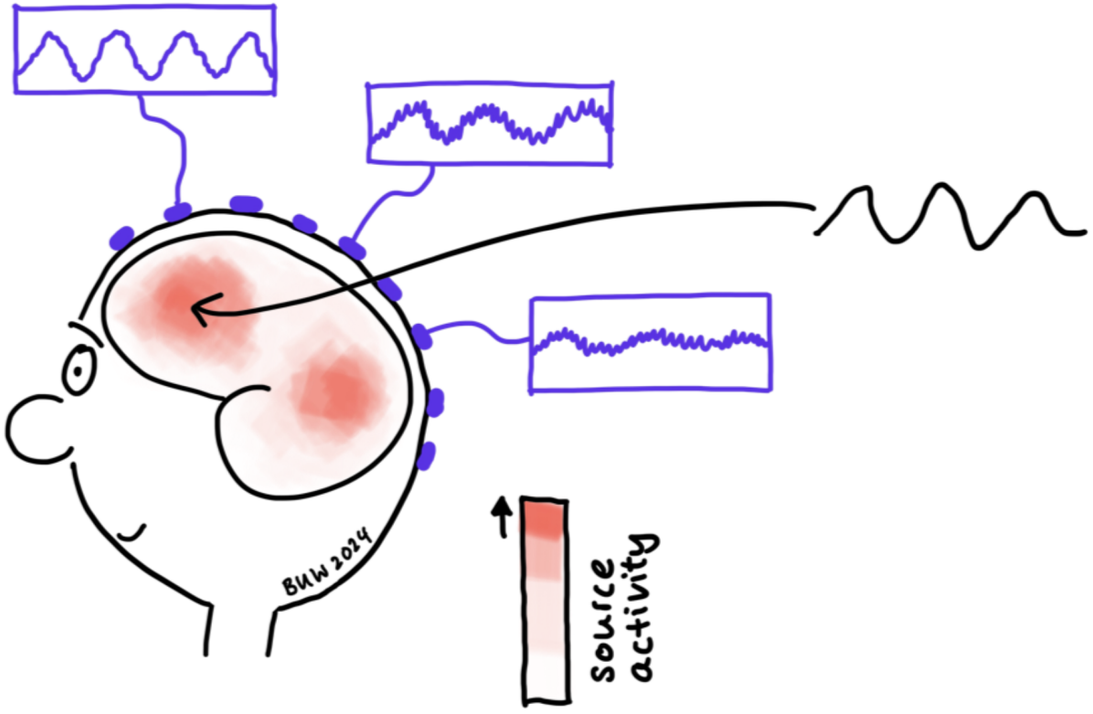


Fig.: original figure

Constraints:

- strength gets estimated across all dipoles
- distribution of sources with **minimum current**
- minimizing the residuals (error towards the measured data)

Different flavours:
MNE, dSPM, eLORETA, sLORETA, ...
Just so you've heard the acronyms - no need to learn by heart.

Minimum norm estimation in practice

MNE solution for auditory evoked field

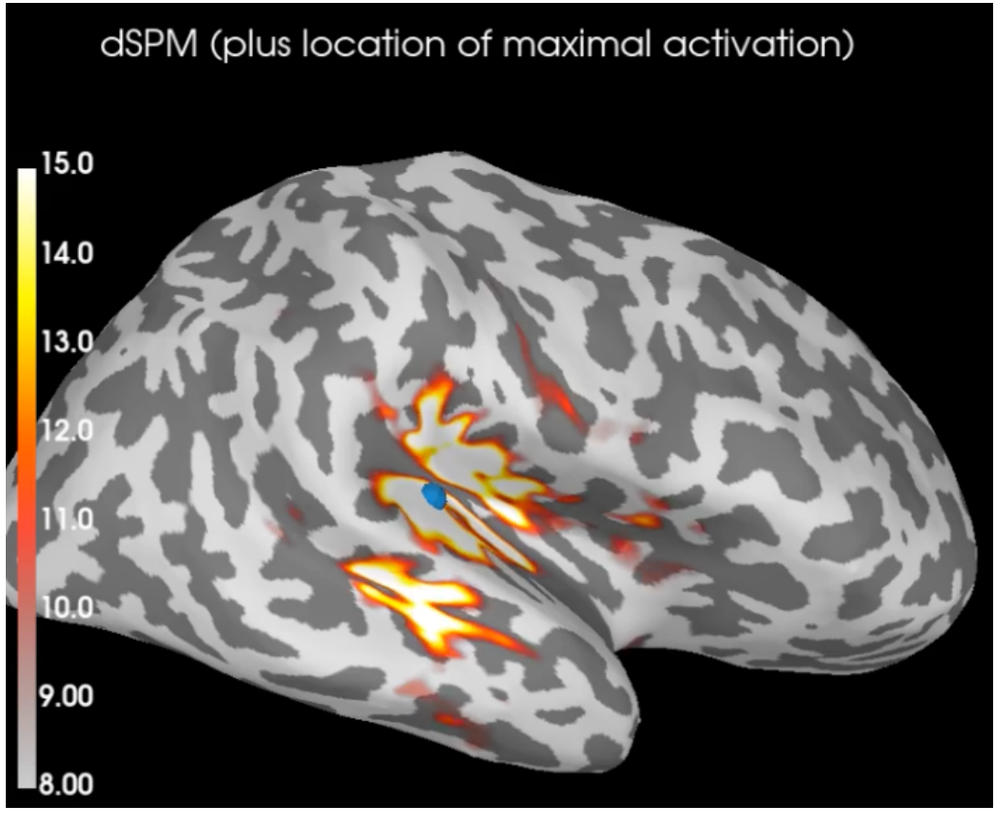


Fig.: MNE-Python

Pros and Cons:

- activity gets estimated over **whole brain**
- all measured activity (+ noise) lands in source space
- lower spatial resolution

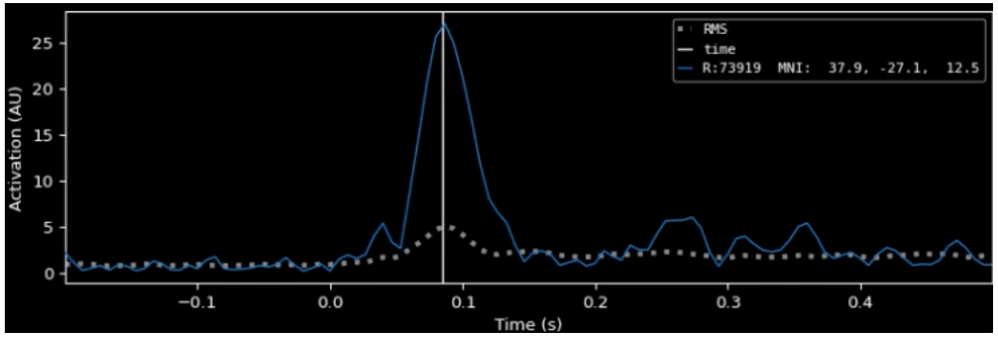
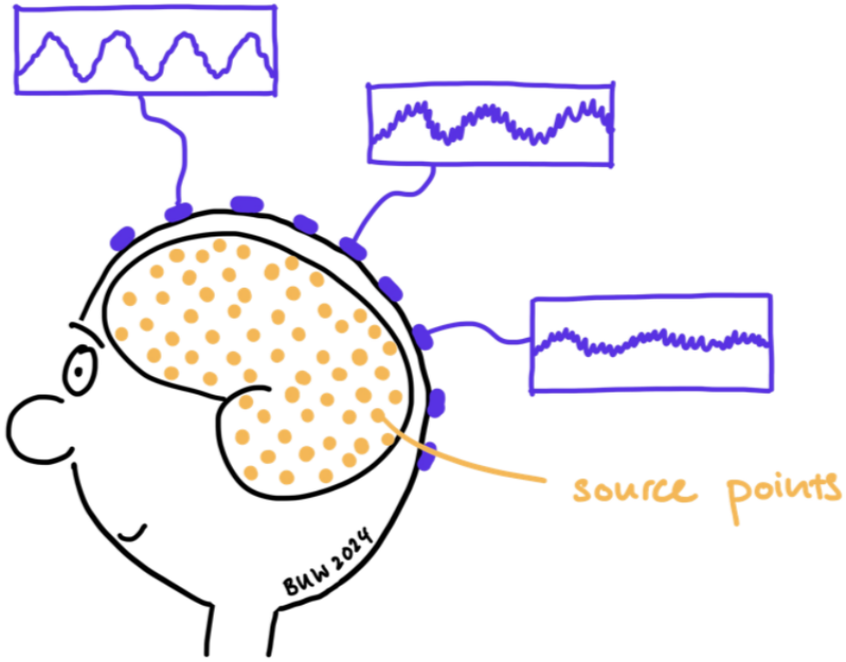


Fig.: MNE-Python

Beamforming (aka: spatial filtering)

Idea: Estimate **source activity** for pre-defined positions **independently**.

Set up a source space on **surface** or throughout the brain



Beamforming (aka: spatial filtering)

Idea: Estimate **source activity** for pre-defined positions **independently**.

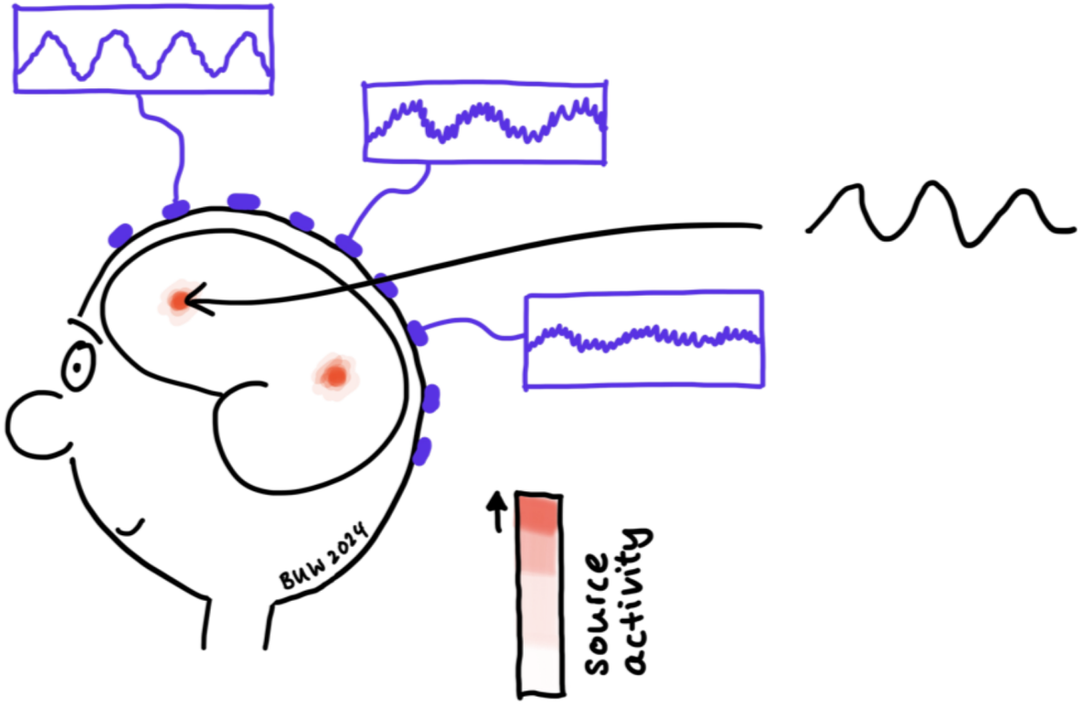


Fig.: original figure

Constraints:

For each source point, create a spatial filter that:

- passes activity of this source point without loss
- attenuates other sources: **minimize the variance** across all sources

Different flavours:
most known are LCMV & DICS

Just so you've heard the acronyms - no need to learn by heart.

Beamforming in practice

Beamformed auditory evoked field

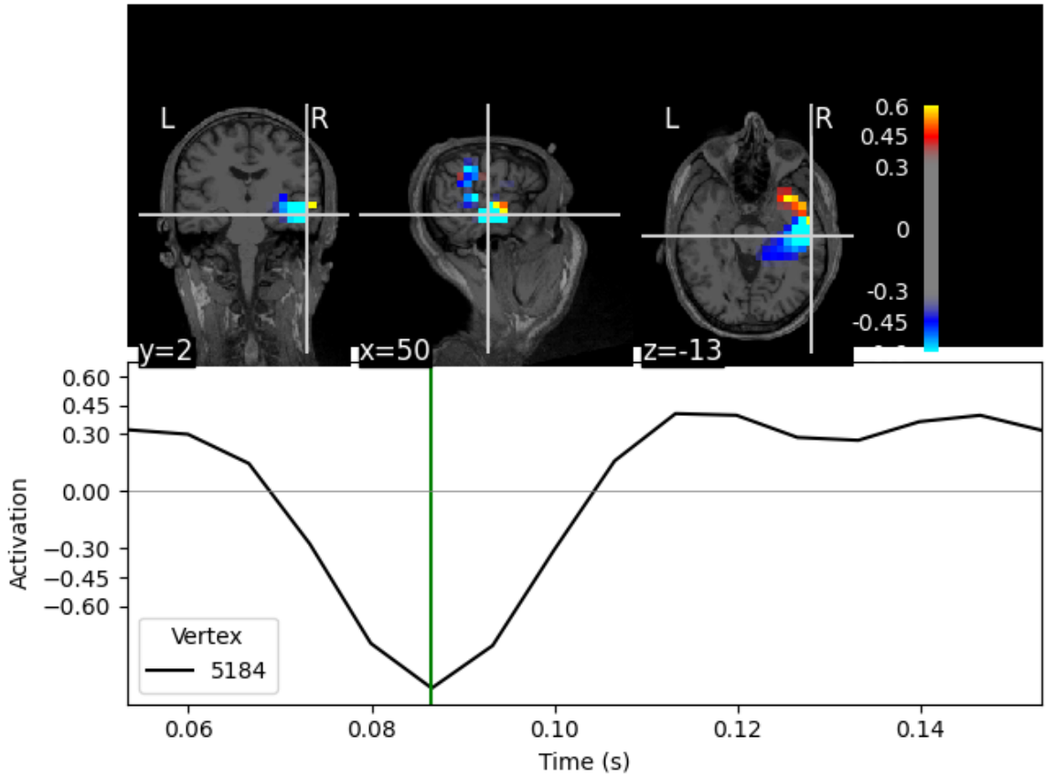


Fig.: MNE-Python

Pros and Cons:

- activity gets estimated over **whole brain**
- **selective** to activity (noise suppressant)
- needs **very precise forward model**
- tricky with **correlated sources**

Further reading

Beamforming: Westner et al. (2022), *NeuroImage*:

A unified view on beamformers for M/EEG source reconstruction

Britta U. Westner[a,b,*], Sarang S. Dalal[b], Alexandre Gramfort[c], Vladimir Litvak[d], John C. Mosher[e], Robert Oostenveld[a,f], Jan-Mathijs Schoffelen[a]

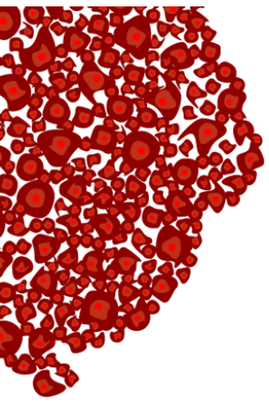
[a] *Radboud University, Donders Institute for Brain, Cognition and Behaviour, Nijmegen, The Netherlands*
[b] *Center of Functionally Integrative Neuroscience, Department of Clinical Medicine, Aarhus University, Aarhus, Denmark*
[c] *Université Paris-Saclay, Inria, CEA, Palaiseau, France*
[d] *Wellcome Centre for Human Neuroimaging, UCL Queen Square Institute of Neurology, London, UK*
[e] *Texas Institute for Restorative Neurotechnologies, McGovern Medical School, University of Texas Health Science Center at Houston, TX USA*
[f] *NatMEG, Karolinska Institutet, Stockholm, Sweden*

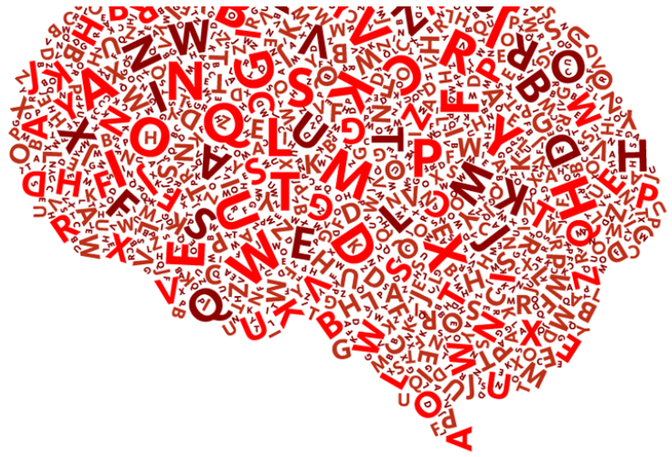
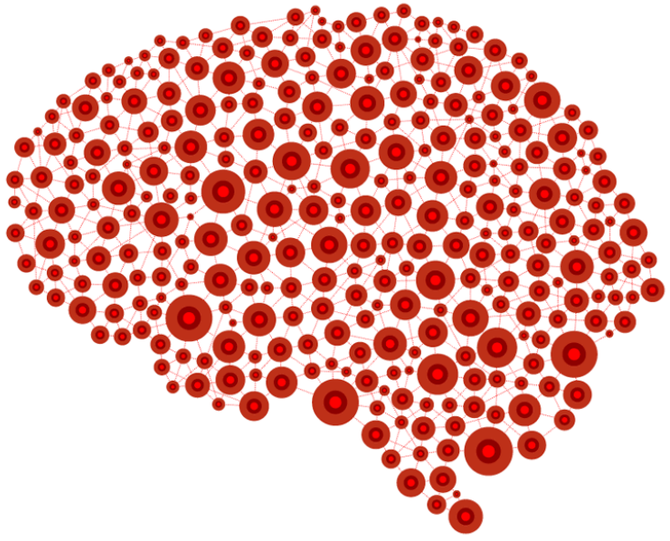
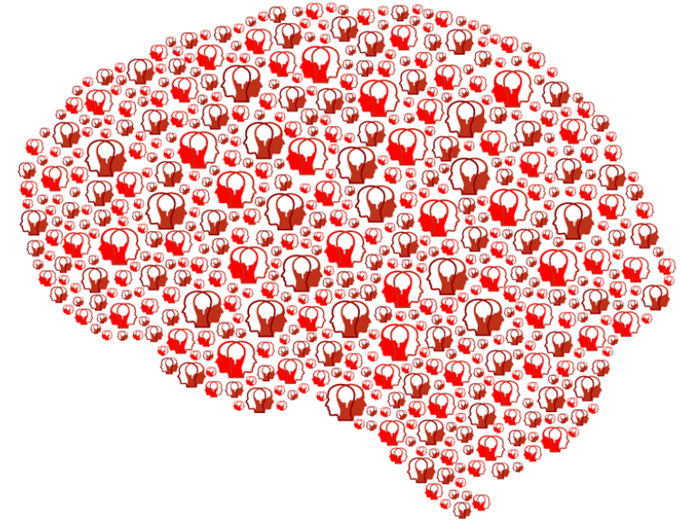
Topics you can dive into

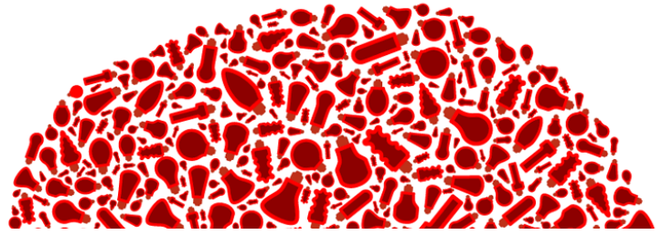
We have prepared **4.5 notebooks** for you.

1. **Best practices in beamforming**: `Beamforming_best_practices.ipynb`
2. **How to combine channel types**: `Combining_channel_types.ipynb`
3. **How to do source reconstruction with EEG data**: `Source_reconstruction_with_EEG.ipynb`
4. **How to deal with severly rank deficient data**: `Working_with_SSSed_data.ipynb`
5. Background notebook: `Forward_modelling.ipynb`

All of this can be found in the **course material** folder.
Let me show you how to get started!



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