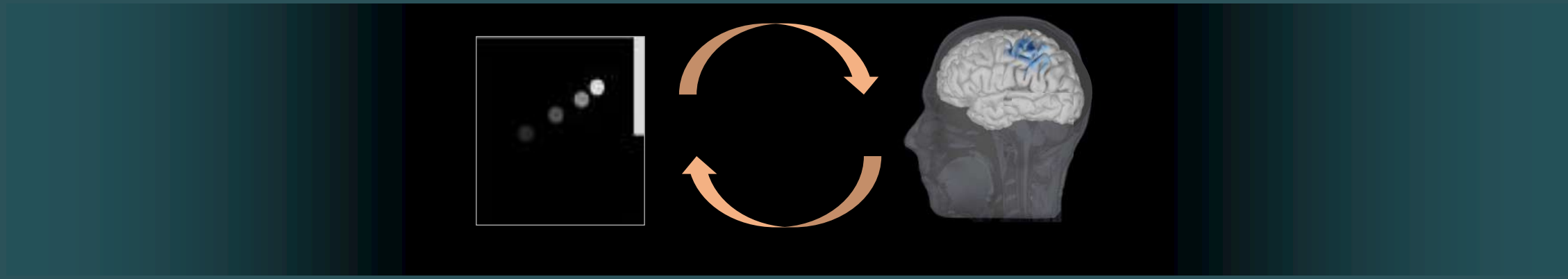
M/EEG DATA ANALYSIS: WHERE IT ALL BEGINS !



Marie-Constance Corsi

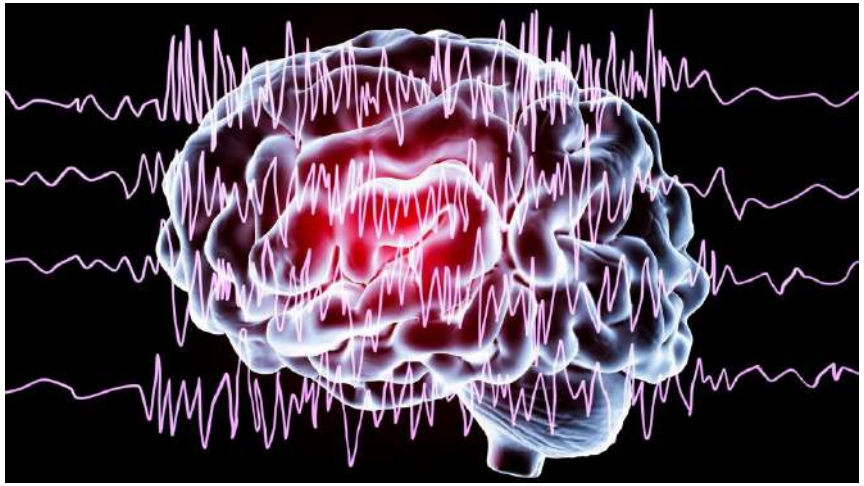
Postdoctoral researcher,

ARAMIS team, Paris Brain Institute

CONTEXT

Measurement of brain activity, focus on two non-invasive tools:

- Electroencephalography (EEG): electrical activity
- Magnetoencephalography (MEG): magnetic activity



Question addressed here:

- Where do the signals come from ?
- How can I measure M/EEG signals ?
- How can I perform an anlysis of my dataset ?

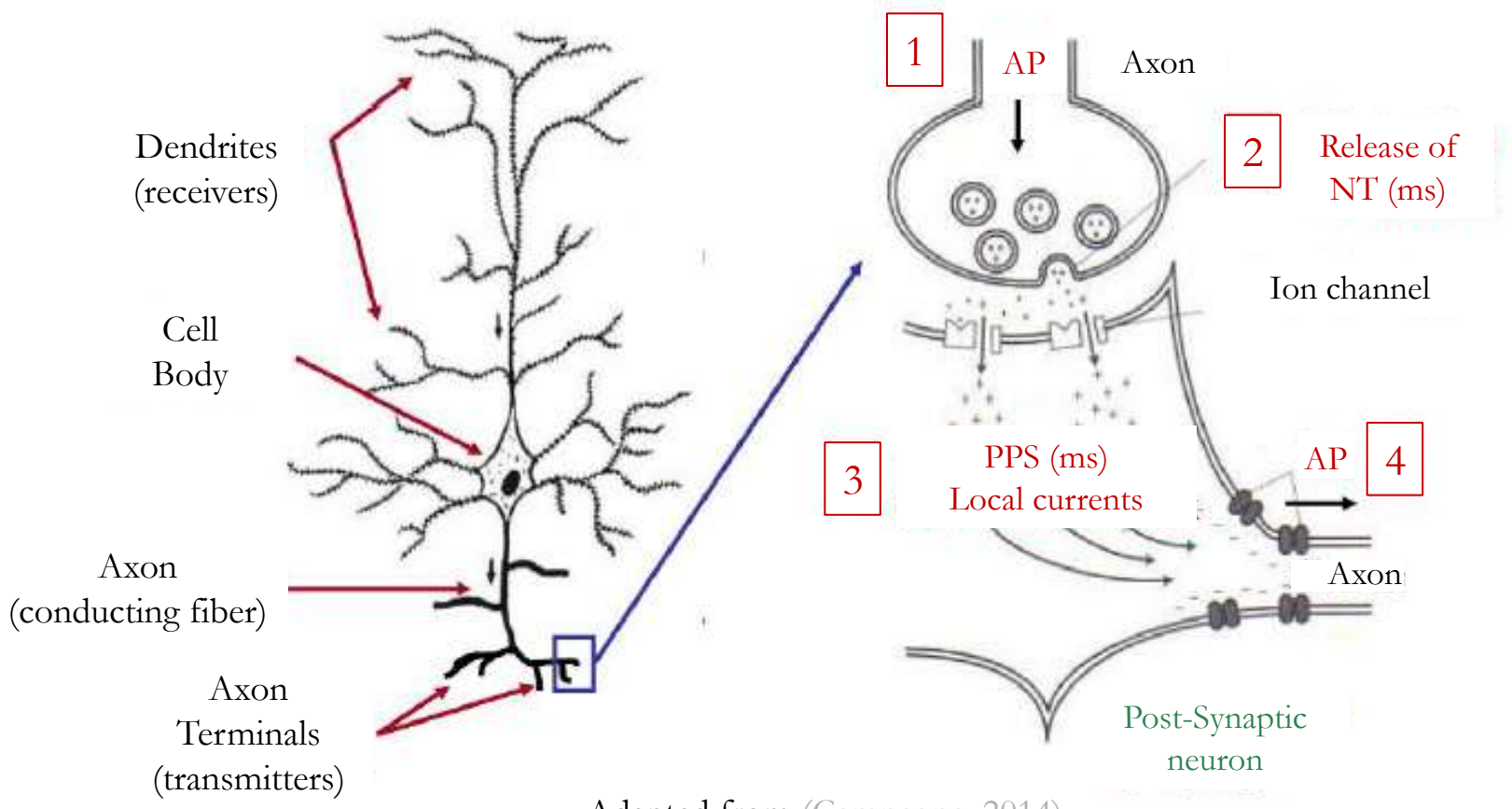
OUTLINE

- Introduction
- M/EEG signals
- Data acquisition
- Data analysis
- Illustrative example

M/EEG SIGNALS

ORIGINS

ORIGINS

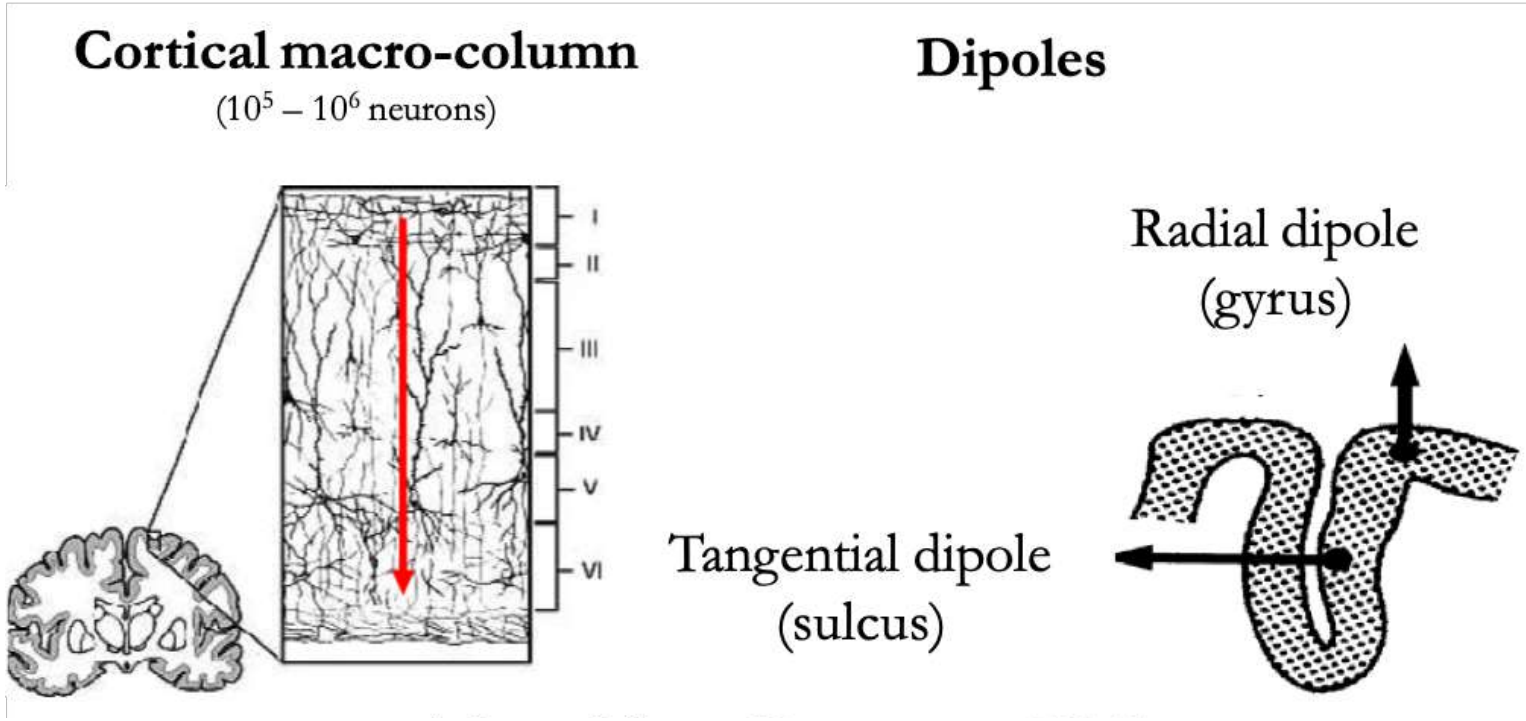


AP: Action Potential
NT: Neurotransmitters
PSP: Post-Synaptic Potentials

Adapted from (Campagne, 2014)

M/EEG signals come from **post-synaptic potentials**

ORIGINS



Adapted from (Campagne, 2014)

E/MEG signals result from the **spatial & temporal sum** of the activity at the level of a **large population** of synchronous neurons

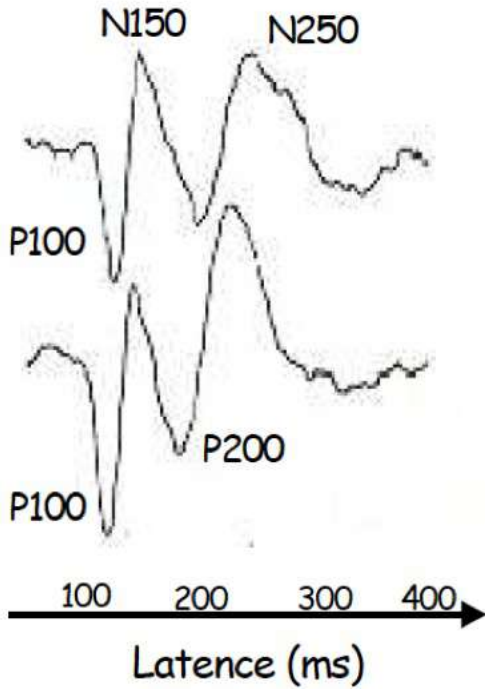
EVOKED RESPONSES - TODO

Nomenclature: the latency, the amplitude, the shape and the polarity

- Nxxx: one negative wave @ xxx ms (EEG)
- Pxxx: one positive wave @ xxx ms (EEG)
- Mxxx: one wave @ xxx ms (MEG)

Components

- Early components (exogenous): related to stimulus characteristics
- Late components (endogenous): related to the task, to the subject's state



Adapted from (Campagne, 2014)

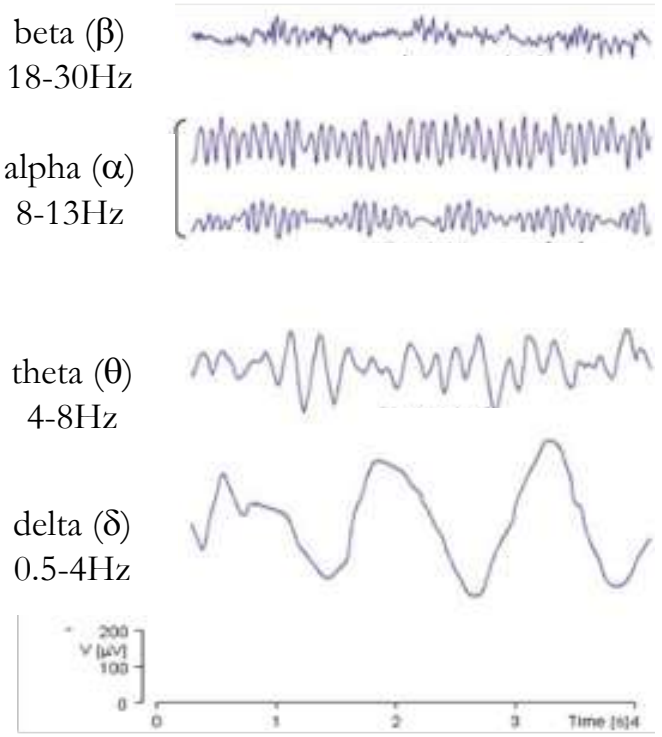
BCI application: P300 Speller

RHYTHMS (THALAMO-CORTICAL LOOPS)

Spontaneous activity, characteristics:

- Frequency
- Amplitude
- Shape
- Localization
- Psychopsychological context
- Duration
- Vanishing

alpha (α): 8-13Hz (occipital)
mu (μ): 7-11Hz (movement)
beta (β): 18-30Hz (motor)
gamma (γ): 30-50Hz (muscles)
delta (δ): 0.5-4Hz (sleep)



Adapted from (Campagne, 2014)

BCI application: motor-imagery based BCI

ORIGINS OF M/EEG SIGNALS – TO GO FURTHER

In French:

- P. Hot & S. Delplanque, *Electrophysiologie de la cognition,* 2013, Ed. Dunod, ISBN: 9782100593064

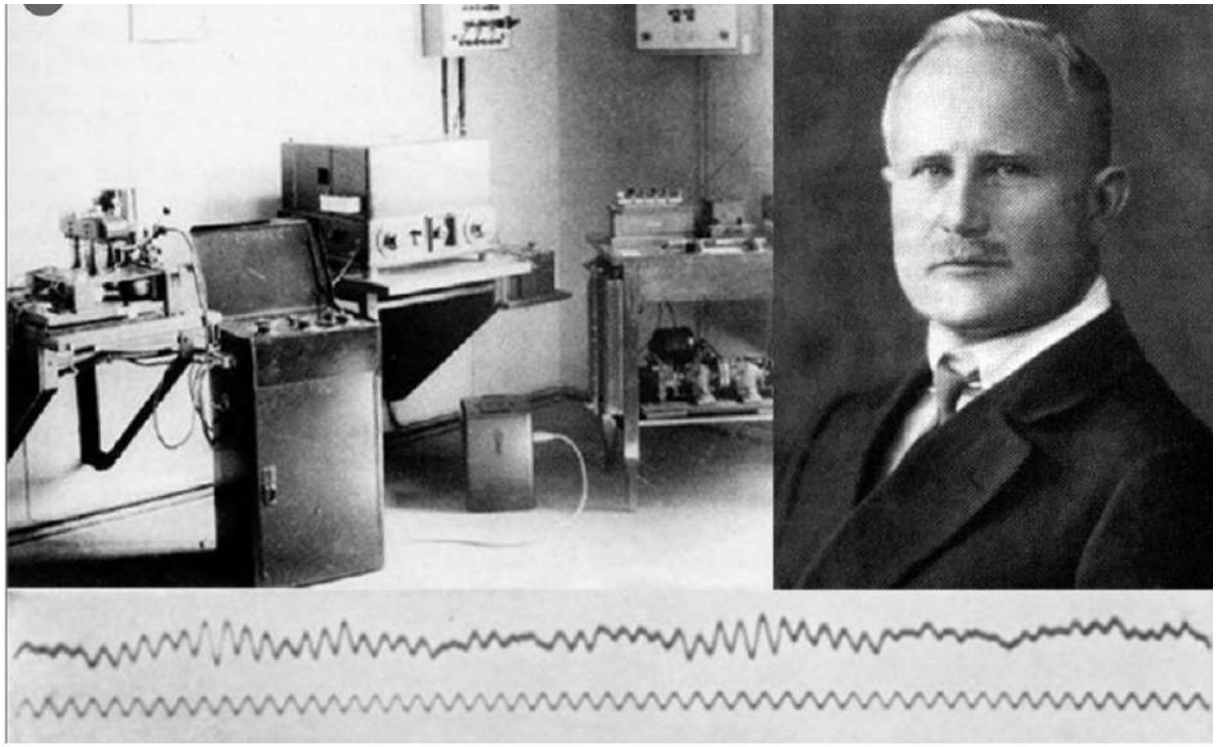
In English:

- Hämäläinen et al, *Magnetoencephalography theory, instrumentation, and applications to noninvasive studies of the working human brain*, 1993, doi: 10.1103/RevModPhys.65.413

DATA ACQUISITION

INSTRUMENTATION & MEASUREMENTS

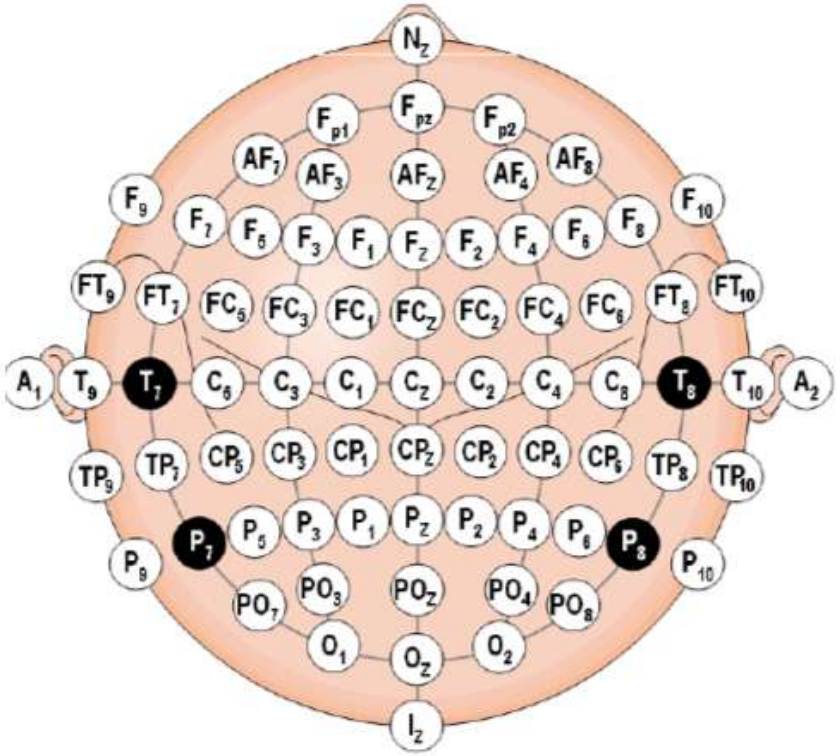
EEG INSTRUMENTATION



First EEG recordings

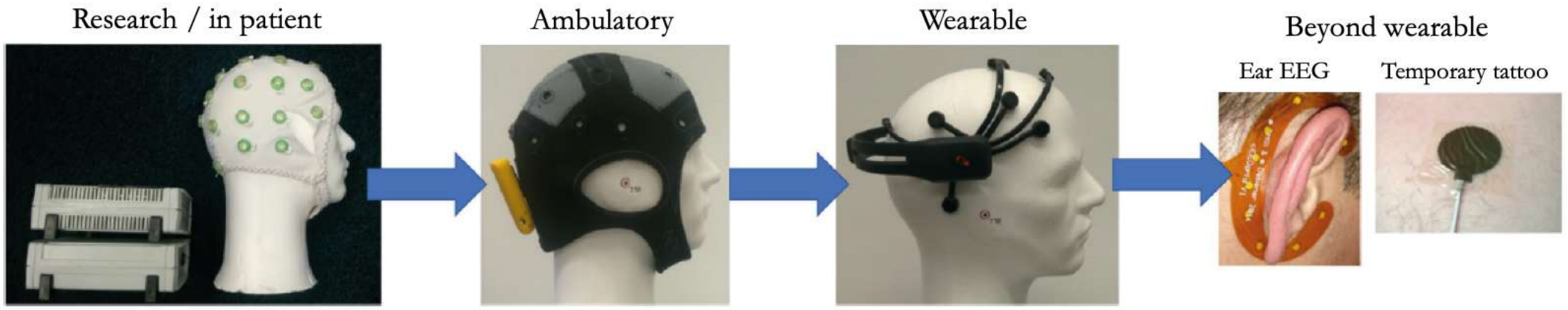
Nice resource dedicated to the pioneers of the EEG -> here

EEG INSTRUMENTATION



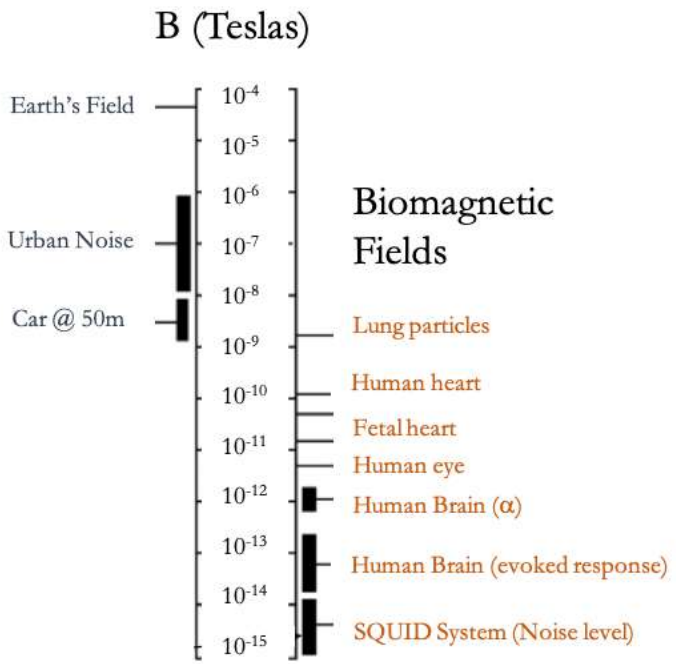
Electrode localization adapted from [Sharbrough, 1991]

EEG INSTRUMENTATION

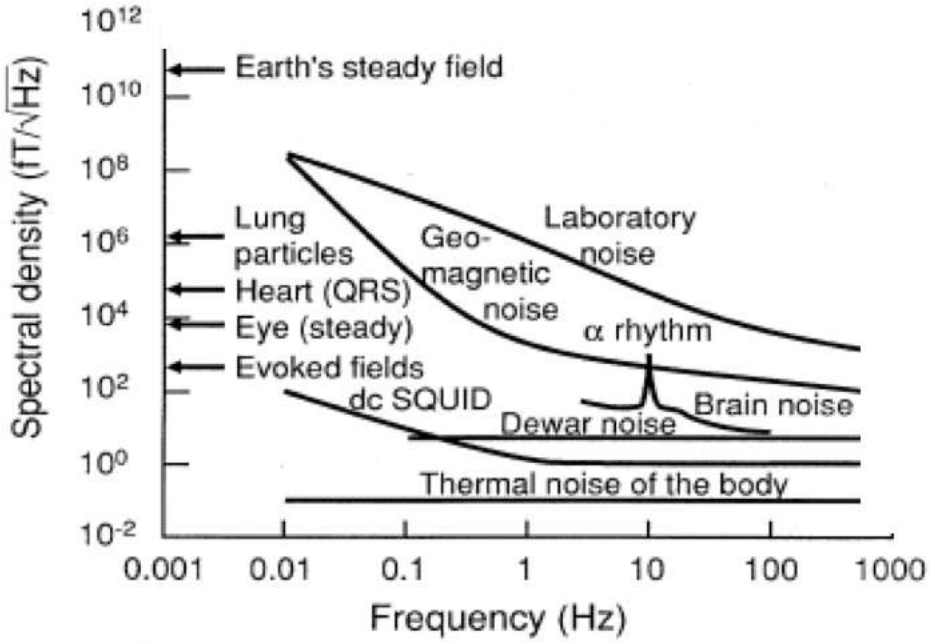


Overview of the evolution of EEG modalities, adapted from [Casson, 2019]

MEG INSTRUMENTATION

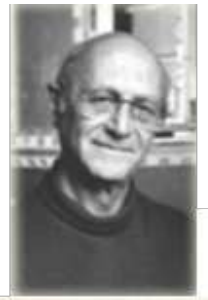


Adapted from [Garnero, 2011]

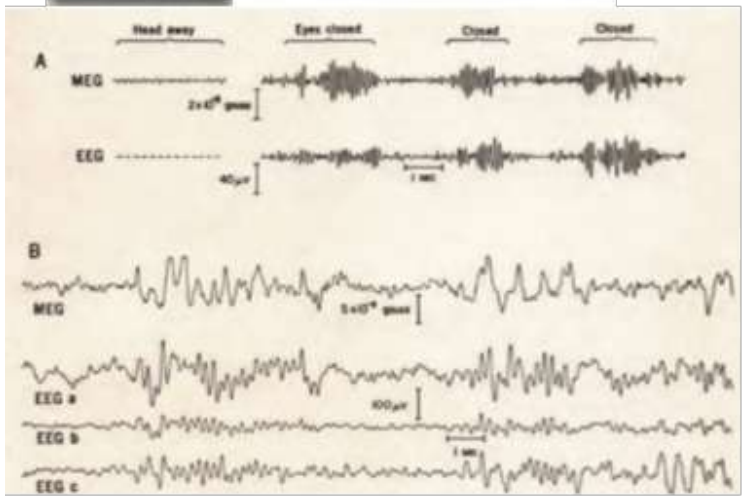


Adapted from [Hämäläinen, 1993]

MEG INSTRUMENTATION



David Cohen



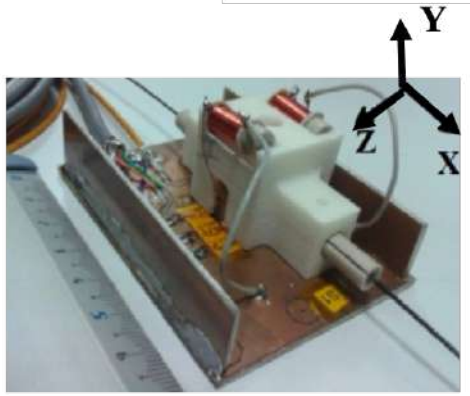
Registration obtained in 1971

1st MEG device

MEG INSTRUMENTATION

Current MEG device

OPM devices by Cerca



^{4}He OPM & experimental setup adapted from [Labyt, Corsi et al, 2019]

TAKE-HOME MESSAGES

	MEG	EEG
Measurement	Magnetic field, + intracellular currents	Difference of electric potentials, + extracellular currents
Spatial resolution	1 cm	2-3 cm
Temporal resolution	1 ms or less	
Avantages	- Absolute values - Less affected by bone - Focal	- Portable - Cost
Drawbacks	- Financial & mechanical constraints - Sensitive to physiological artifacts	- Need of a reference - Affected by bone - Diffuse - Sensitive to physiological artifacts

DATA ANALYSIS

THE MAIN STEPS (OFFLINE)

DATA ANALYSIS – PRELIMINARY REMARKS

Plethora of methods to preprocess and analyze your data but before everything :

- Have a look to your data

- Take the time to consider different preprocessing pipelines instead of applying one blindly
  - Each method has its pro/cons
  - Some of them can **alter** your signal (filters)
  - It strongly depends on the quality of your dataset
  - It depends on the **purpose of your study**

The simpler the better !

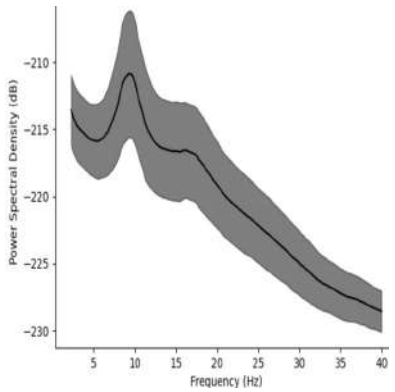
DATA ANALYSIS – MAIN STEPS

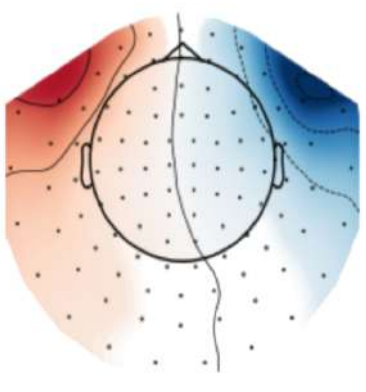
Data inspection

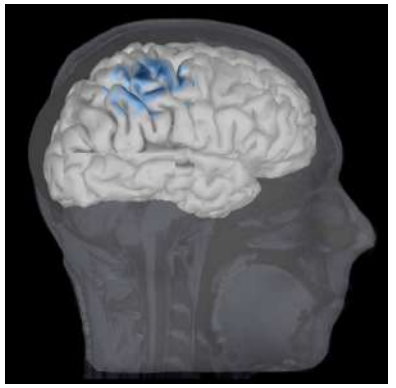
Artifacts removal

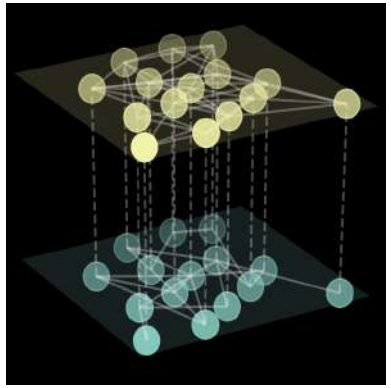
Source reconstruction

Advanced analysis



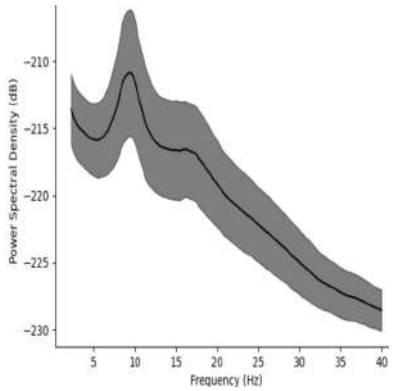


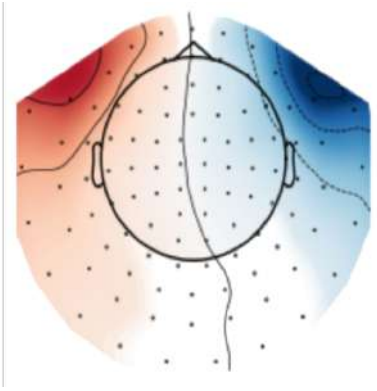


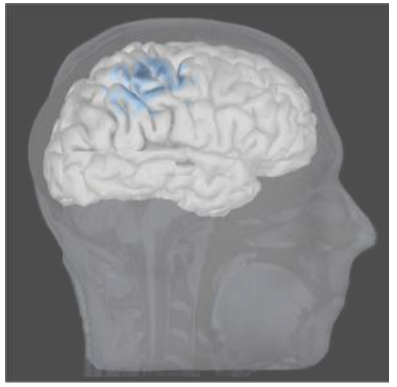


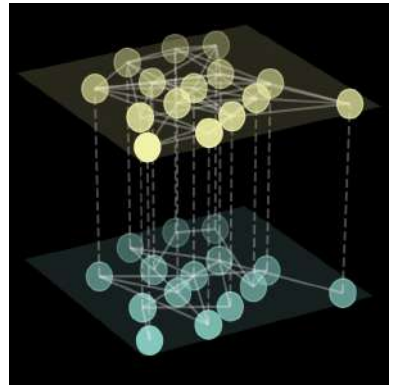
DATA ANALYSIS – MAIN STEPS

Data inspection → Artifacts removal → Source reconstruction → Advanced analysis



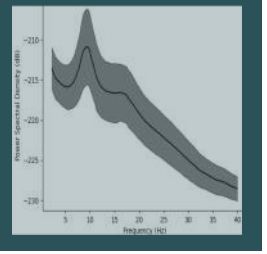






The most crucial steps – addressed here

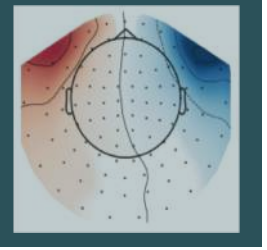
DATA INSPECTION



- Questions
  - What kind of artifacts do I have ?
  - Do they present a pattern ?
  - Do they affect one/several channels ?
  - How long do they last ?

- Tools to address them
  - Timeseries
  - Power spectra
  - Use of biosignals/triggers to detect events

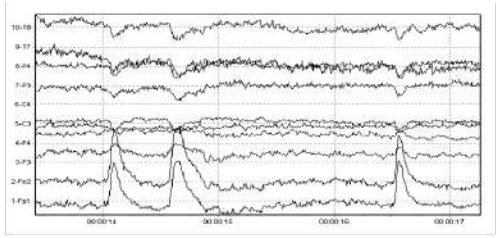
ARTIFACTS REMOVAL – WHAT METHODS ?

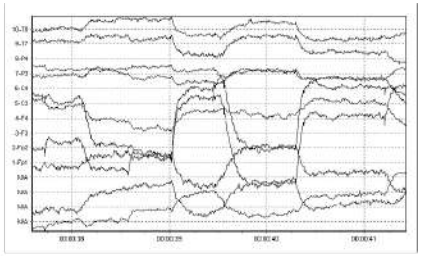


Depends on the type of artifacts & your problematic to be addressed

- Powerline & need to study activity in the gamma band

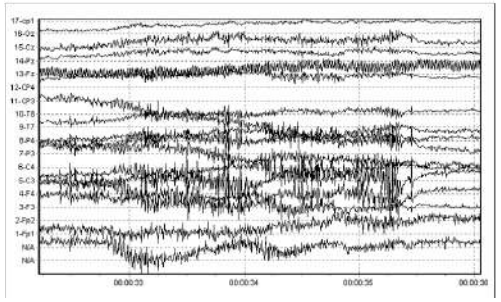
⇒ Notch filter @ 50Hz

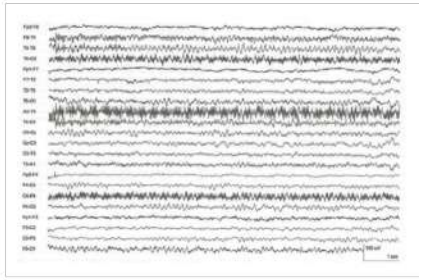




- Clear patterns (blinks, saccades, cardiac activity)

⇒ Independent component analysis & use of biosignals

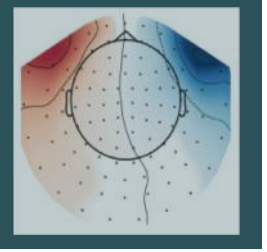




- A broken channel

⇒ Interpolation (depends on the location though)

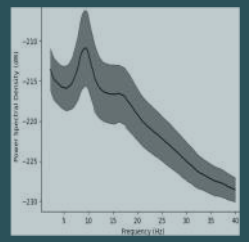
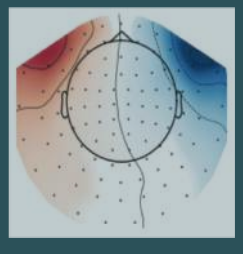
ARTIFACTS REMOVAL – QUALITY CHECK

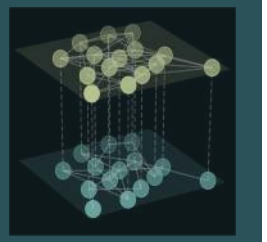


Do not underestimate this step to assess the efficacy of your pipeline !

- Timeseries & power spectra before vs after
- Identify suited judgement criteria: variance, zscore…

DATA ANALYSIS – TOOLS



Matlab

Python

FieldTrip

Brainstorm

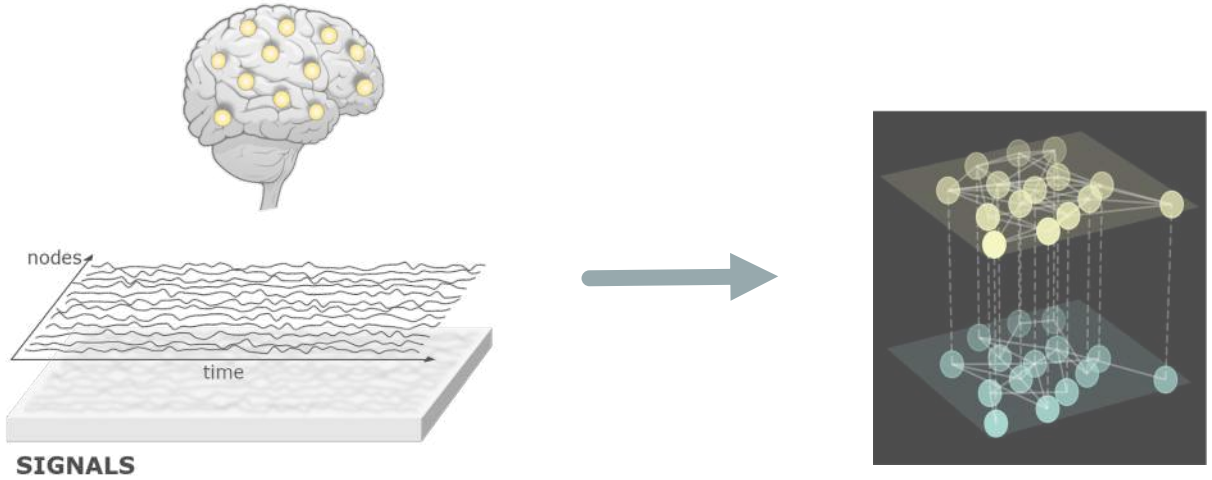
MNE
MEG + EEG ANALYSIS & VISUALIZATION

All of them provides **tips** and **tutorials** to guide you in the analysis of your dataset !

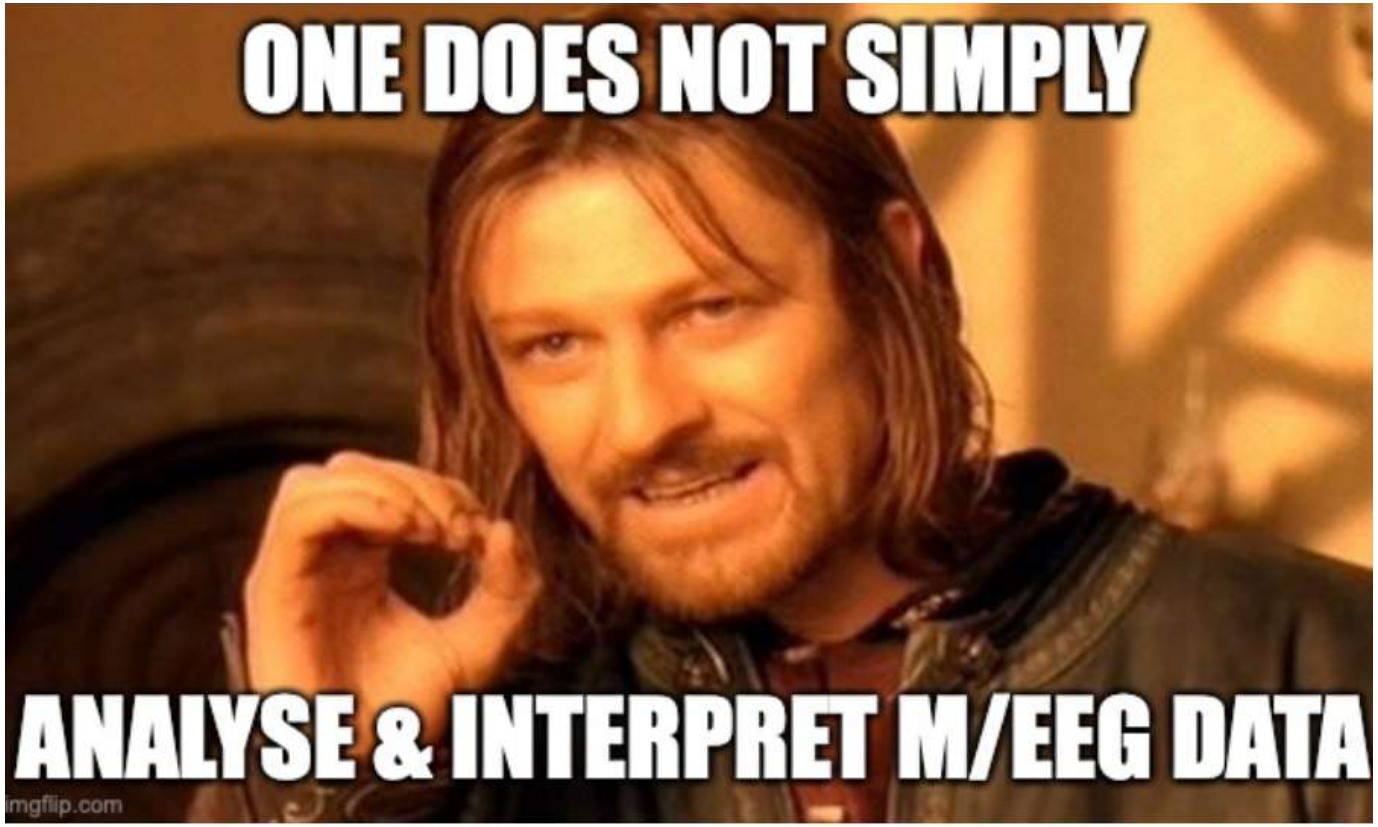
TAKE HOME MESSAGES

Before applying any filter/method:

- During the experiment, take notes
- Take the time to inspect your data !
- Construct (and test !) a suited pipeline with QC

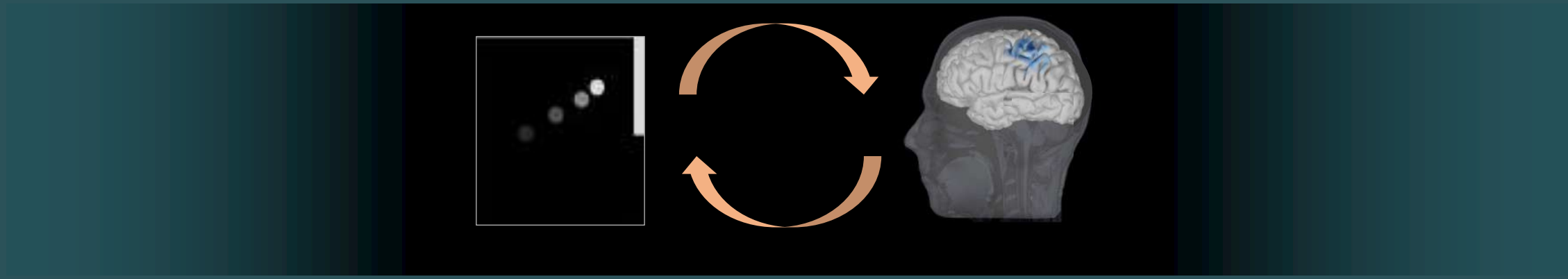


SINCE…



If you want to go further, here is an example with references

Thank you for your attention !



Webpage & contact

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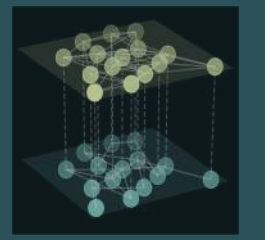
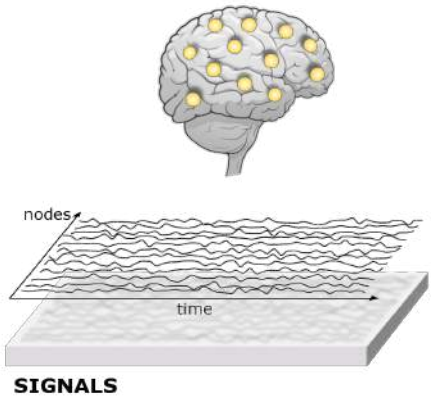
MConstanceCorsi

DATA ANALYSIS – ADVANCED





(Gonzalez-Astudillo et al, 2020)

(De Vico Fallani & Bassett, 2019)

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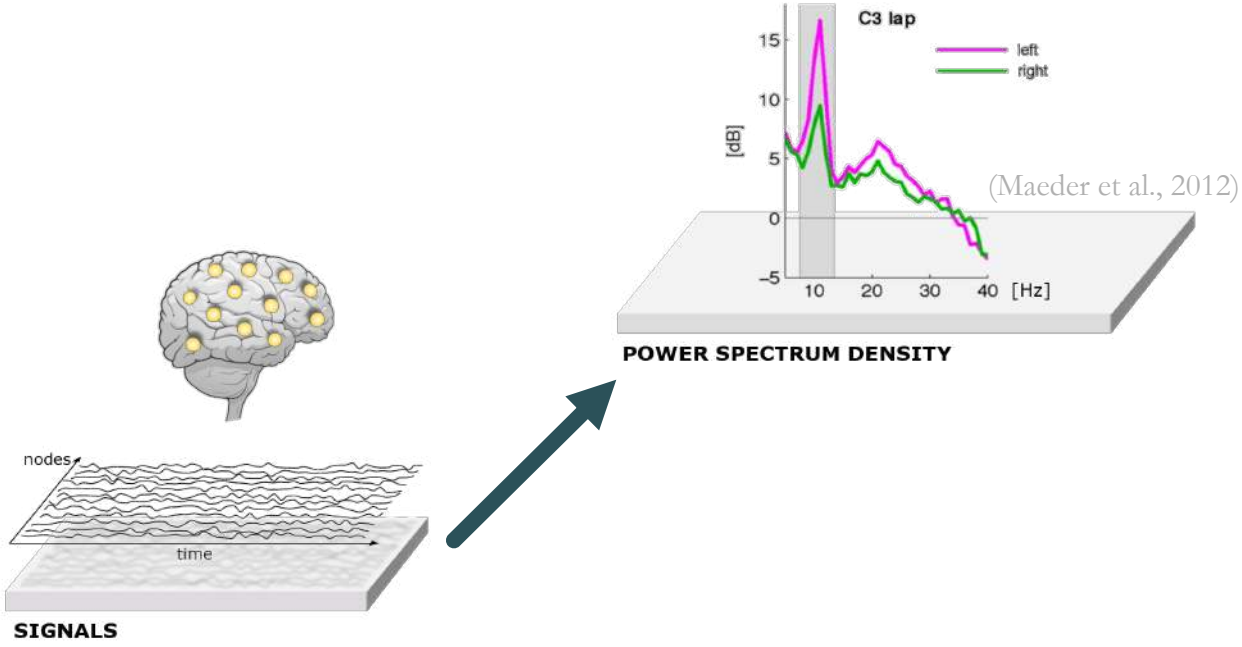

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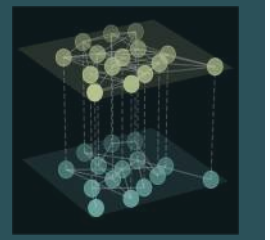

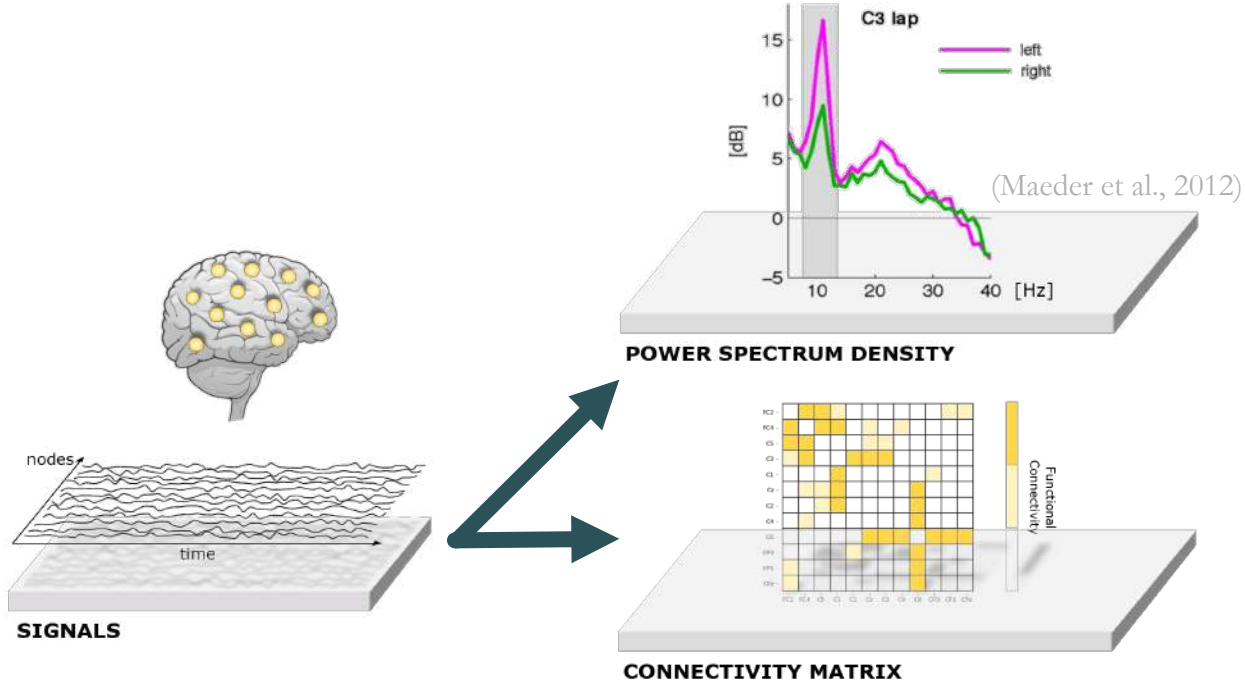

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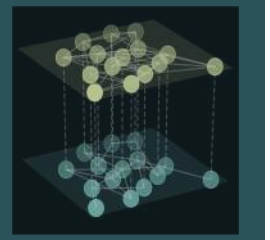

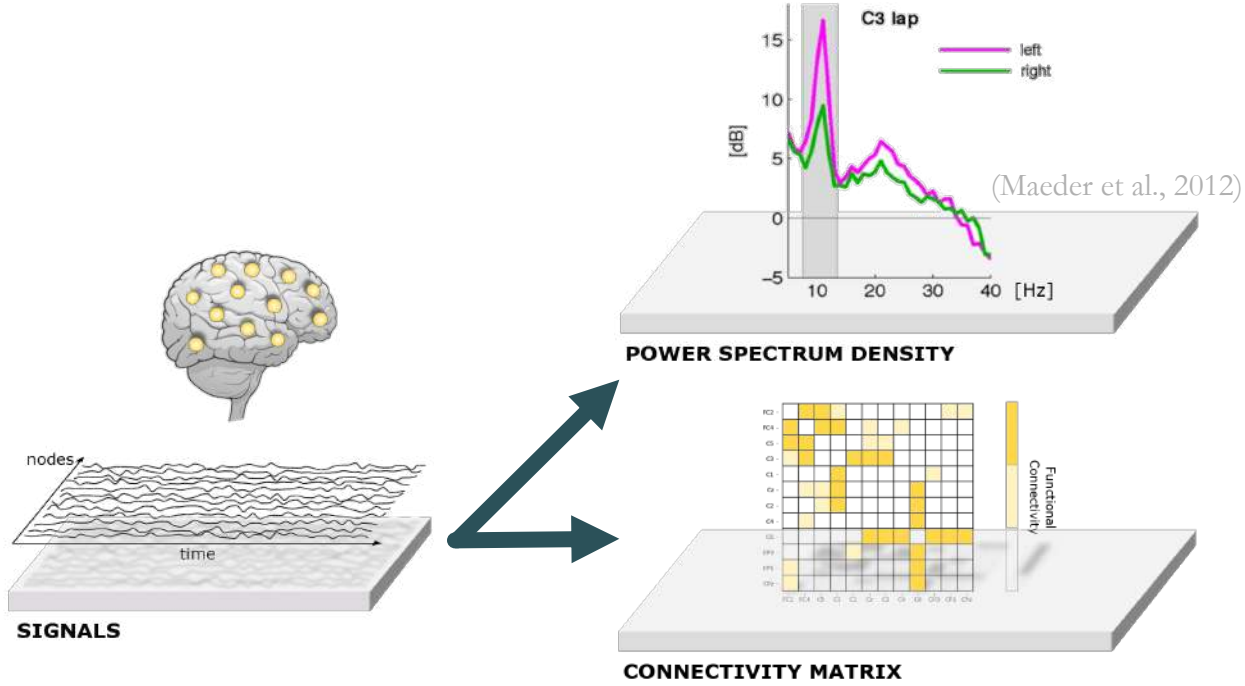

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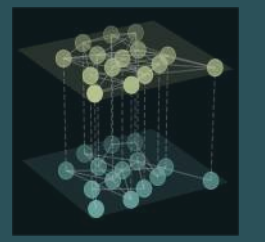

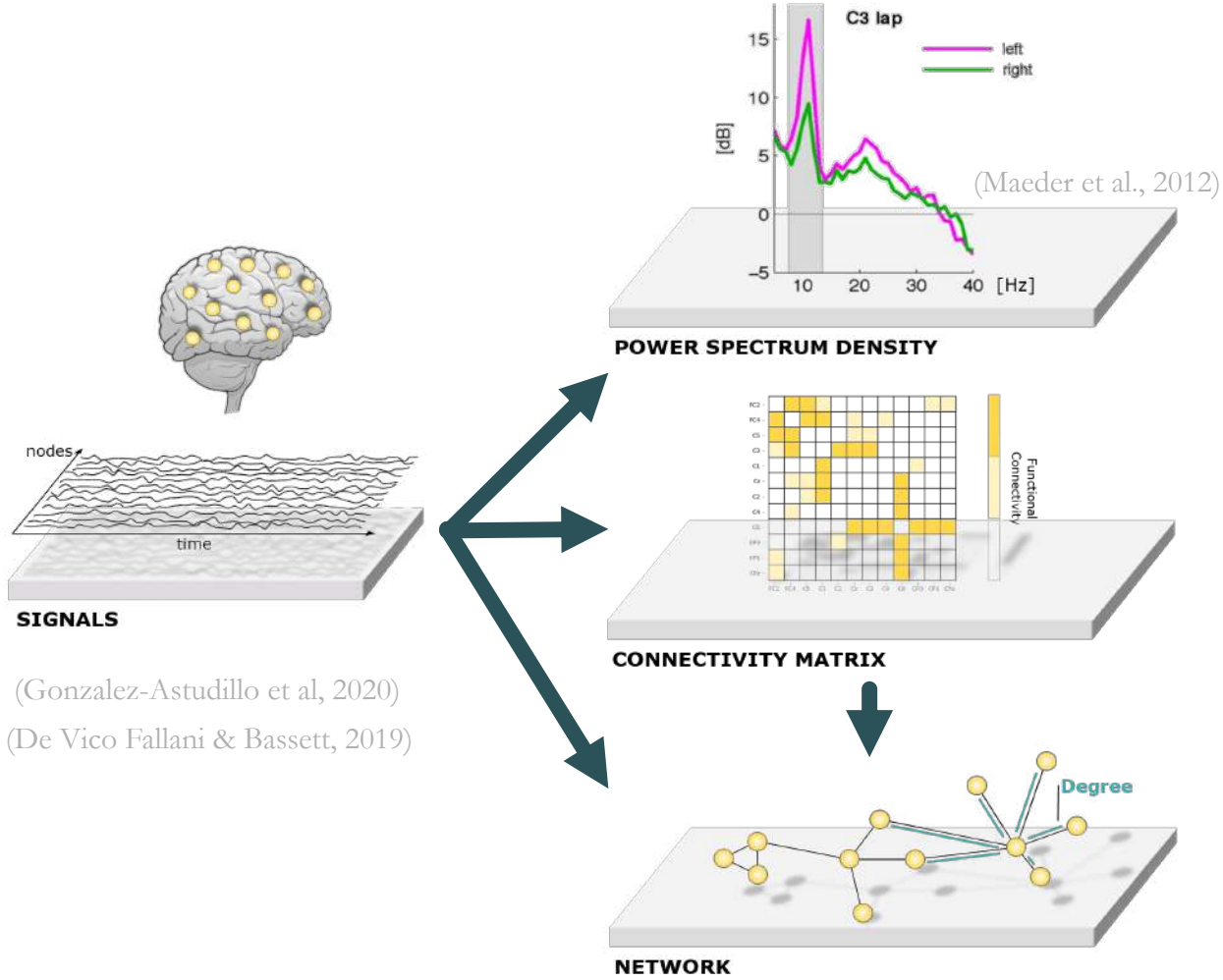

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