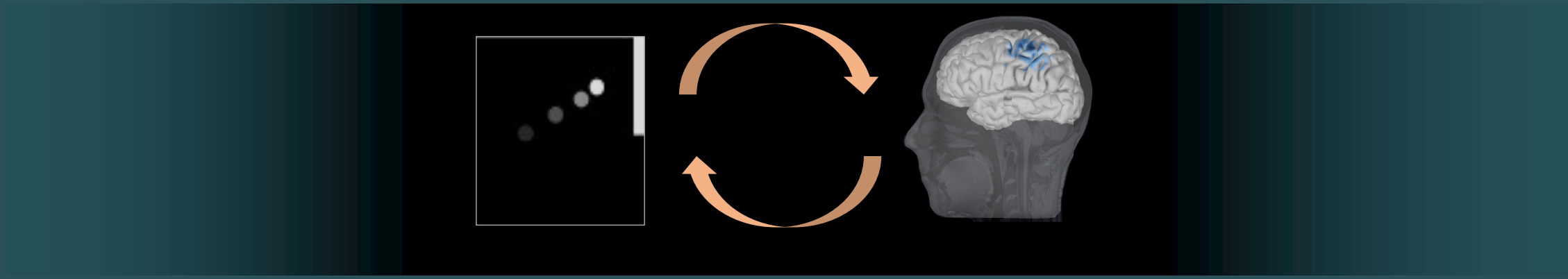
M/EEG DATA ANALYSIS: WHERE IT ALL BEGINS !



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

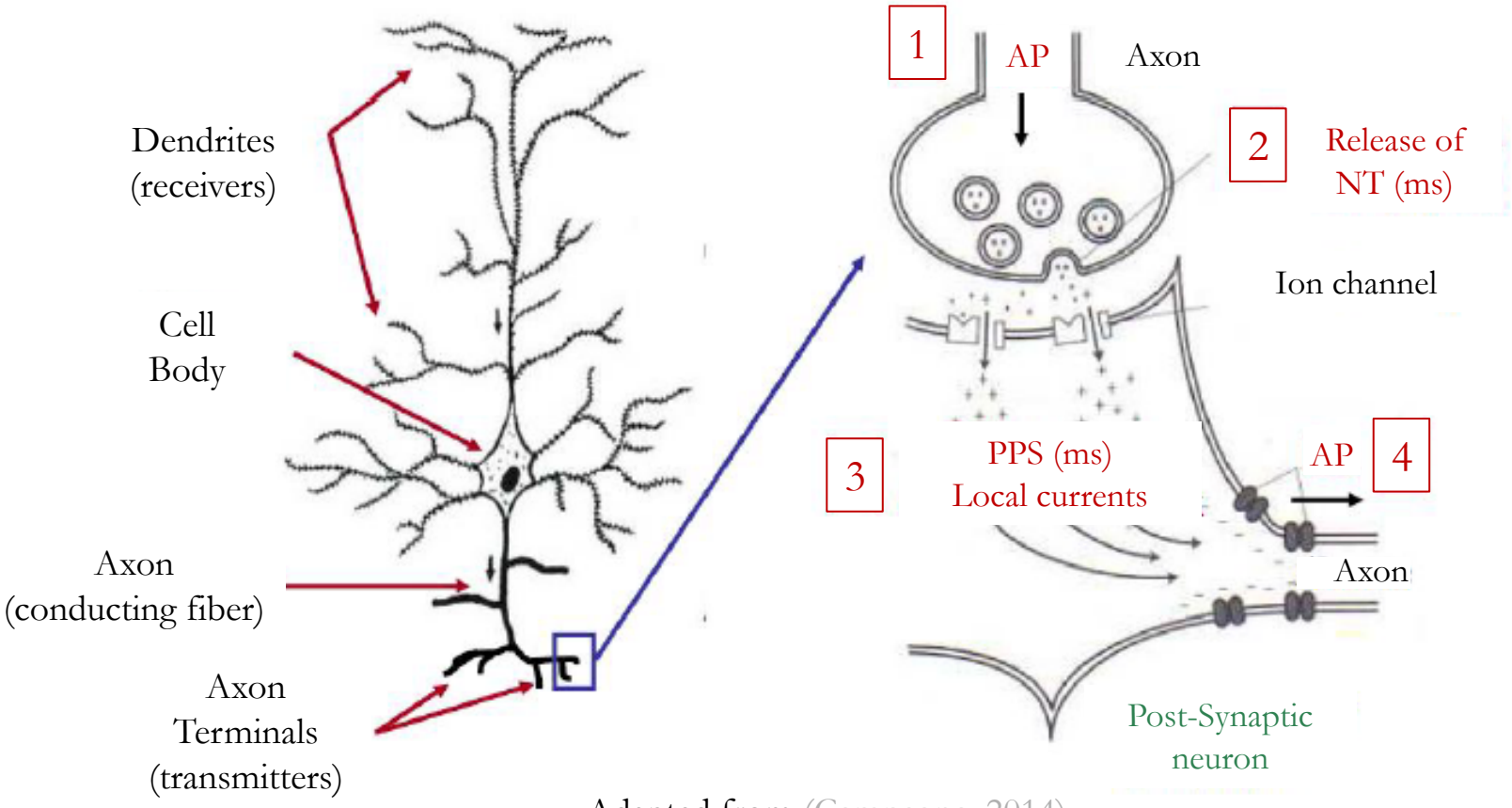
Question addressed here:

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

M/EEG SIGNALS

ORIGINS

ORIGINS

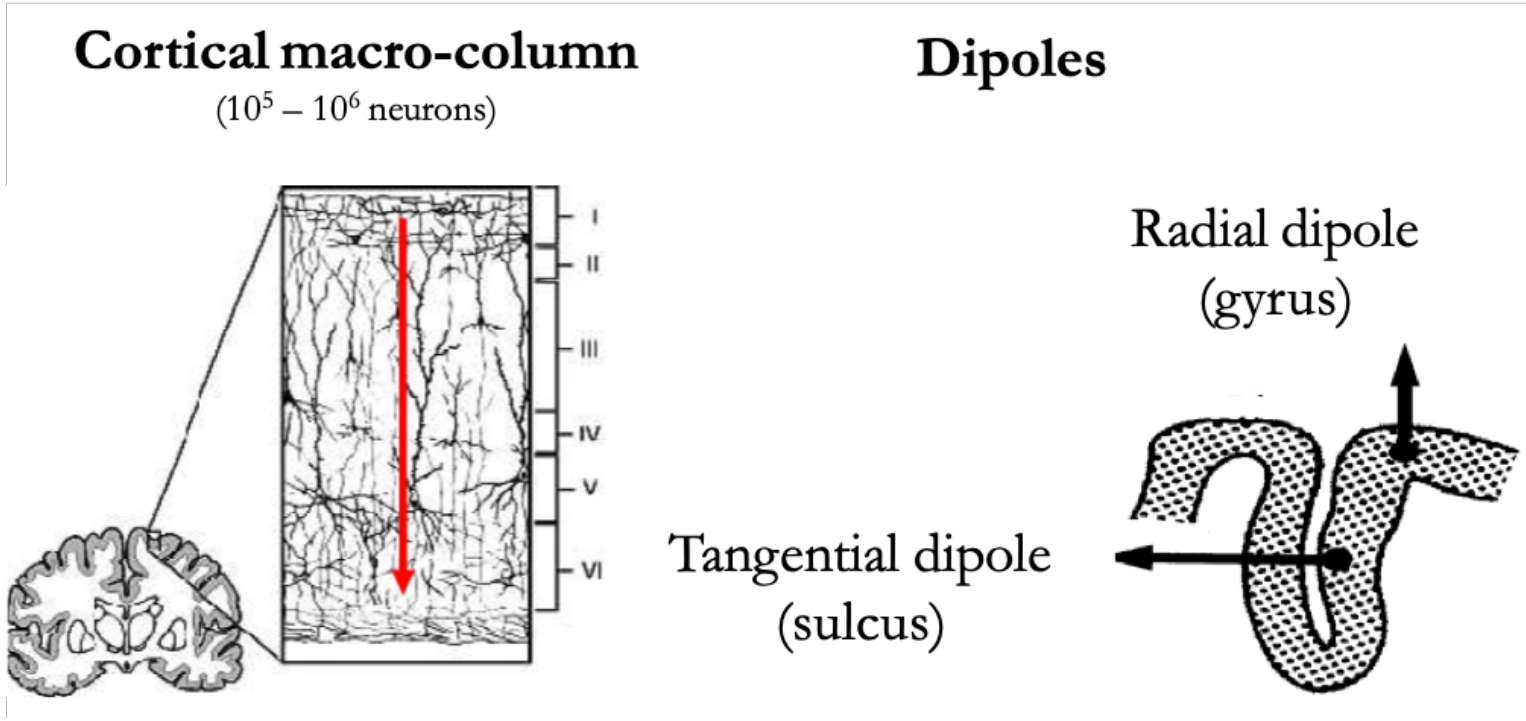


AP: Action Potential
NT: Neurotransmitters
PSP: Post-Synaptic Potentials

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

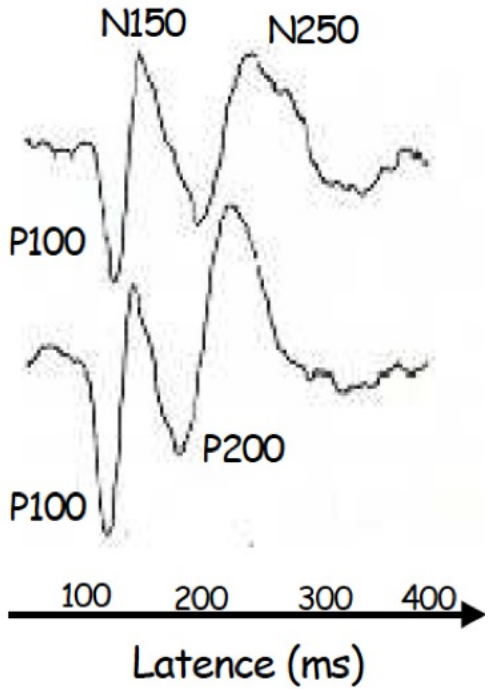
EVOKED RESPONSES

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



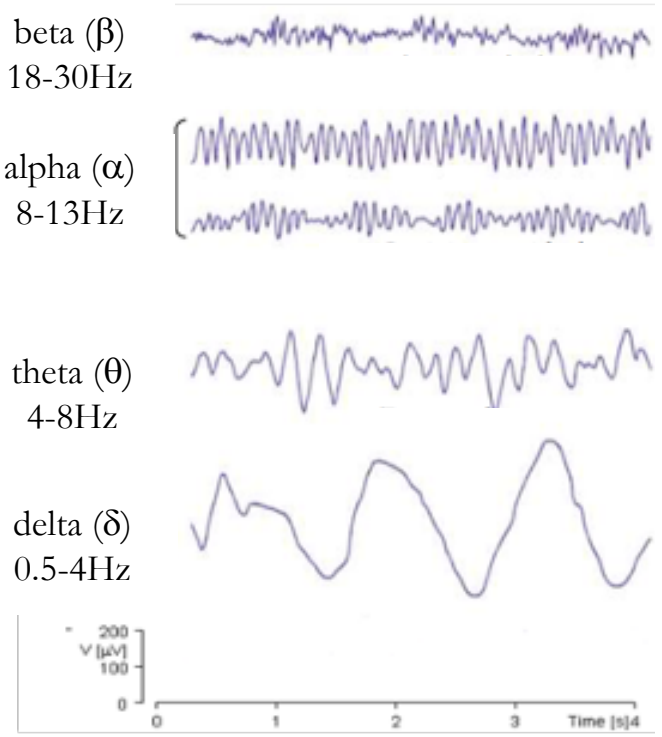
Adapted from (Campagne, 2014)

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

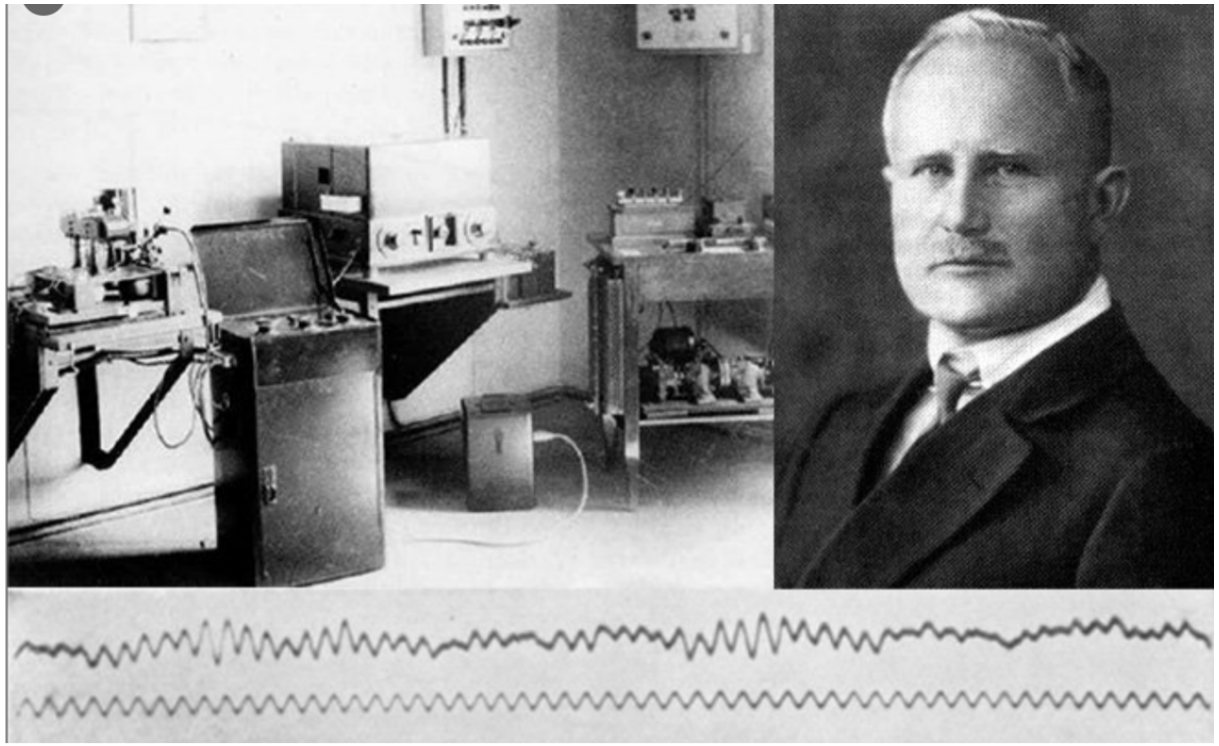
In English:

- 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

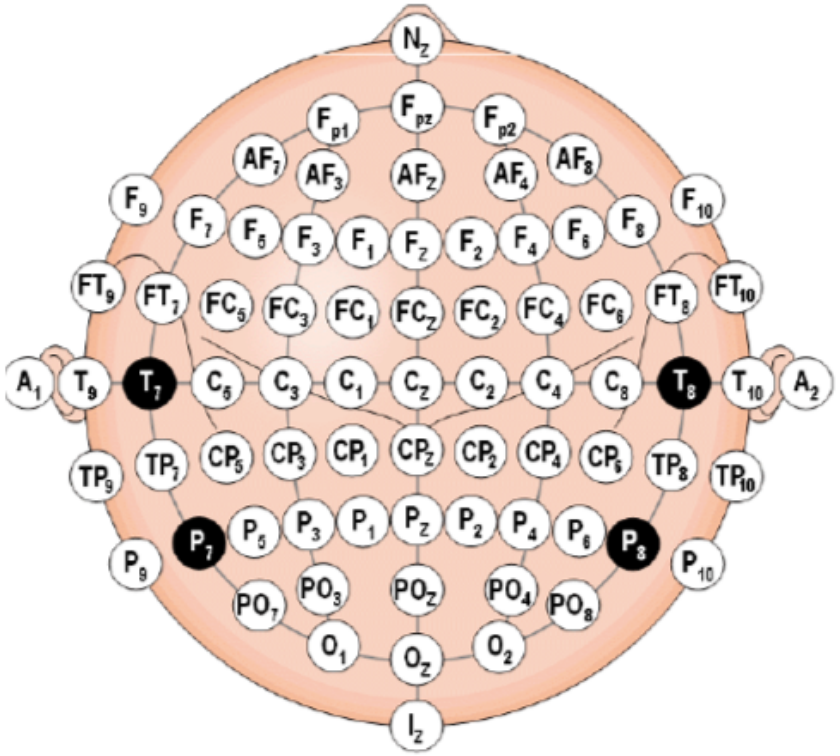
EEG INSTRUMENTATION



First EEG recordings

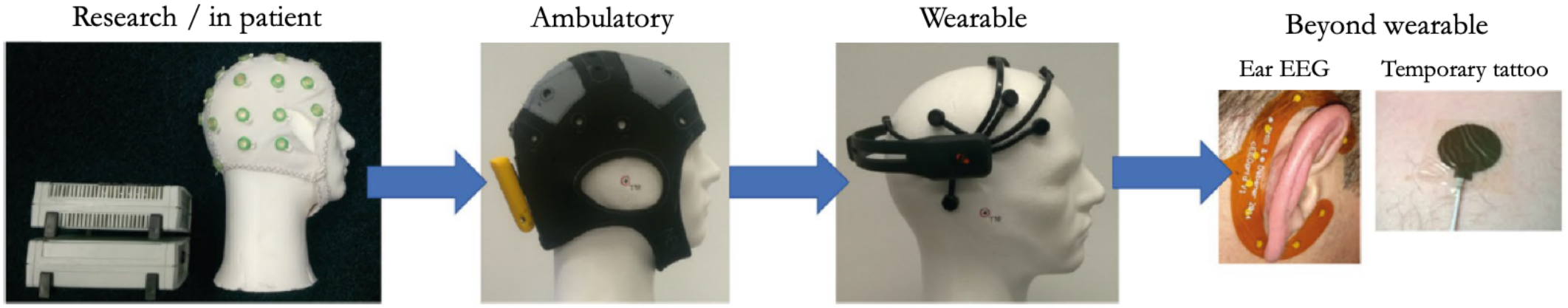
Nice resource dedicated to the pioneers of the EEG -> here

EEG INSTRUMENTATION



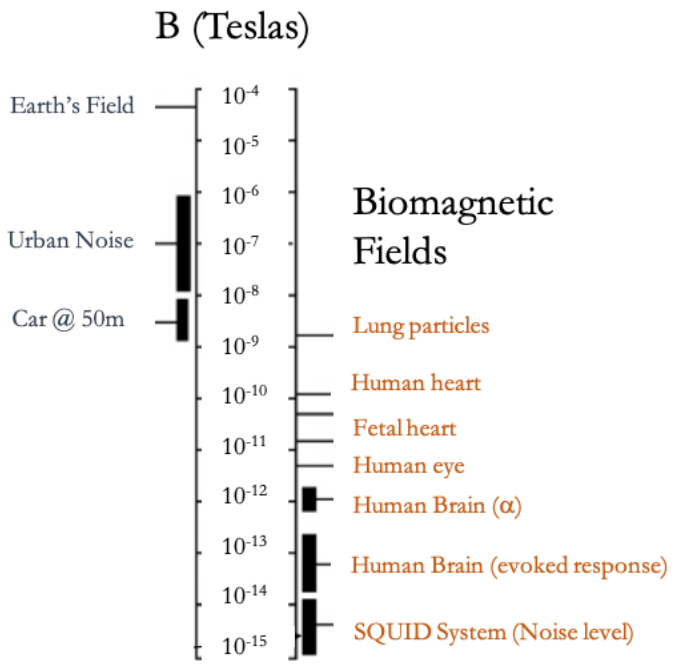
Electrode localization, adapted from (Sharbrough, 1991)

EEG INSTRUMENTATION

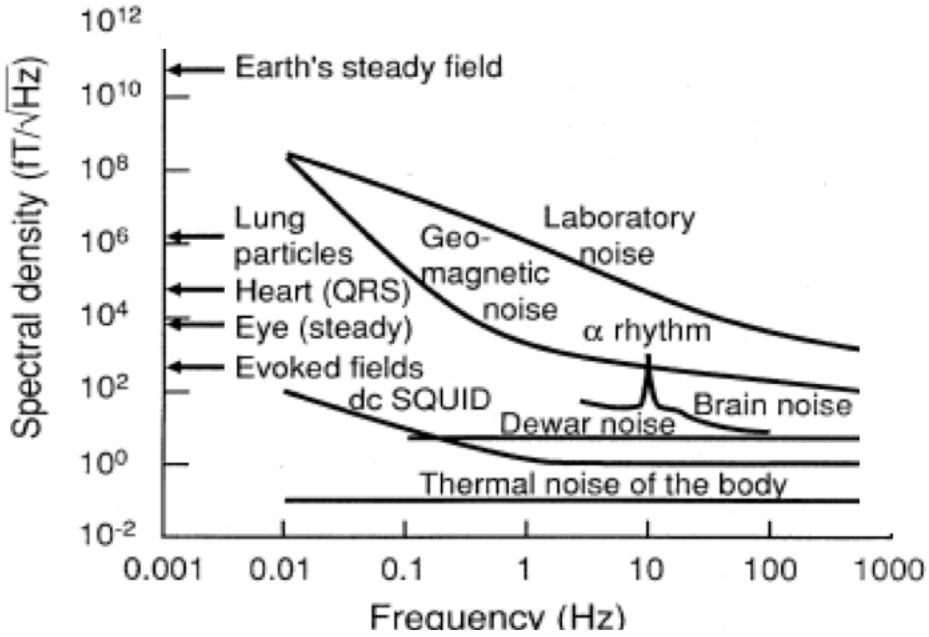


Overview of the evolution of EEG modalities, adapted from (Casson, 2019)

MEG INSTRUMENTATION

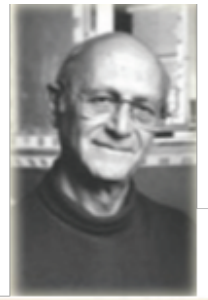


Adapted from (Garneto, 2011)

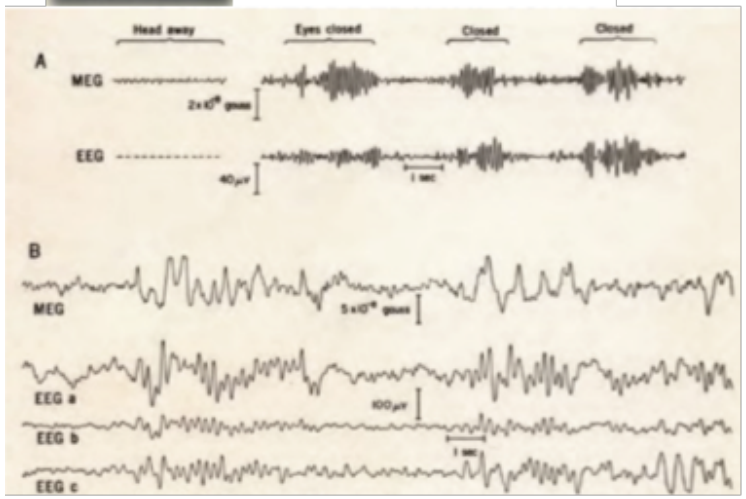


Adapted from (Hämäläinen et al, 1993)

MEG INSTRUMENTATION



David Cohen



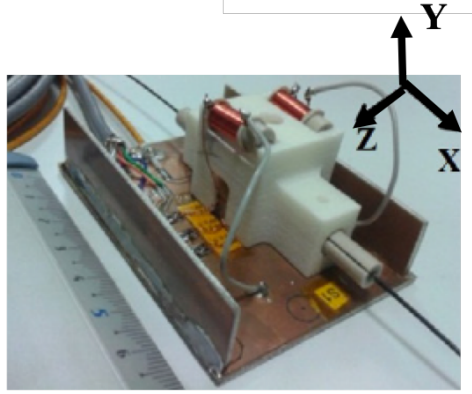
Registration obtained in 1971

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 !

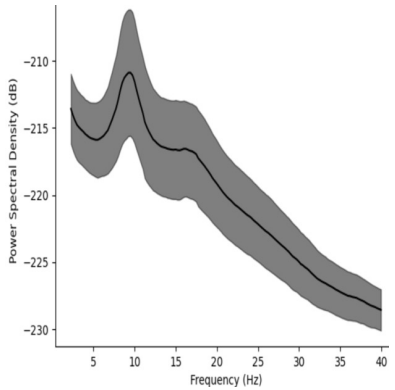
DATA ANALYSIS – MAIN STEPS

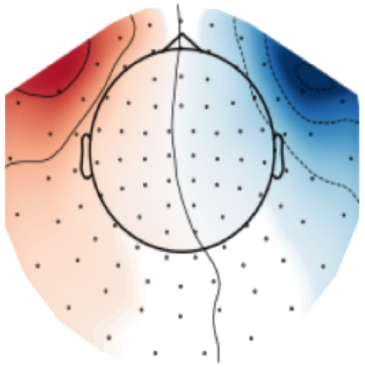
Data inspection

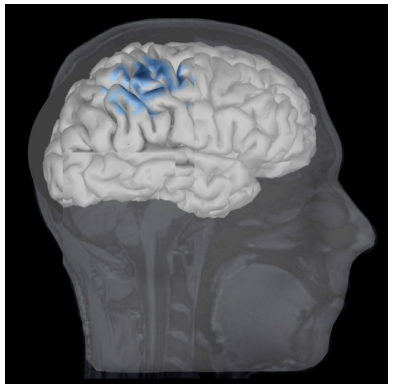
Artifacts removal

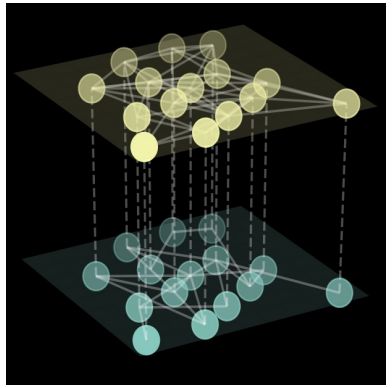
Source reconstruction

Advanced analysis



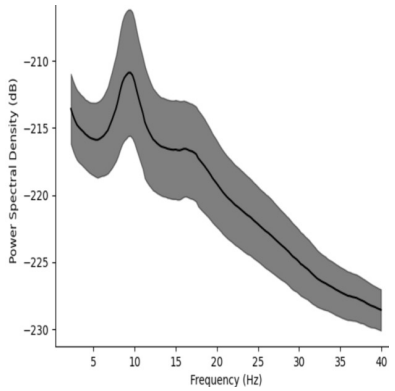


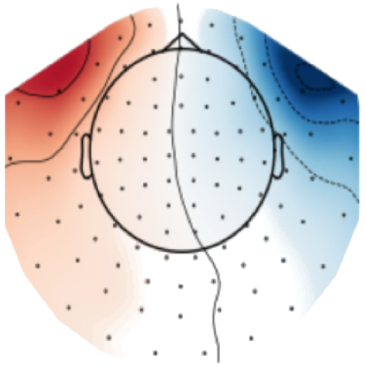


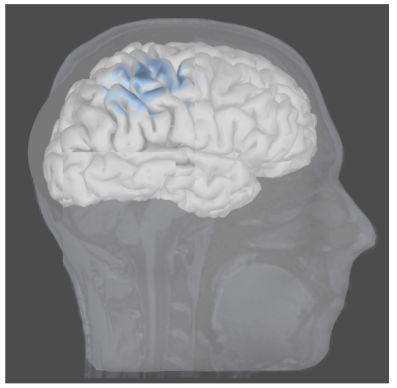


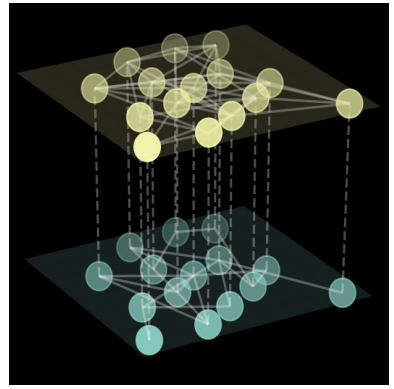
DATA ANALYSIS – MAIN STEPS

Data inspection → Artifacts removal → Source reconstruction → Advanced analysis



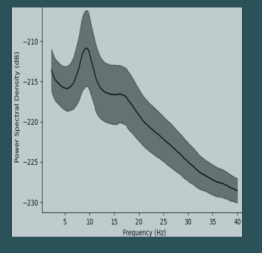






The most crucial steps – addressed here

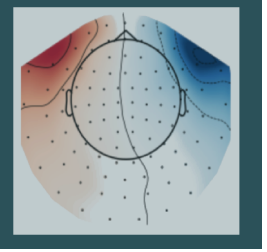
DATA INSPECTION



- 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

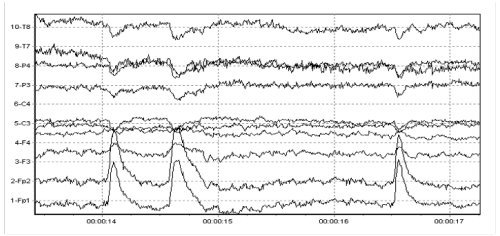
ARTIFACTS REMOVAL – WHAT METHODS ?

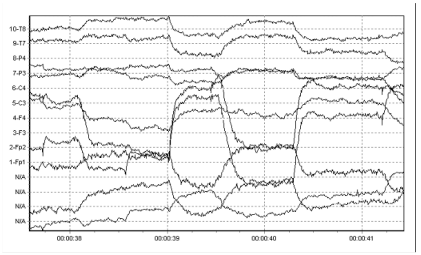


Depends on the type of artifacts & your problematic to be addressed

- Powerline & need to study activity in the gamma band

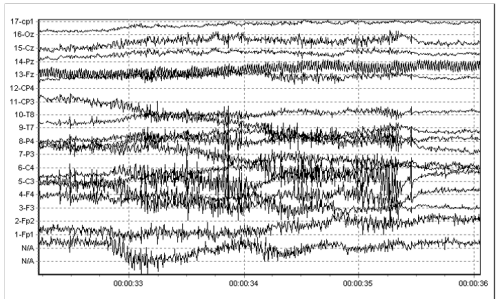
⇒ Notch filter @ 50Hz

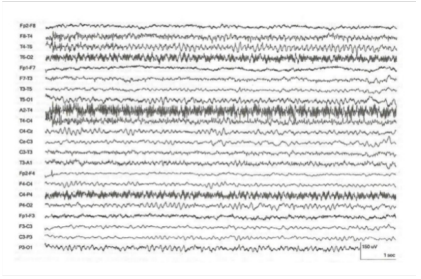




- Clear patterns (blinks, saccades, cardiac activity)

⇒ Independent component analysis & use of biosignals

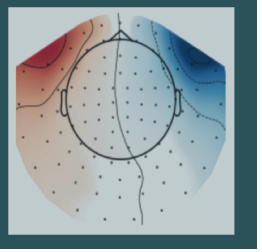




- A broken channel

⇒ Interpolation (depends on the location though)

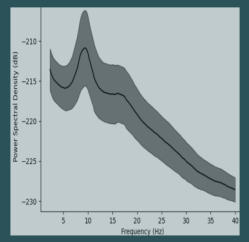
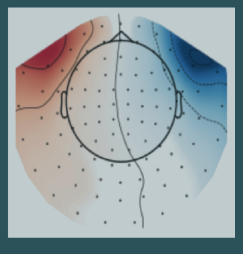
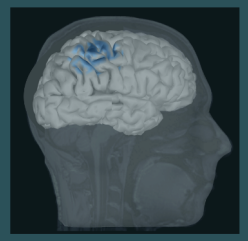
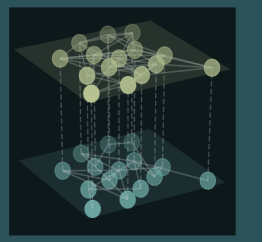
ARTIFACTS REMOVAL – QUALITY CHECK



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

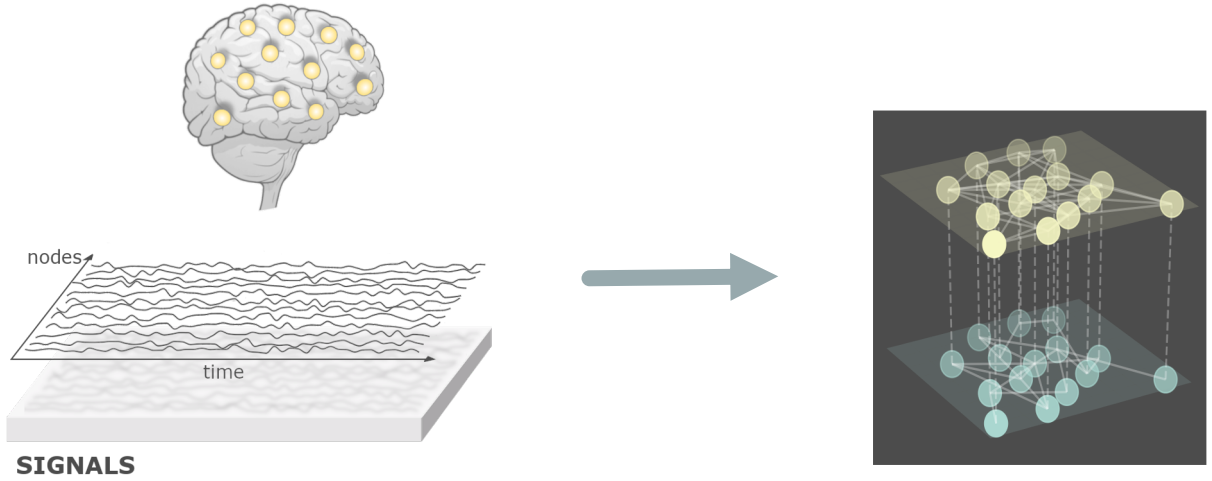
MNE
MEG + EEG ANALYSIS & VISUALIZATION

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

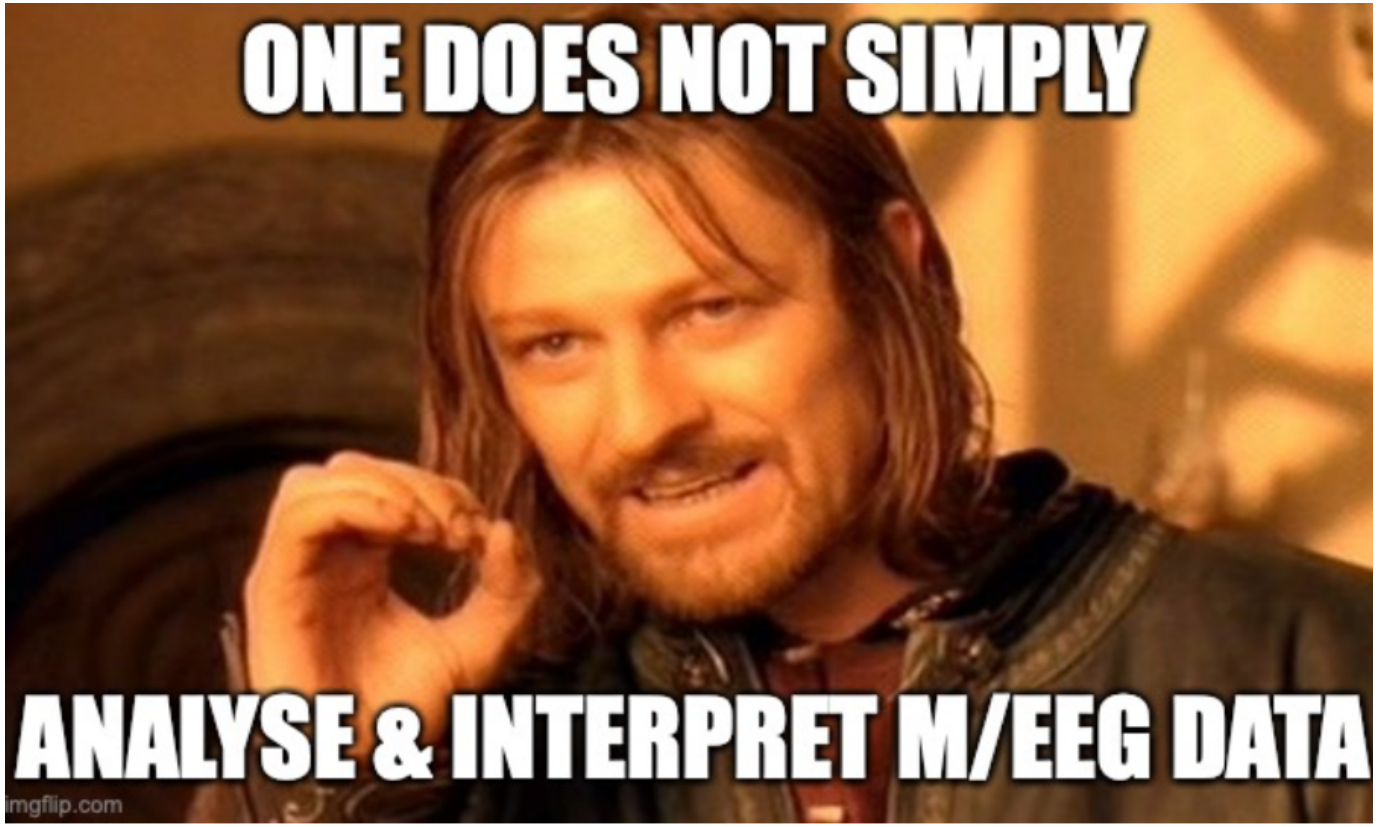
TAKE HOME MESSAGES

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

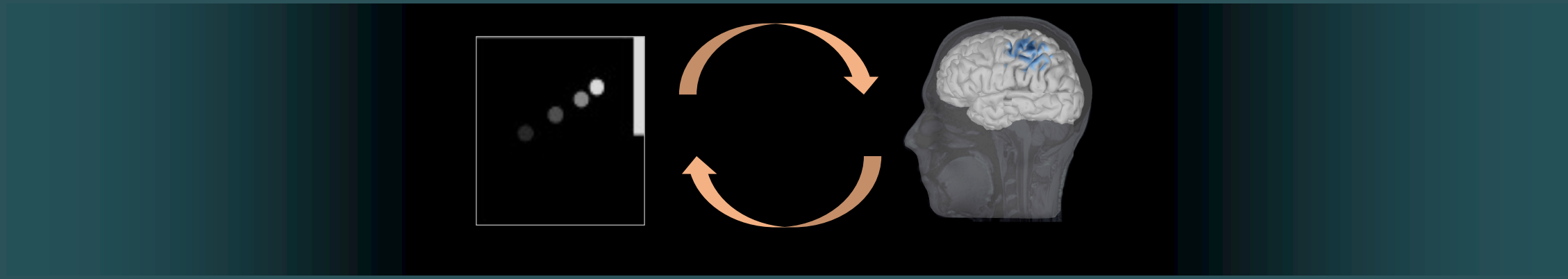


SINCE…



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

Thank you for your attention !



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