# Brain network dynamics in health and disease

*Lab Presentation Day*
*International Master Course in Neuroscience – University of Trieste*
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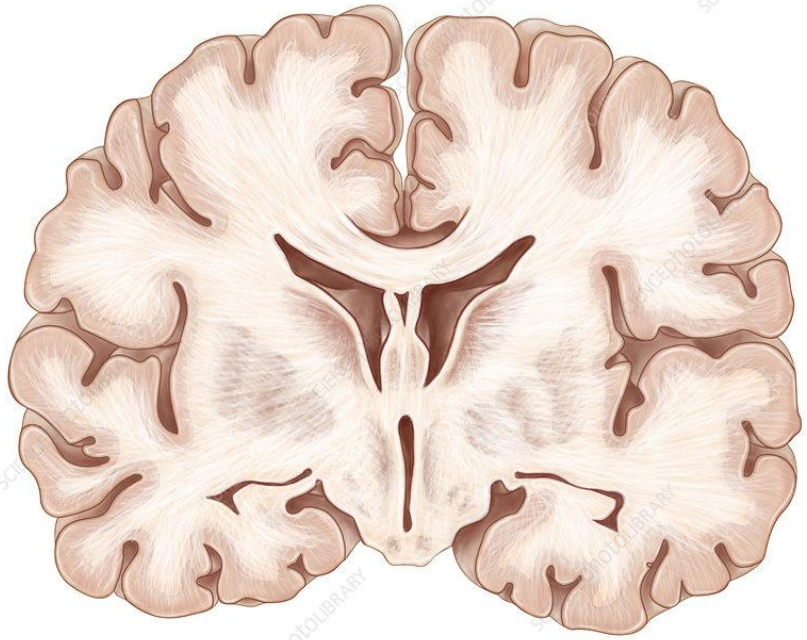
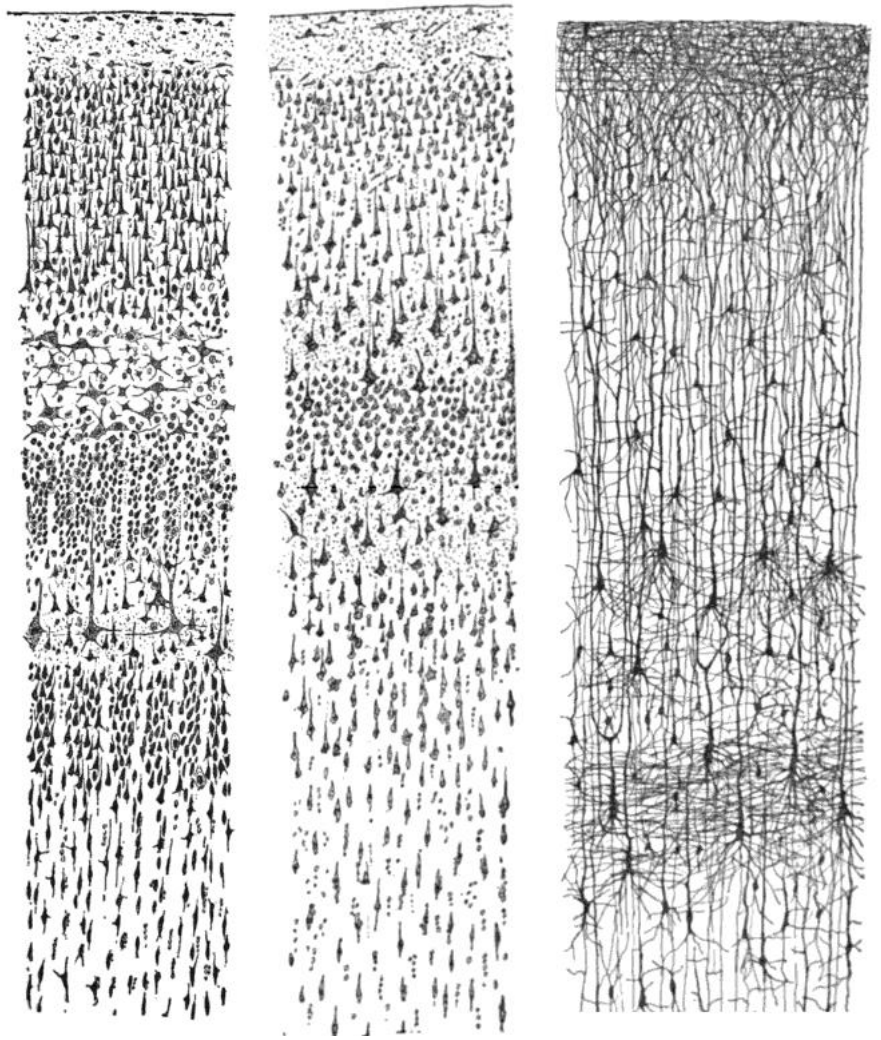
We aim to understand:

- Brain circuit function, *in vivo*, at systems level, by characterizing neuronal network activity and analyzing patterns of activity within local and wider networks;
- How distinct patterns of activity support distinct behaviours;
- How rhythms of the brain are affected by the circadian rhythm and sleep-wake cycle;
- How these processes are disrupted in model organisms of brain diseases

# Neuronal information is transferred along specific neuronal circuits

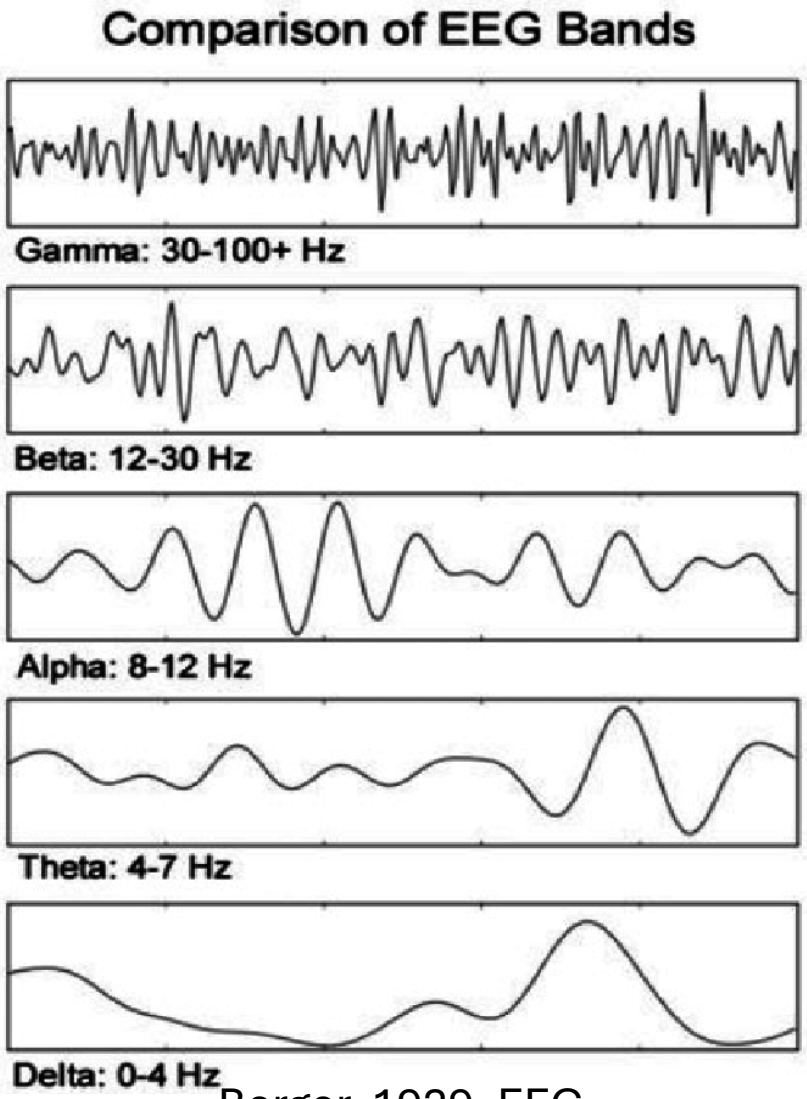




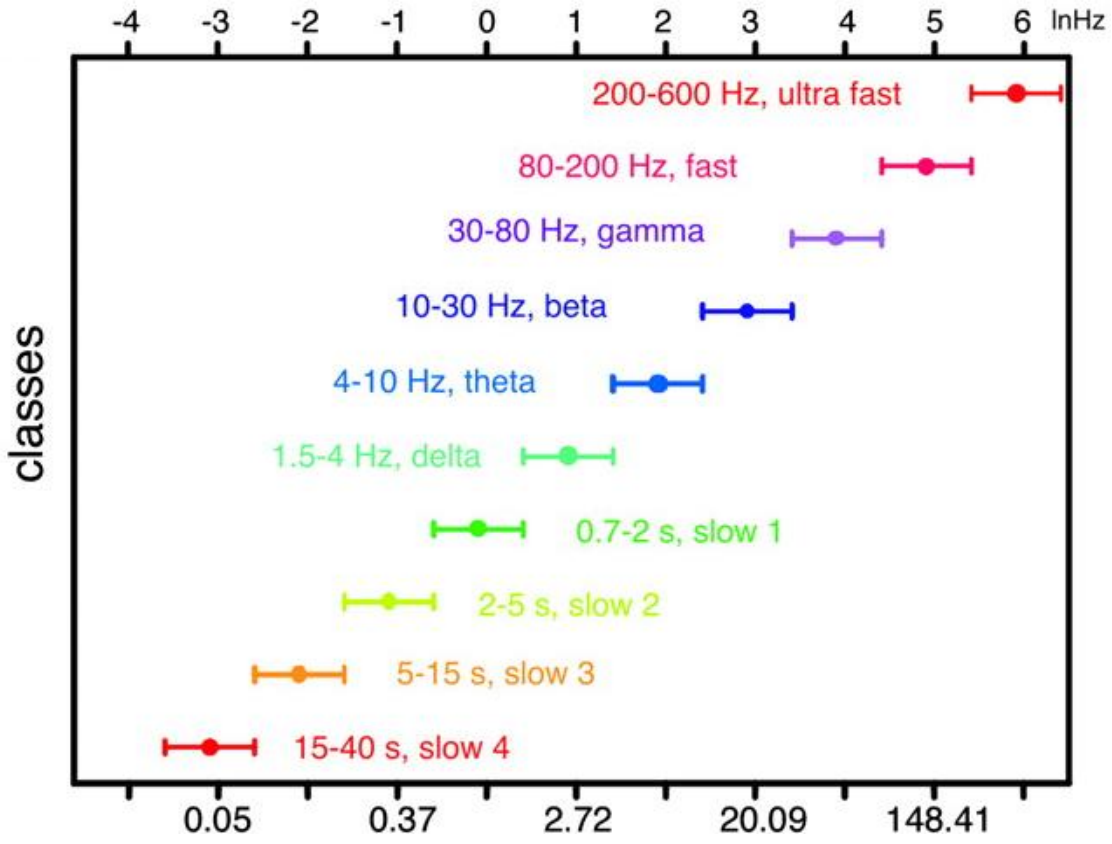
86 billions of neurons (humans)
100 millions of  neurons (mice)
1 neurons up to 100.000 connections

Cajal

# Brain neuronal circuits generate pattern of activities /oscillations that support sensory, cognitive and executive functions

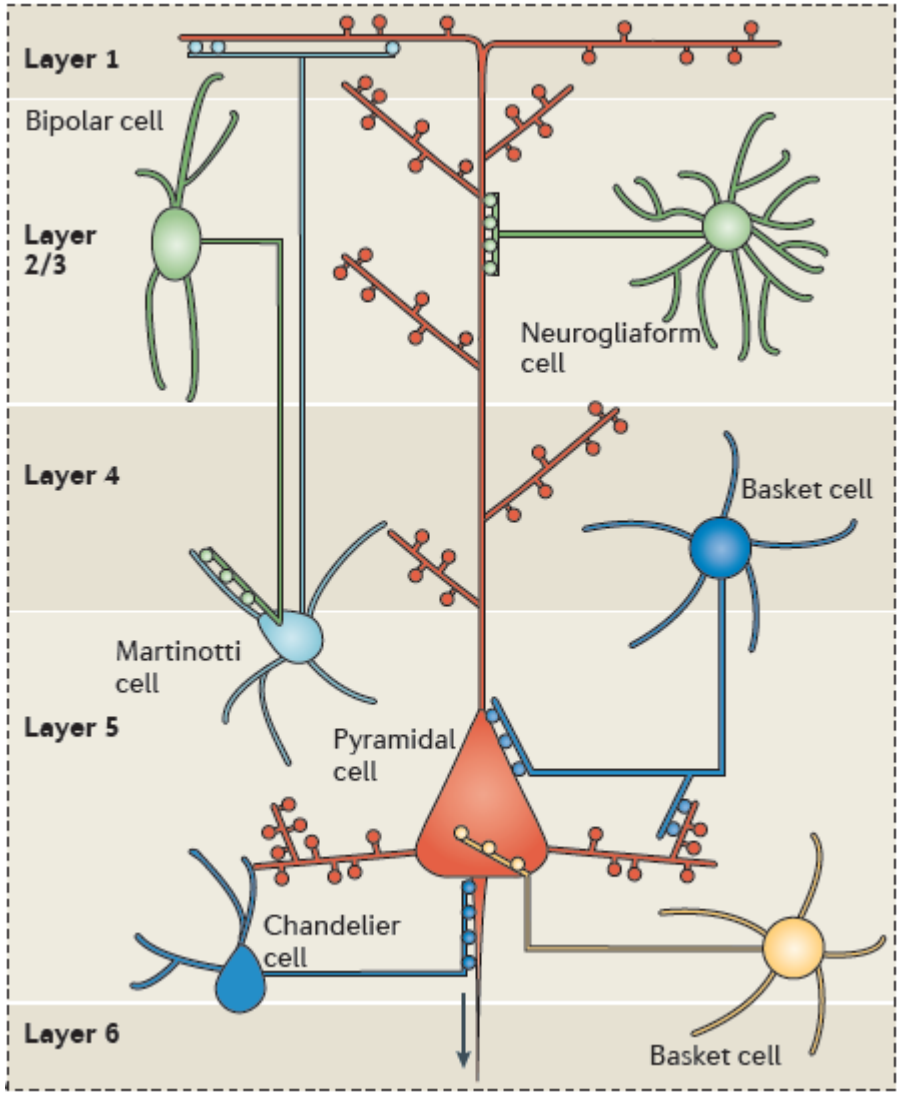



Berger, 1929, EEG




Buzsaki and Draghun, 2004

# Rhythms of the brain are regulated by GABAergic inhibitory interneurons




The main source of inhibition in adults

Shape neuronal firing

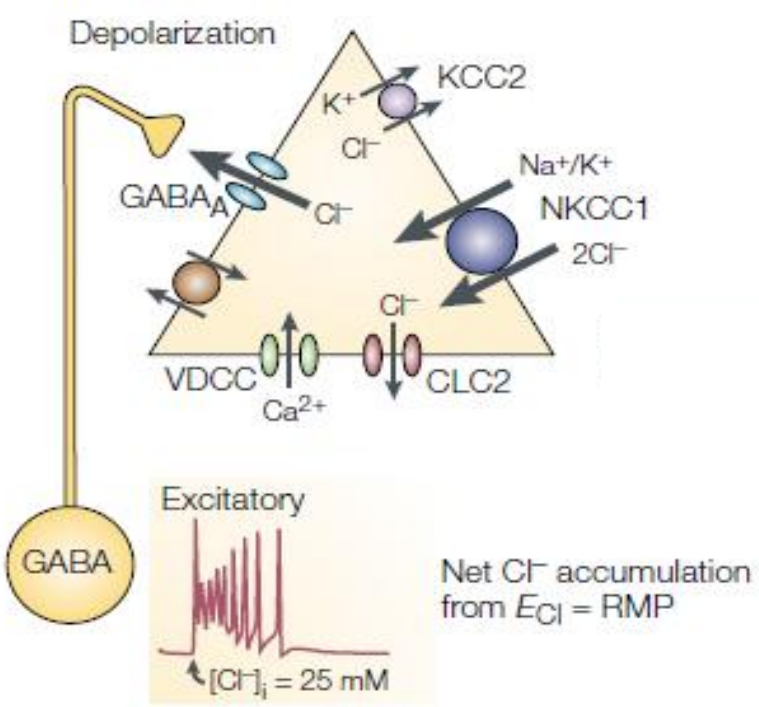
Regulate oscillations

E/I balance

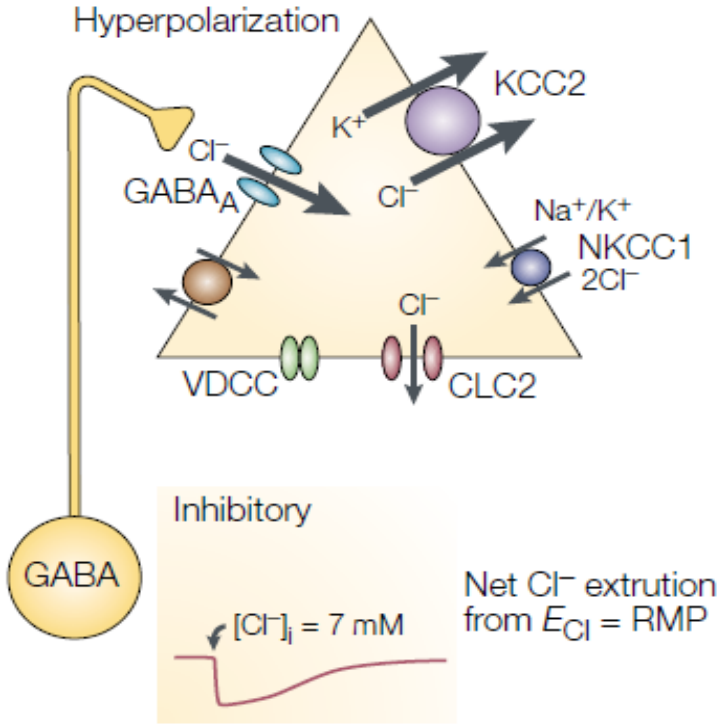
Modified from Marìn, 2012

# Intracellular $Cl^-$ concentration determines GABA response polarity

High $[Cl^-]_i$ in immature neurons




Low $[Cl^-]_i$ in mature neurons



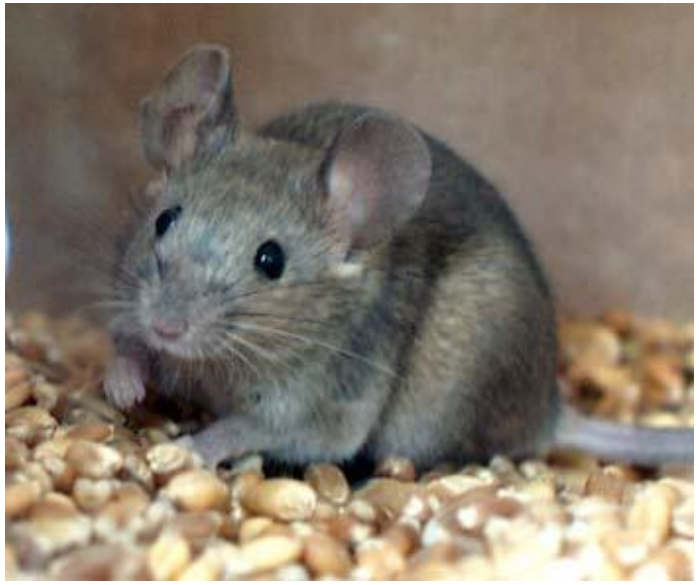

Modified from Ben-Ari , 2002

More recently it has been shown that the inhibitory tone and therefore neuronal excitability, varies in a much more dynamics manner:

- Circadian rhythms (Pracucci et al., 2023, Alfonsa et al., 2023, Lodovichi et al.,2023)

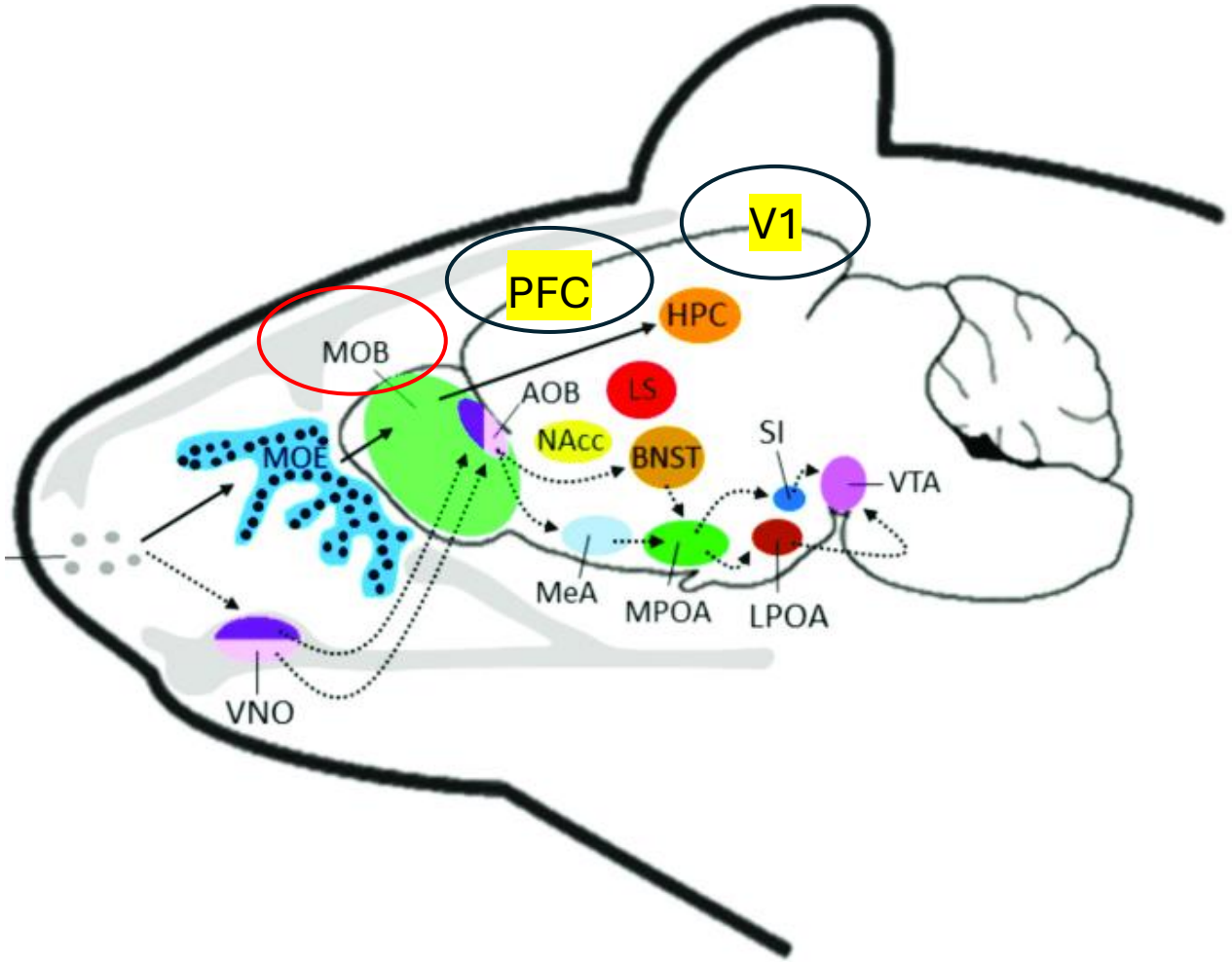
- Developmental disorders ( Maset et al., 2021, Deidda et al., 2015)

# The mouse as a model to study the brain



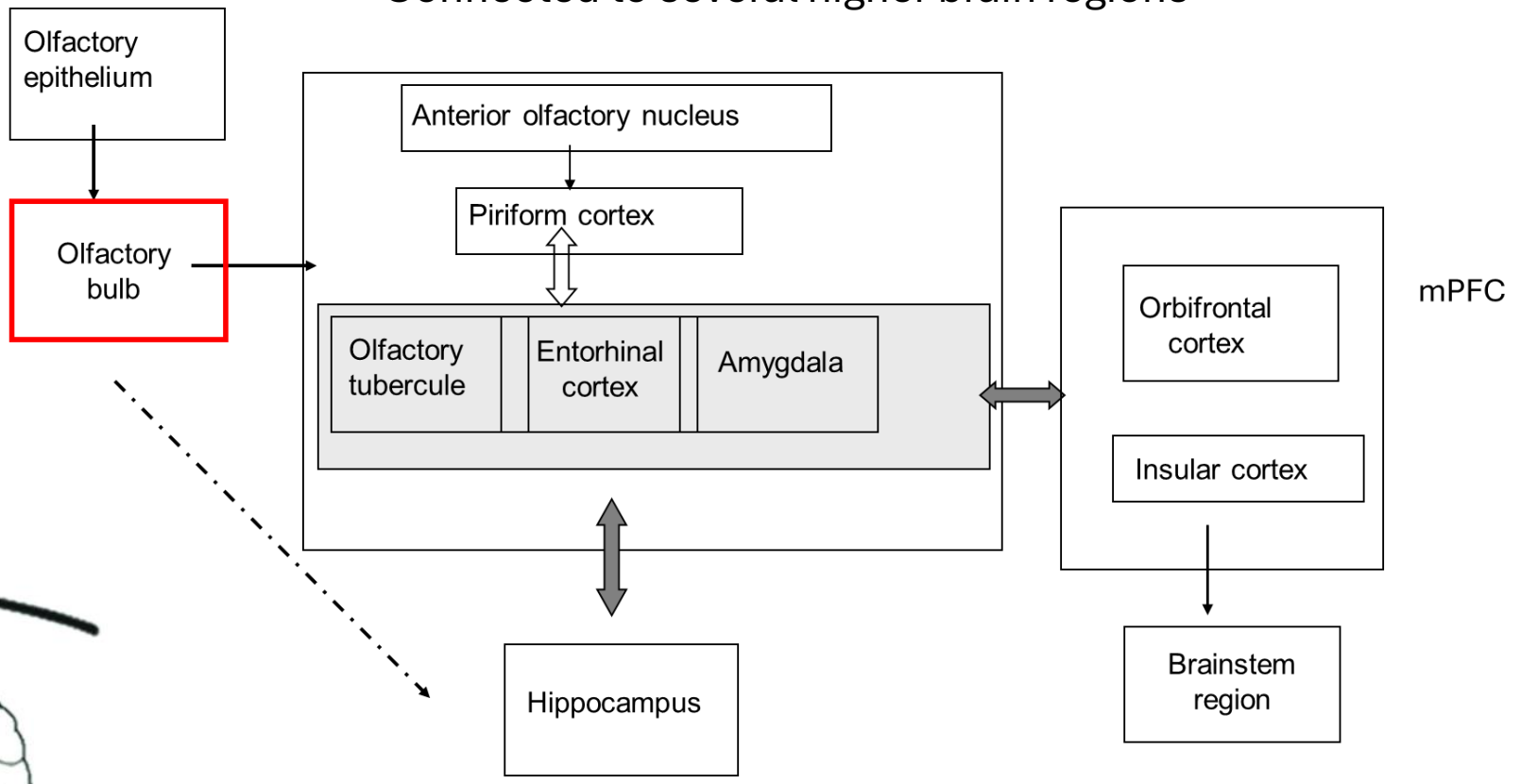
We study the following brain areas:

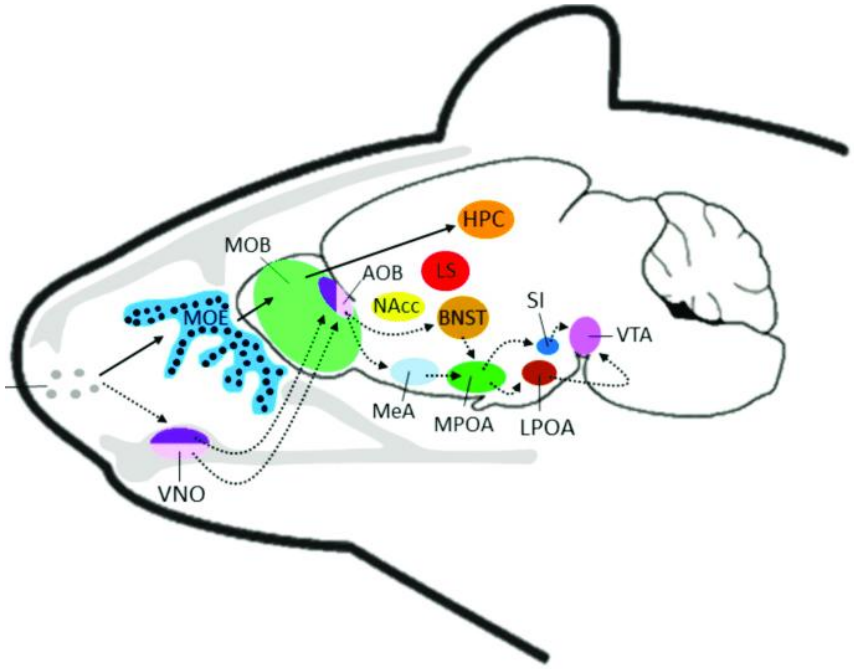
- Olfactory bulb
- Prefrontal cortex
- Primary visual cortex



# The olfactory bulb as a hub

## Connected to several higher brain regions




OB and higher connected regions allow to investigate sensory and cognitive functions

Altered patterns of neuronal activity and aberrant oscillations are among the first signs in several neurodevelopmental/neuropsychiatric disorders AND in neurodegenerative diseases

We are interested in studying patterns of neuronal brain circuits dynamics in

-Physiological conditions, along circadian rhythm, and in the sleep-wake cycle

- Mouse model of disorders ( neurodevelopmental disorders, such as ID-ASD, and in neurodegenerative diseases, such as Parkinson’s disease)

Experimental approaches

1. Behaviour

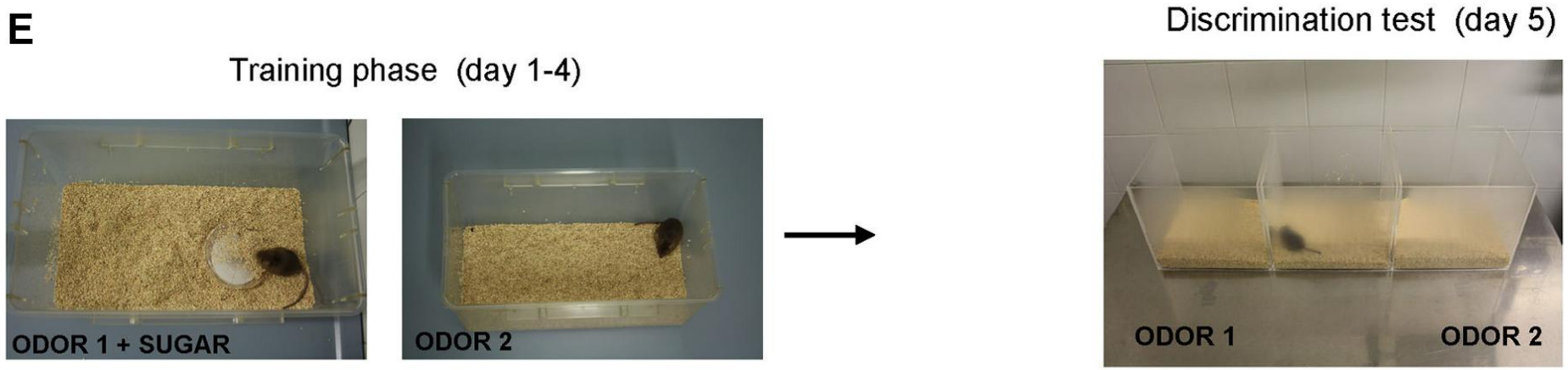
2. high density electrophysiological recordings, *in vivo*

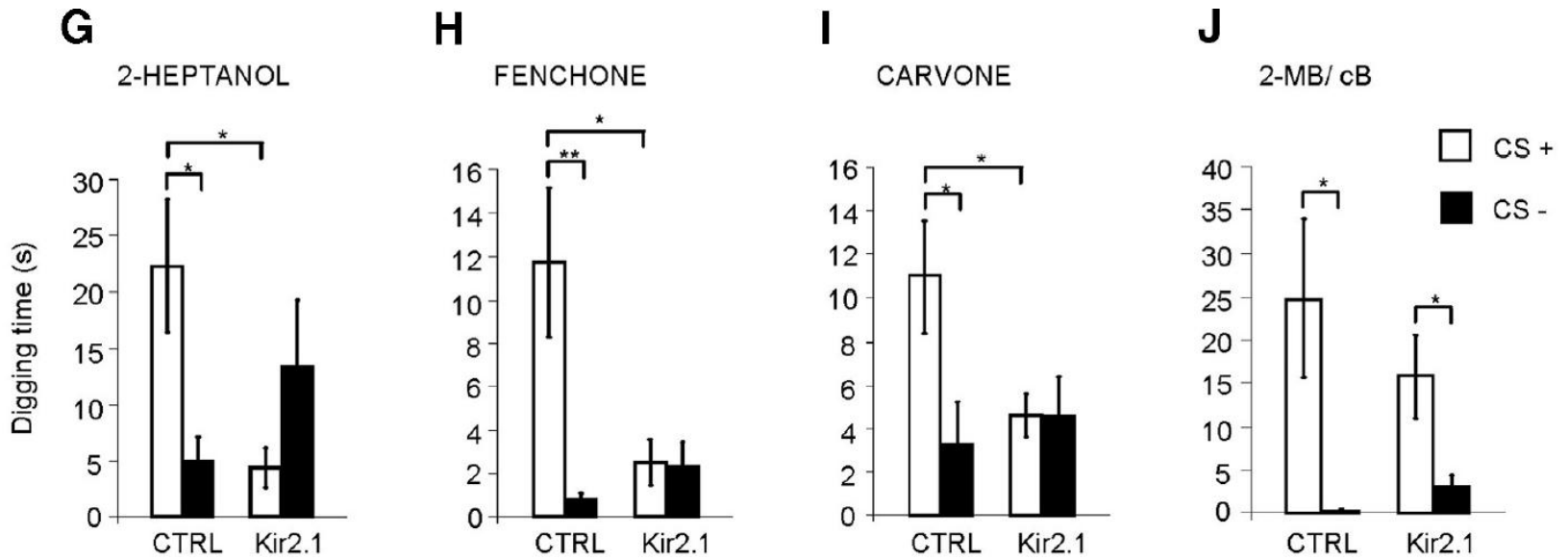
3. two photon functional imaging, *in vivo*

These approaches are used to study the following brain regions: olfactory bulb, prefrontal cortex, visual cortex

We perform different behavioural tests
In the following slide, an example of one of the test we use

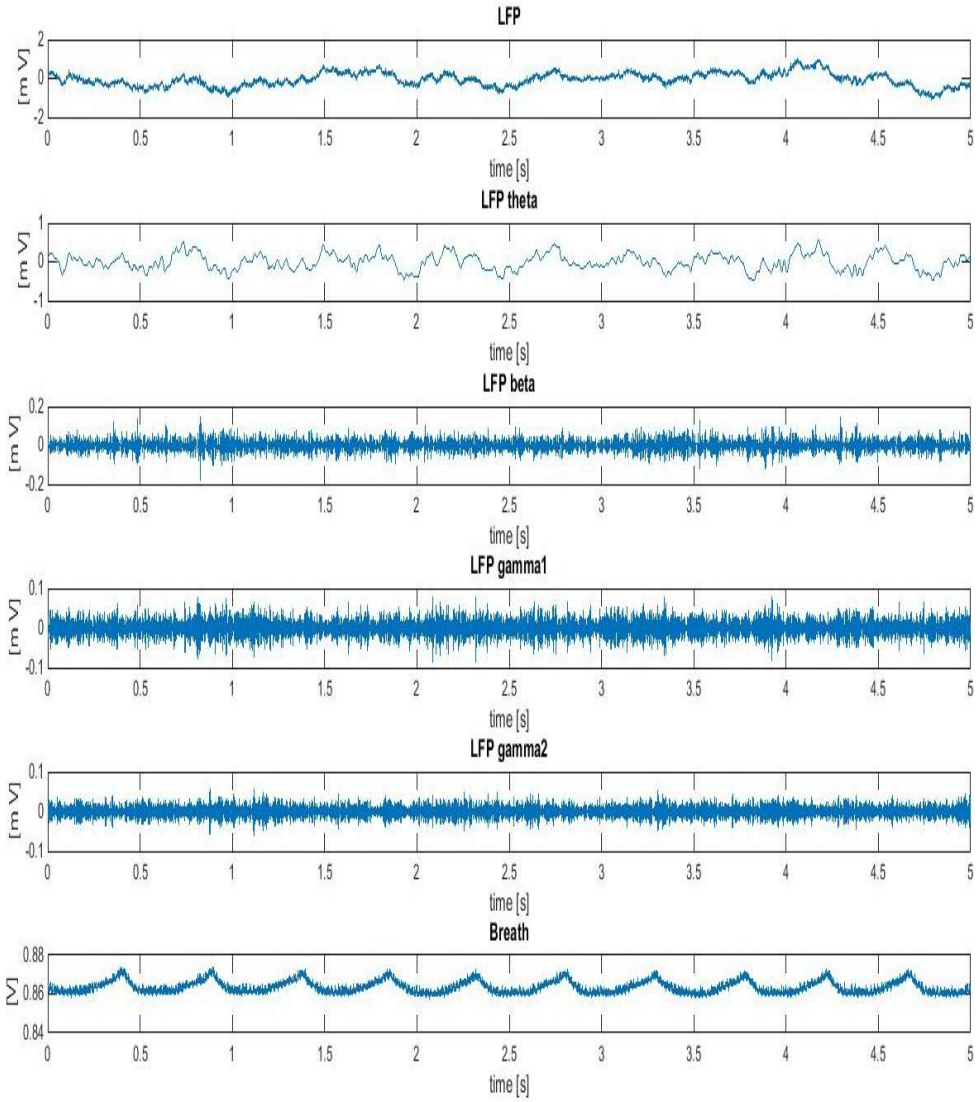
# Discrimination task




Lorenzon et al 2015

# The olfactory bulb exhibits a wide range of different patterns of activity



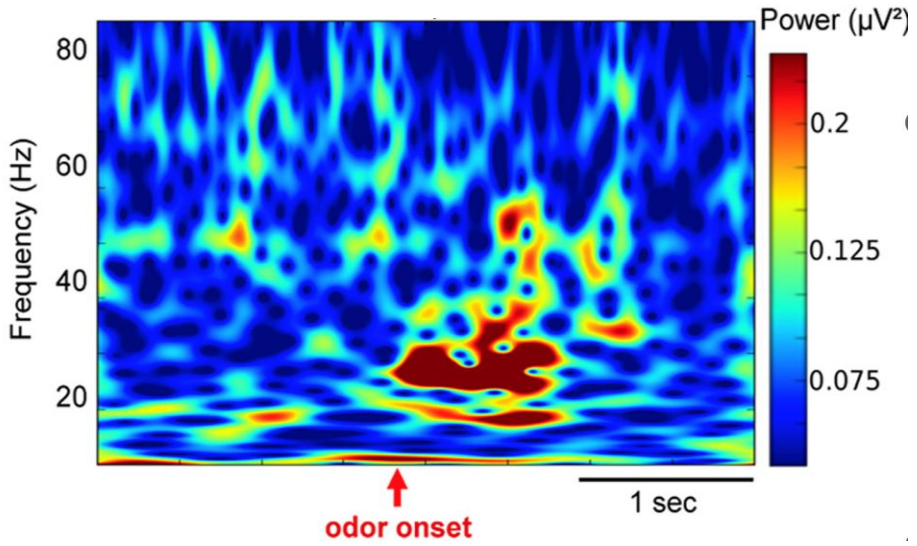

1-12 Hz

15-35 Hz

40-70 Hz

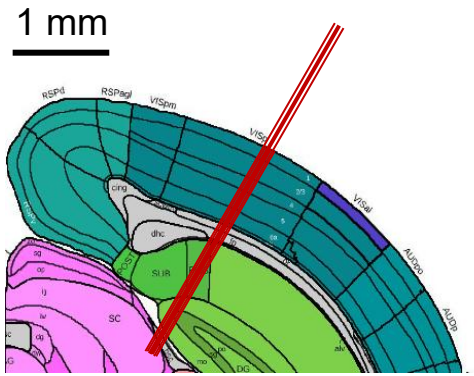
70-100 Hz

odor presentation modifies beta and gamma oscillations

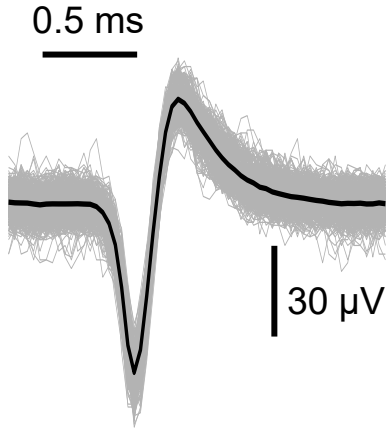


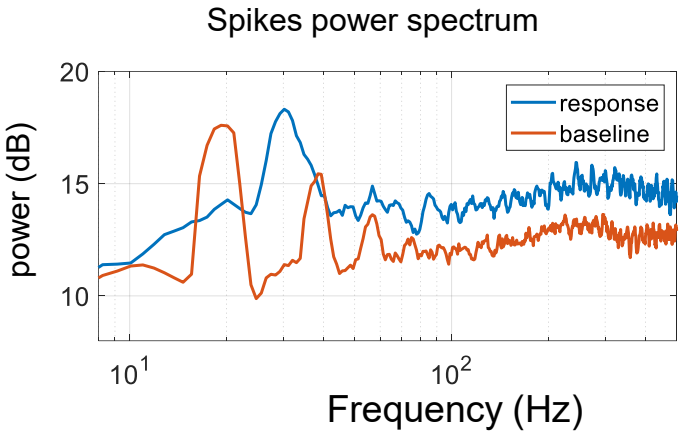

Martin Ravel 2014

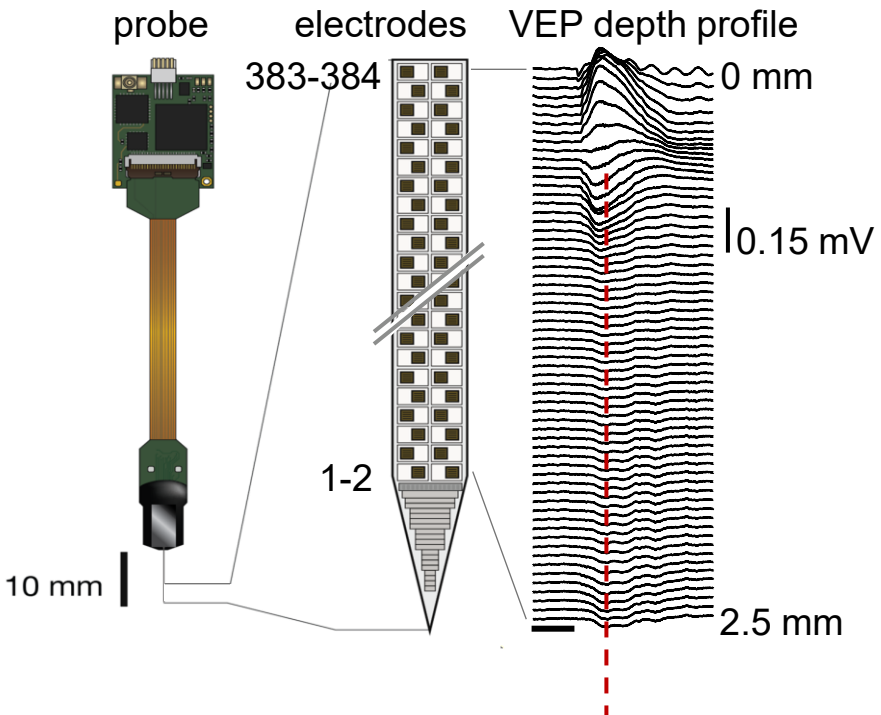
# Recording population of neurons with high density silicon probes: Neuropixel 1.0

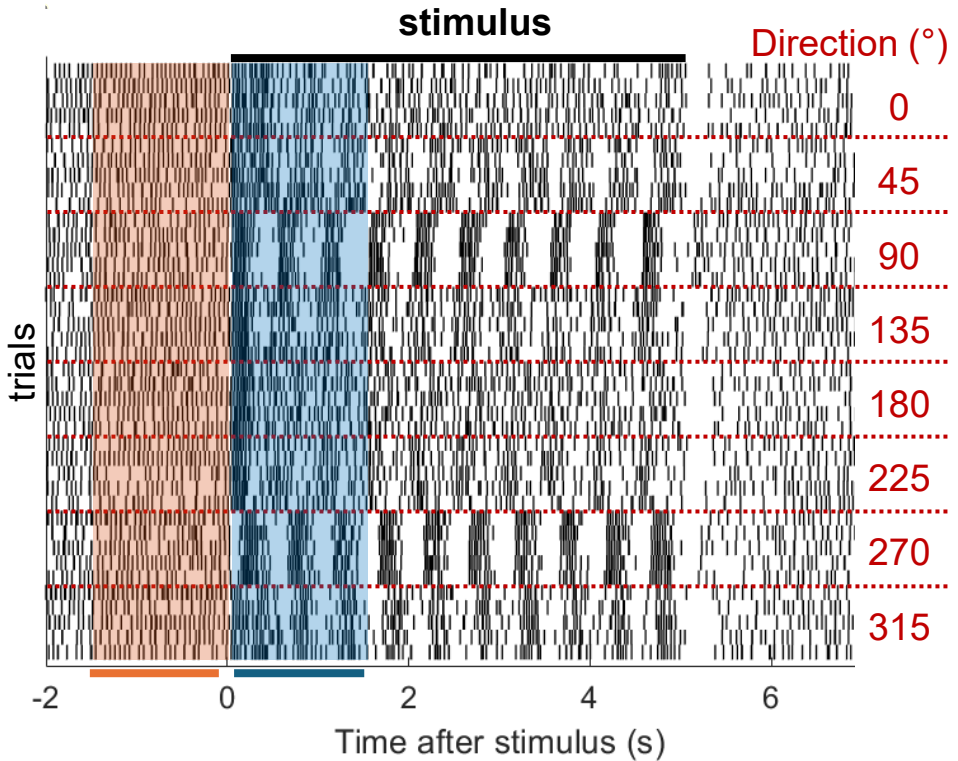



Neuropixel 1

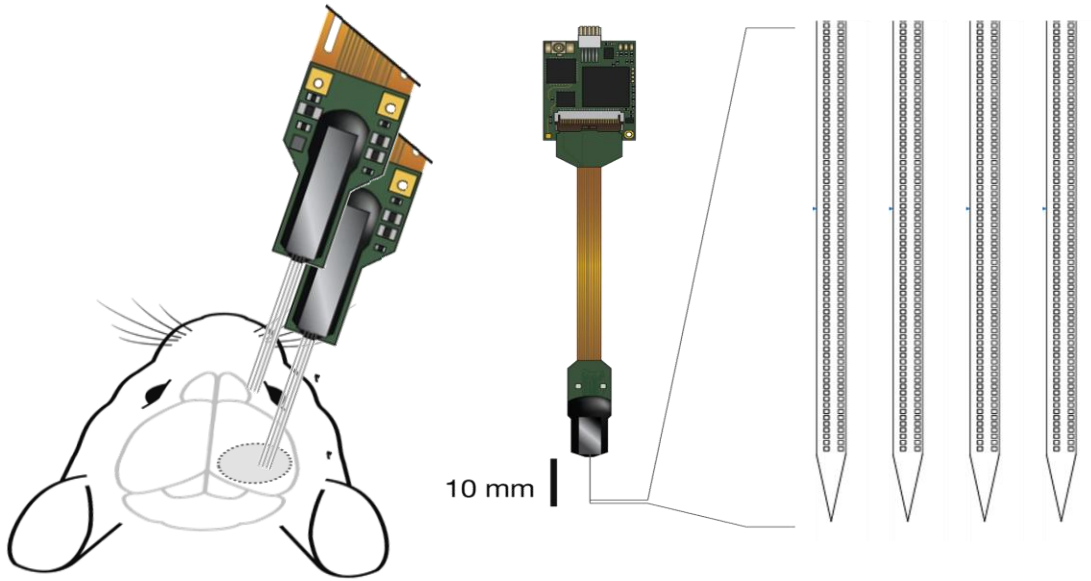


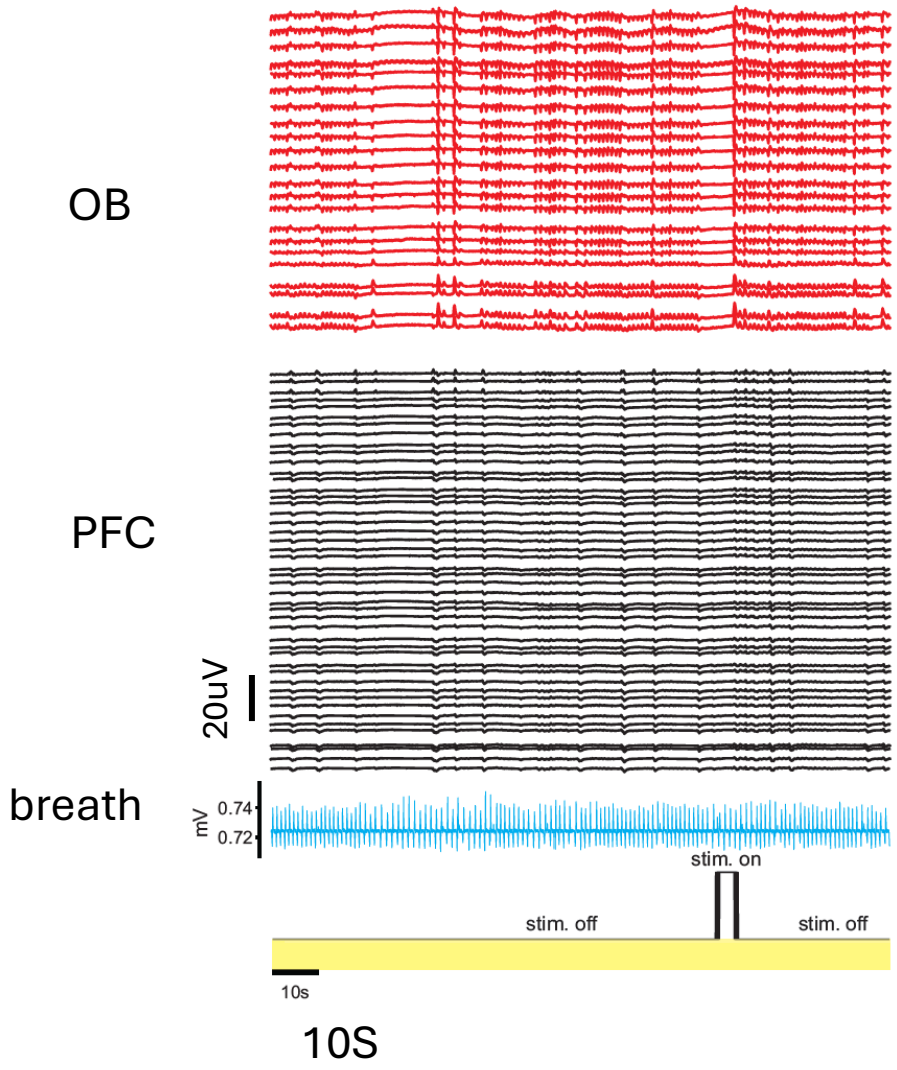



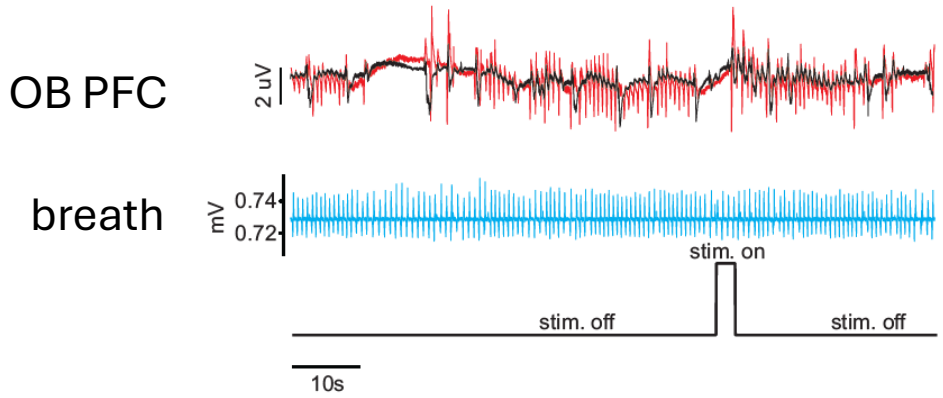
# Neuropixel 2.0



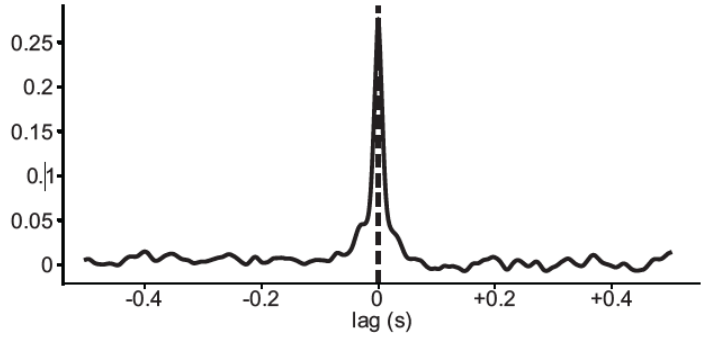

5120 recording site over 4 shanks

# Recording with high density silicon probe ( Neuropixel 2.0) in OB and PFC



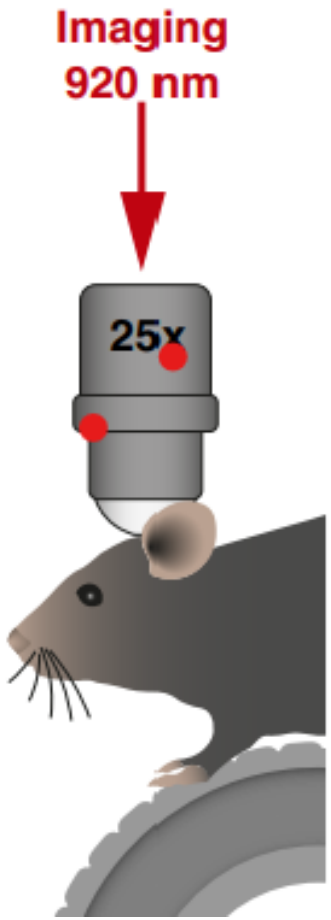



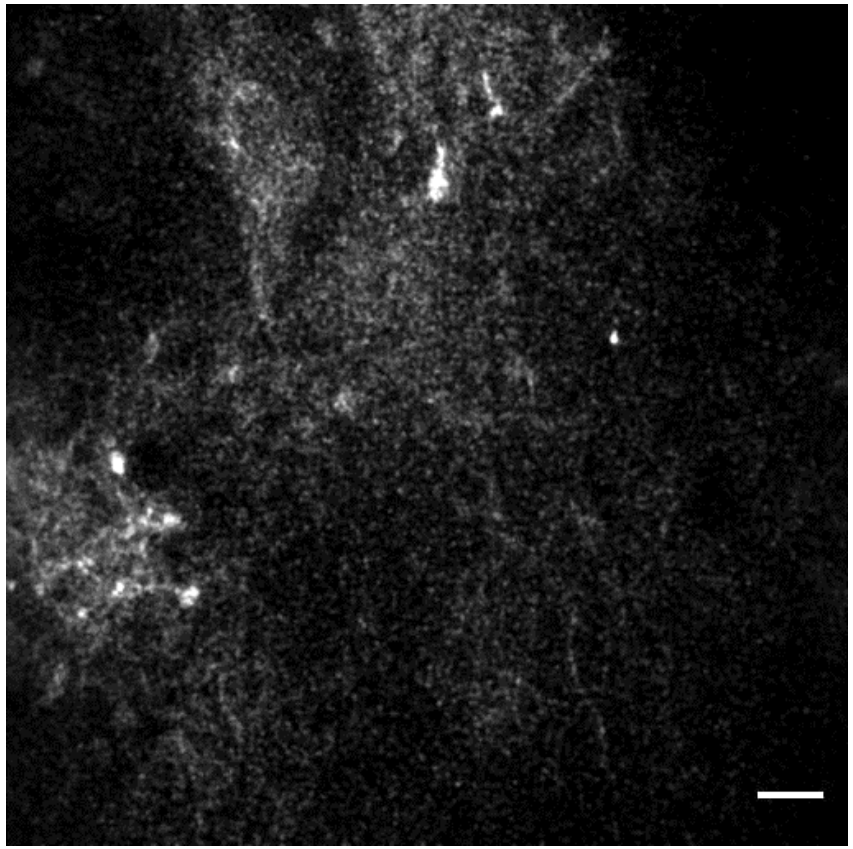

Cross-correlation spectra Gamma (40-100 Hz

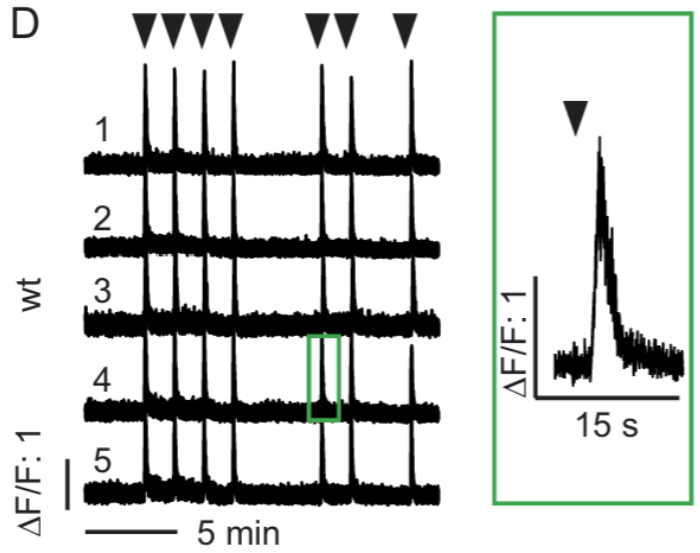


# Recording populations of neurons with single cells resolution by 2 photon imaging

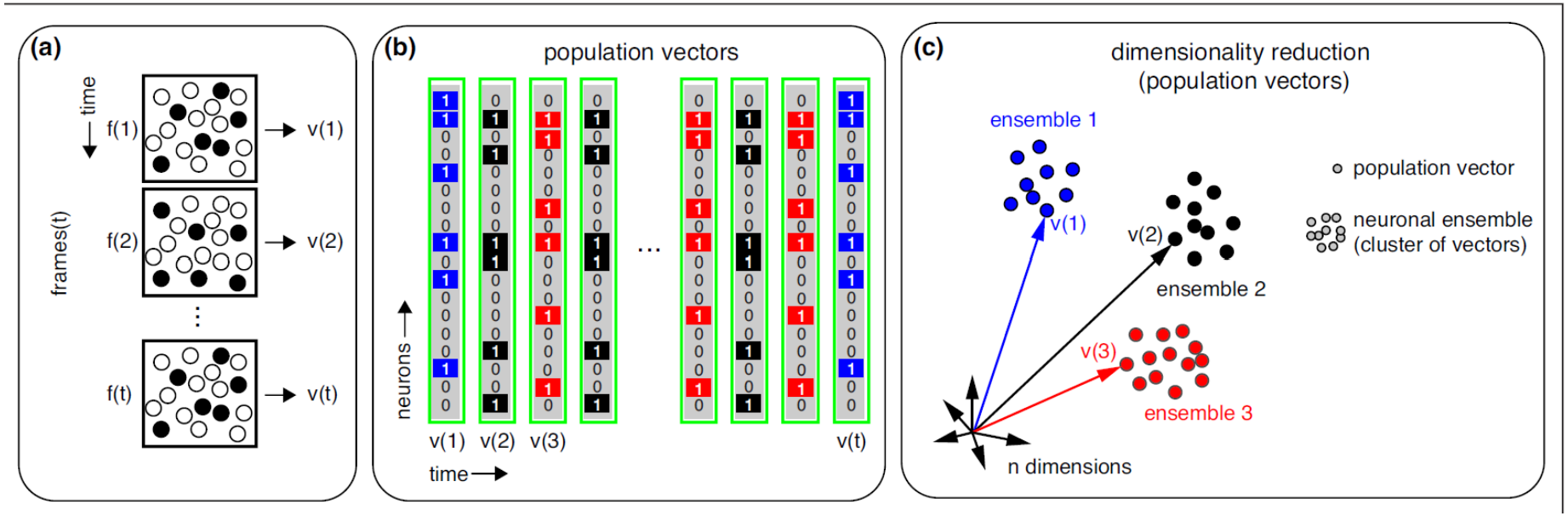
Two photon Calcium imaging



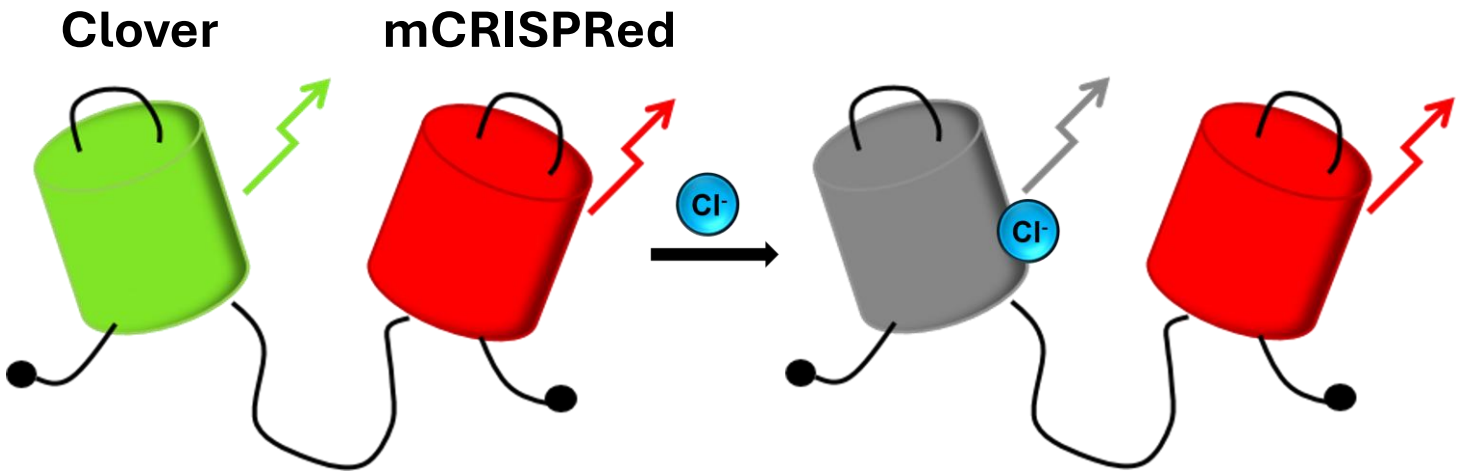


# Identifying ensembles of neurons in the recorded population



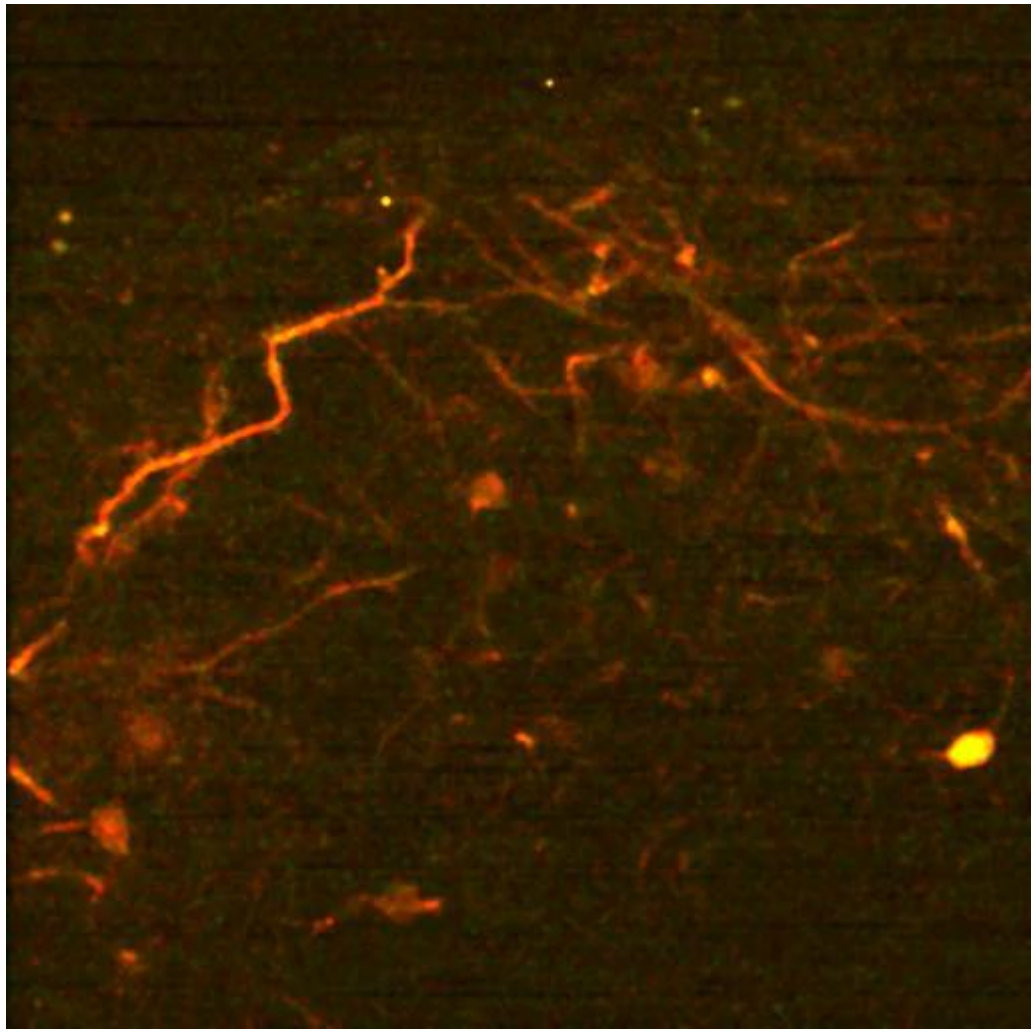

Yuste et al.

# A new genetically encoded sensor for Chloride: iClima



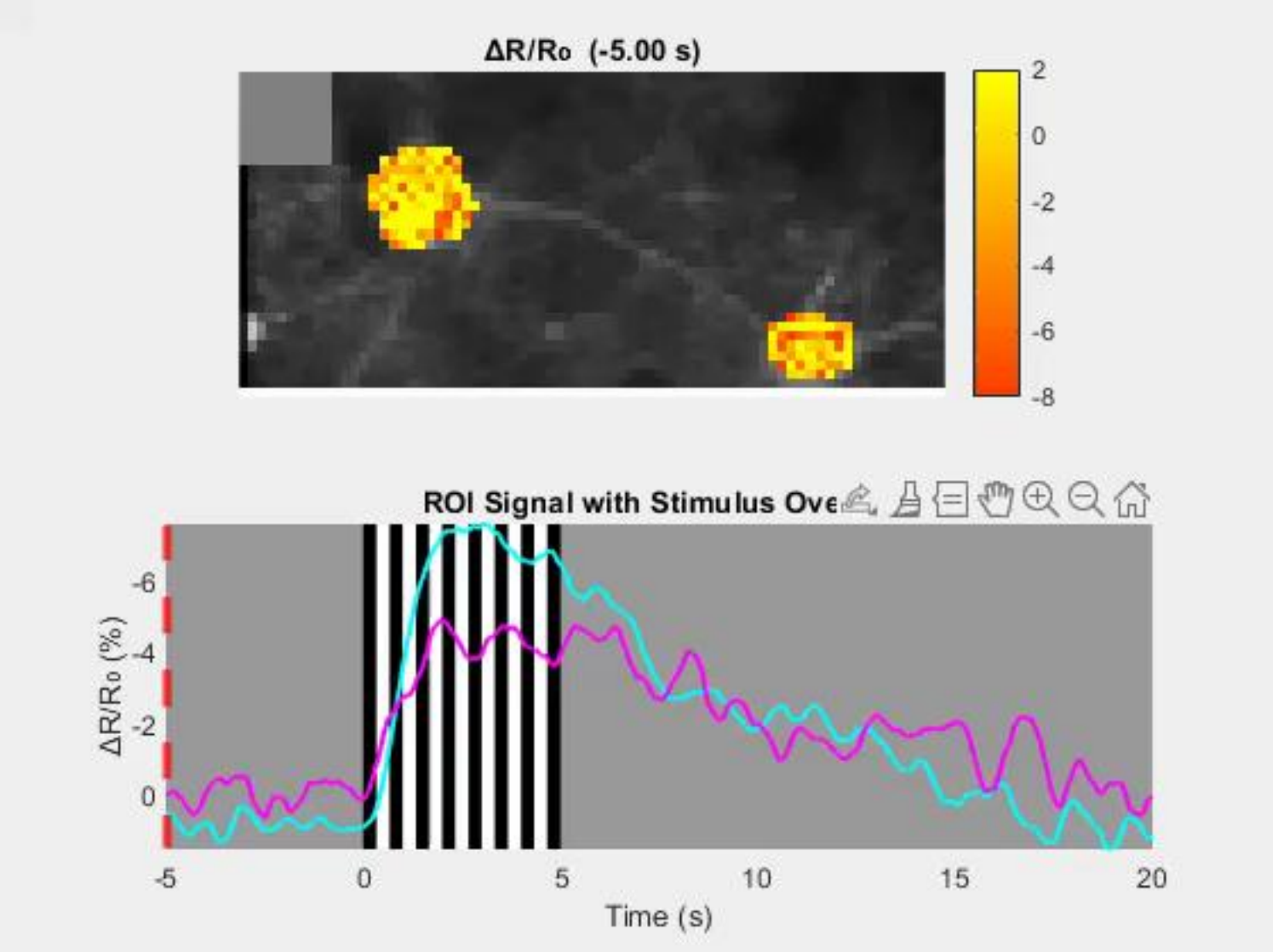

Lodovichi Ratto

# Imaging intracellular Chloride in neuronal populations in awake behaving mice



Erko Beyene, Lodovichi lab

# Visual stimuli elicit distinct $Cl^-$ responses in cell soma and dendrites



The analysis of large datasets necessitates the use of varied computational approaches.

This is another important aspects of the work in the lab, that we do within the lab and in collaboration with computational scientists

We are looking for highly motivated and creative students!

If you are interested, please write to me at:

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