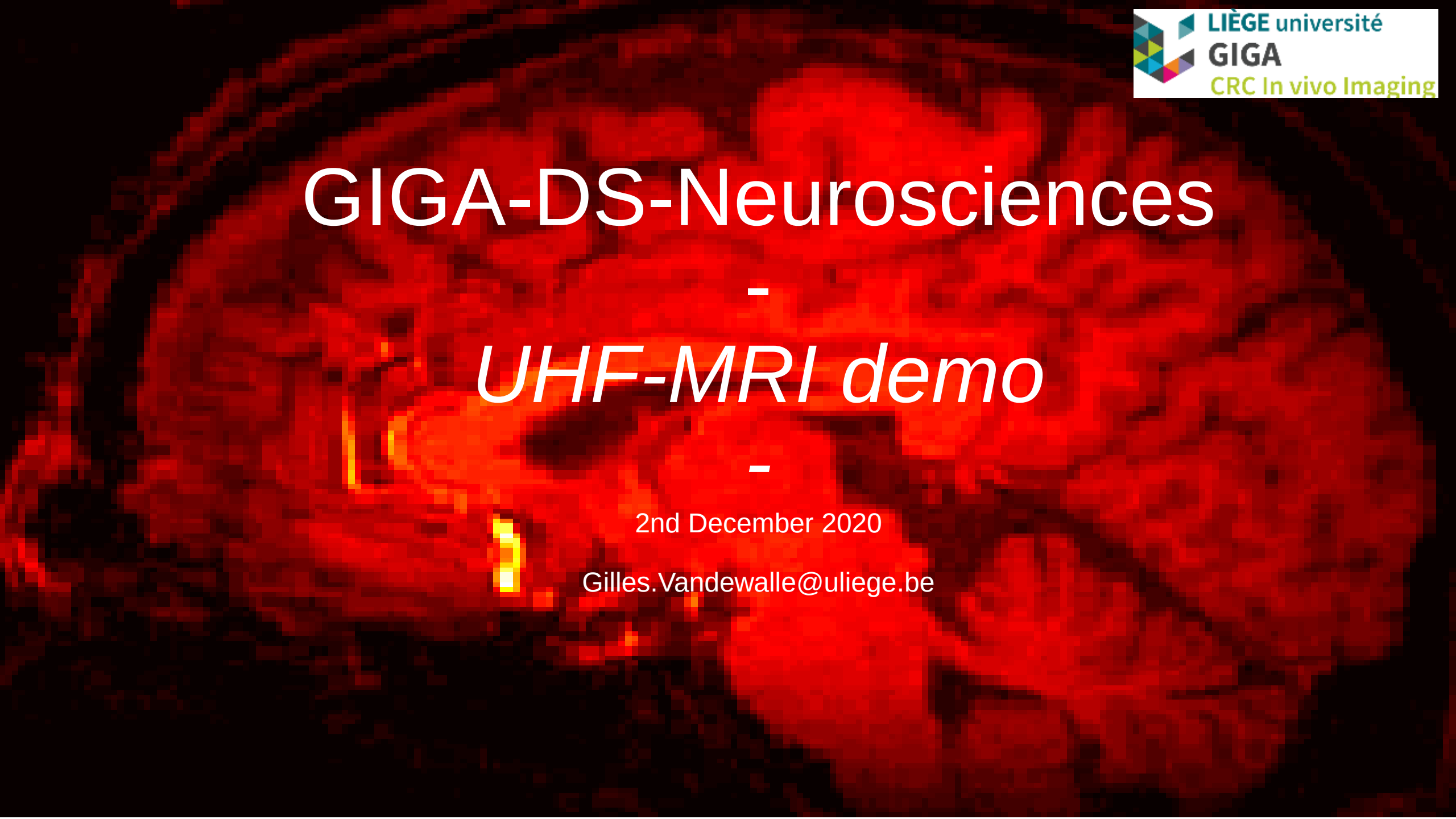

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GIGA-DS-Neurosciences

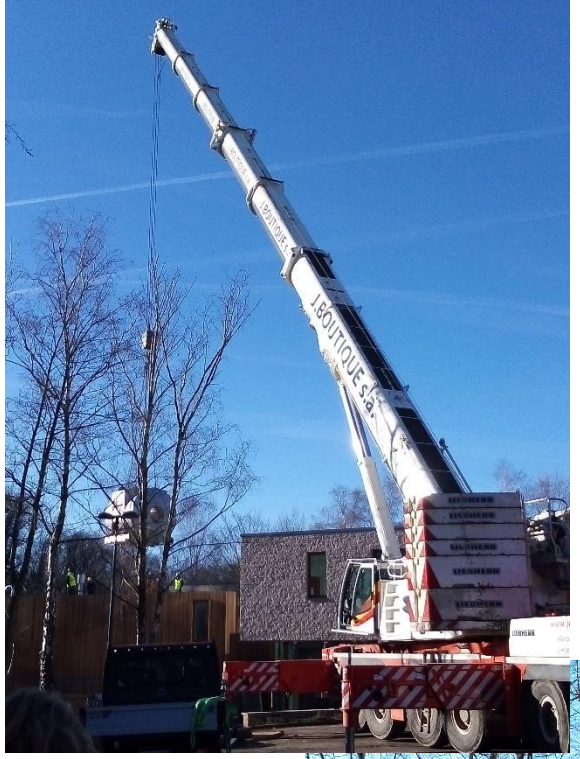
-

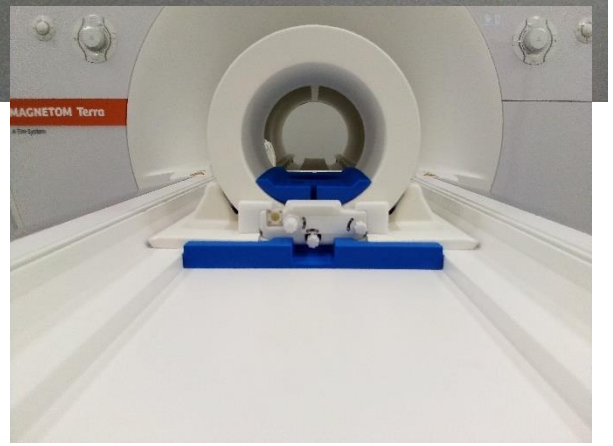
UHF-MRI demo

-

2nd December 2020

Gilles.Vandewalle@uliege.be





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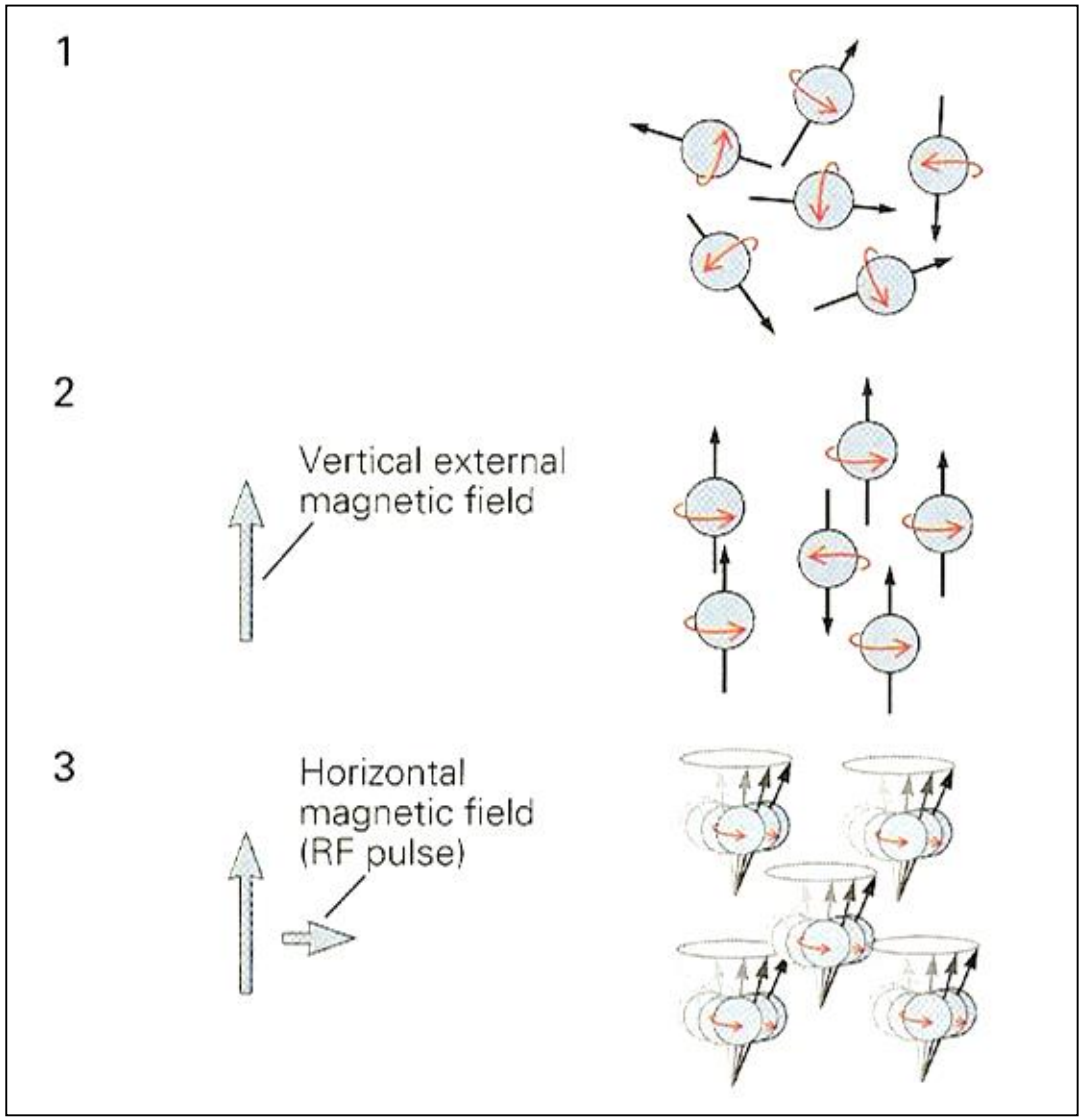
Principles

- (1) Proton (H of H_2O) in normal conditions
- (2) Protons aligned parallel to a constant magnetic field = baseline
  - Most cancel each other, except unmatched protons (1 or 2 in 1 million)
- (3) Perturbation by a perpendicular RF magnetic field specific to H which spin => local variation in magnetic field
- Magnetic gradients (within radio frequencies – RF) cycle on and off to differentiate points in space
- RF ceases
- Protons release energy, detected by coil



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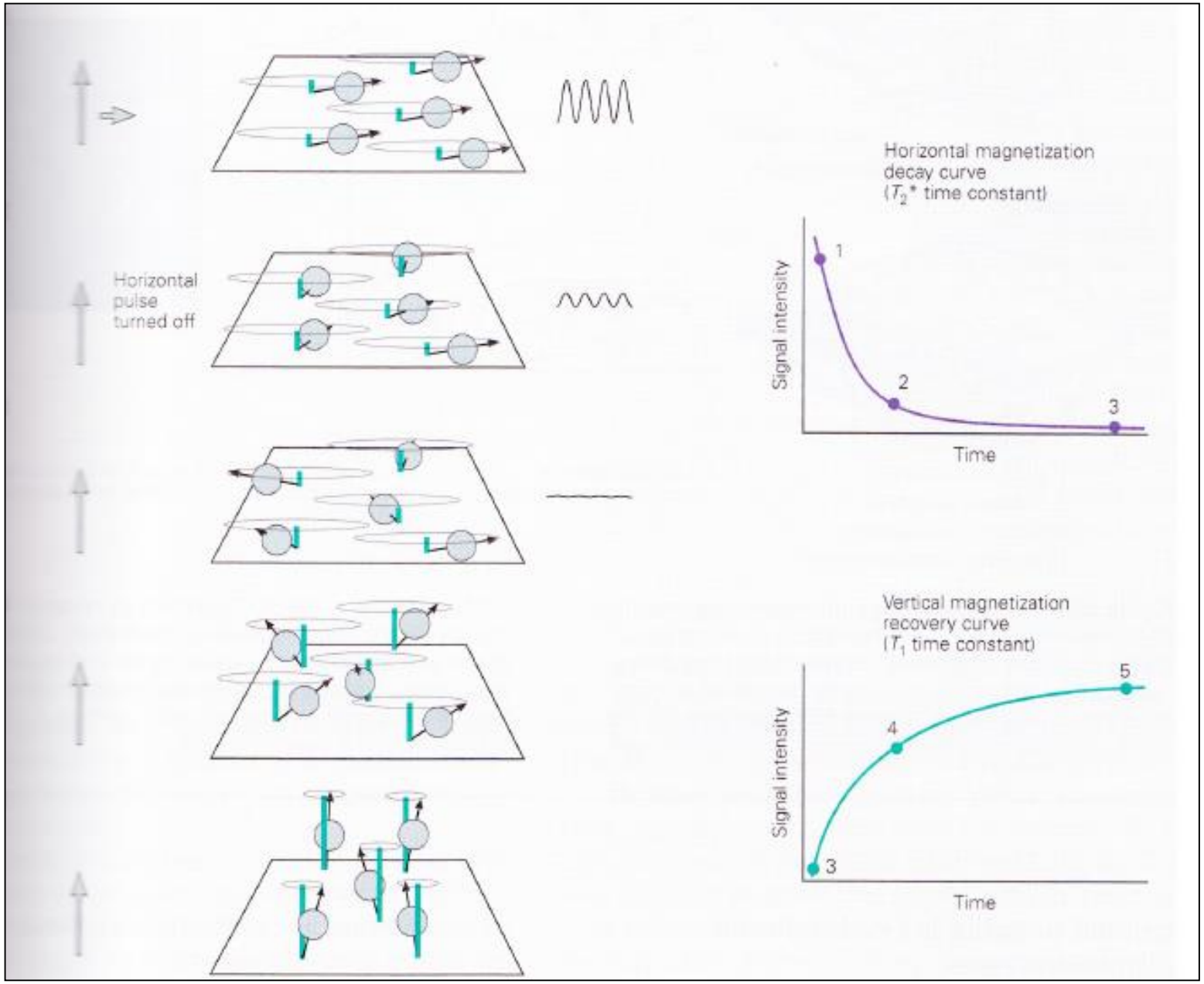
- Protons release energy, detected by coil

- Time to baseline depends on what surrounds a proton



Structural Imaging

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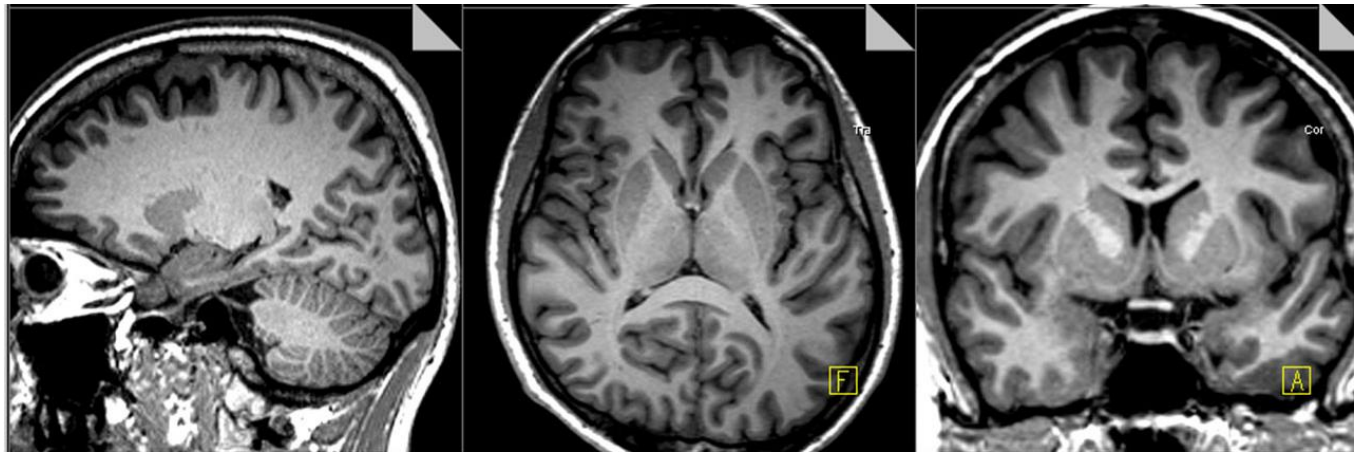
- Structural MRI:
  - Long measure (> 5 – 30min for 1 volume) of detailed brain structure (~ autopsy/biopsy)
  - Resolution up to < 0.1 mm (long acquisition time)
  - Non-invasive (except with contrast agents)

- Humans – primates – big animals
  - Classical clinical scanner: 1T and 1.5T + 3T
  - In research: 3T (60000 x Earth magnetic field)

- **Close function – anatomy link**
- **Non invasive and *in vivo* autopsy**



MRI vs. UHF-MRI

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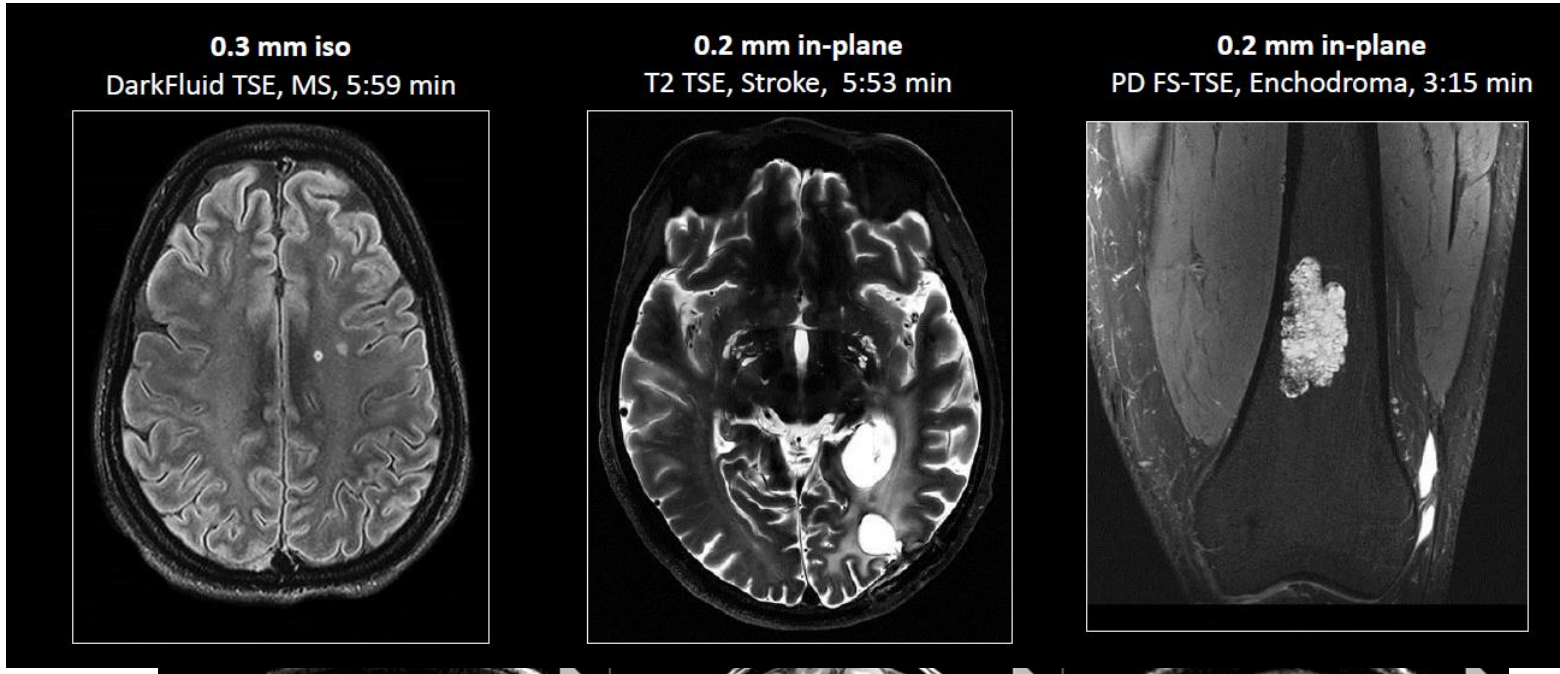
- Ultra high fields: > 3T

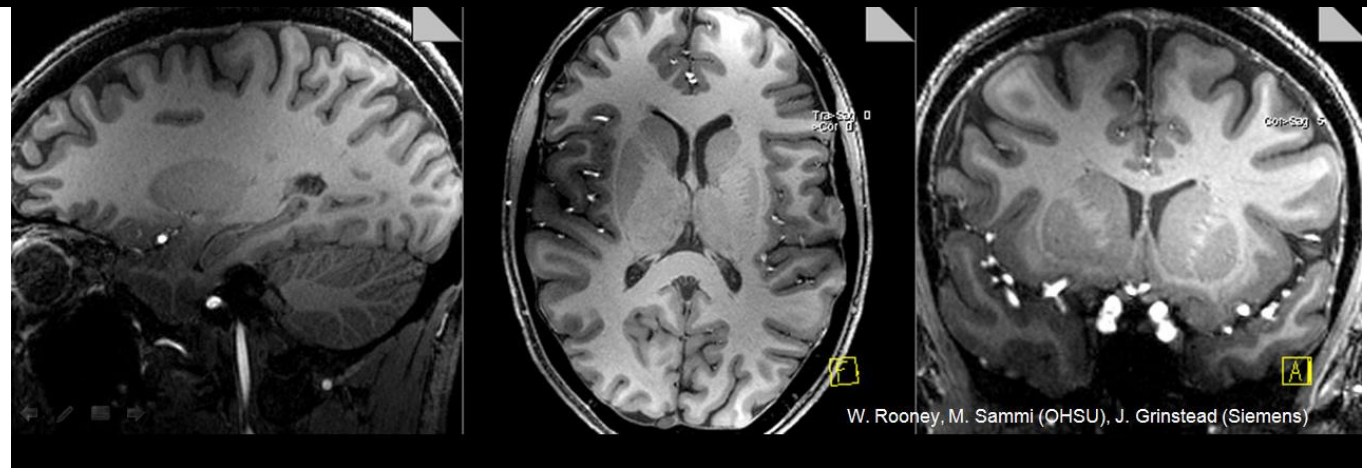
- Human : 7T @ ULiège, 9.4T, …
- Rodents – small animal: Up to 15.2 T for small animals; 9.4T @ ULiège

- **Better the resolution**
  - Typical 3T
    - MRI: 1mm^3
    - fMRI: 3mm^3
  - "Typical" 7T
    - Whole brain MRI: .6 to .75 mm: **.21 to .42mm^3**
    - Part of the brain MRI: .2mm = **.008mm^3**
    - fMRI: **1mm^3**

  - Typical MRI: 1 mm^3 vs. 7T MRI: 0.42 mm^3
- **Better signal to noise ratio** (non linear improvement)

- ***Less homogenous MR field***
- ***More susceptible to movements***





Quantitative MRI allows for tissue micro-structure inferences

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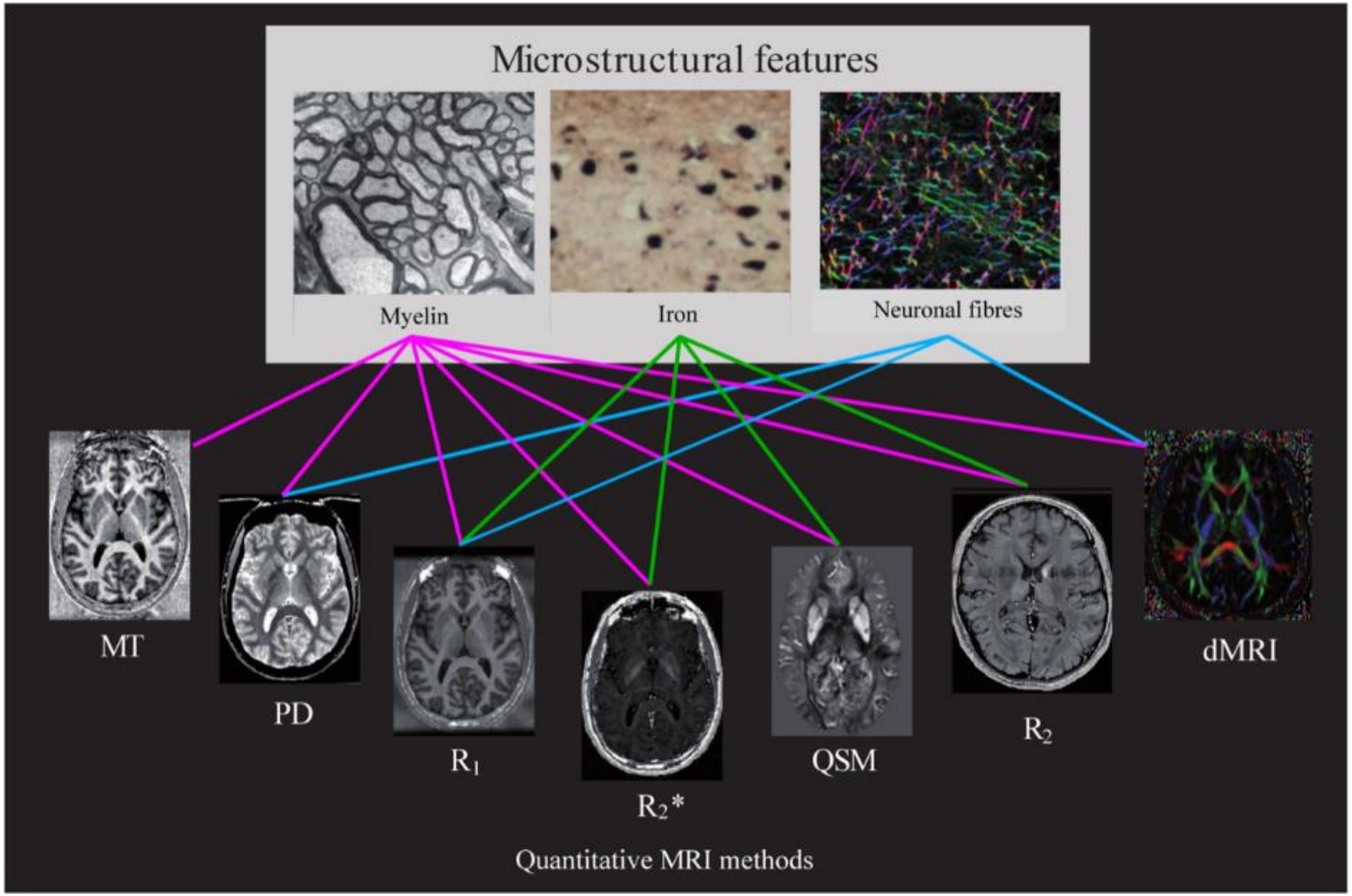

- ***in vivo* histology**

Diffusion Imaging

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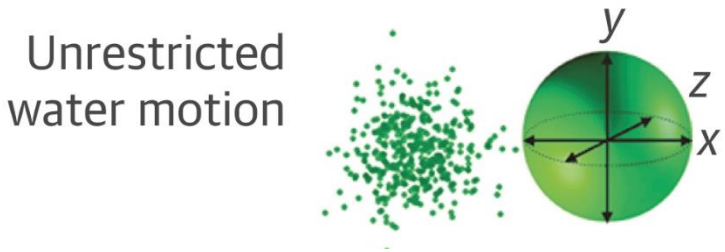
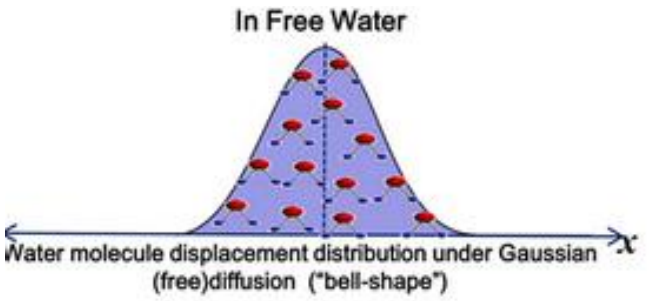
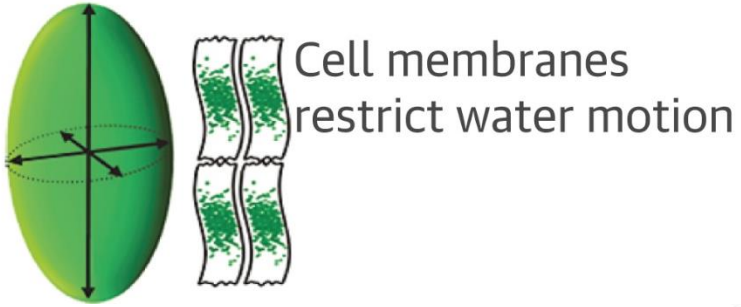
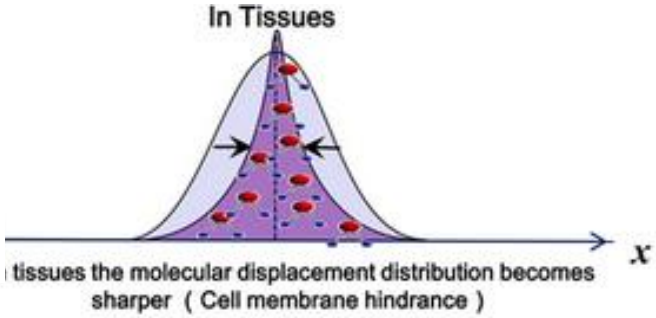
- Diffusion of water molecules in all direction
- Diffusion depends on the local physical constrains:
  - Csf vs. axon
  - Tumor/lesion vs. healthy tissue

- Mainly for white matter tracks/integrity
- Also for brain microstructure (neurites density/organization)









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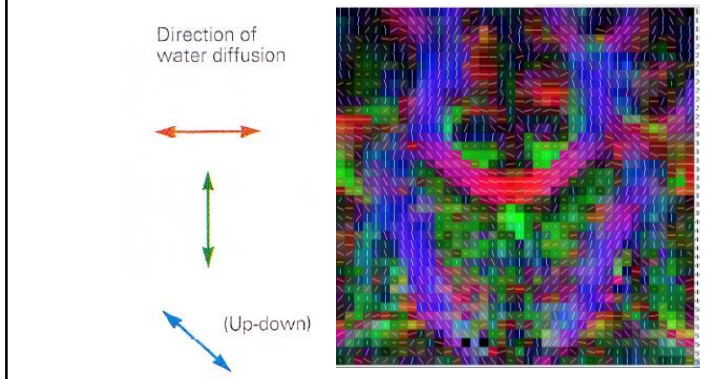
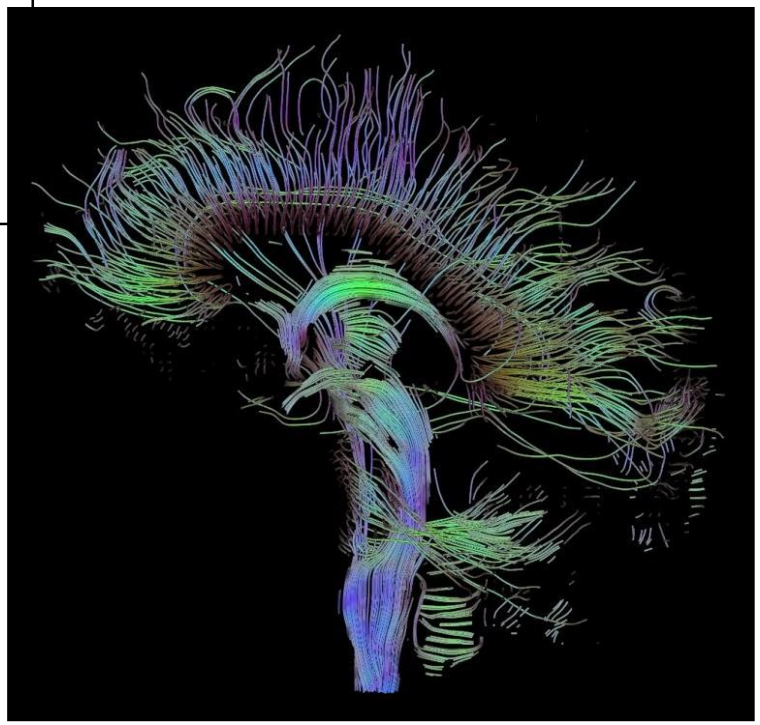
- Tracktography
  - vector(s) of main diffusion direction(s)
  - Then connect the dots.

- Connectomics
  - Brain hubs
  - Fiber density per hub to other hubs

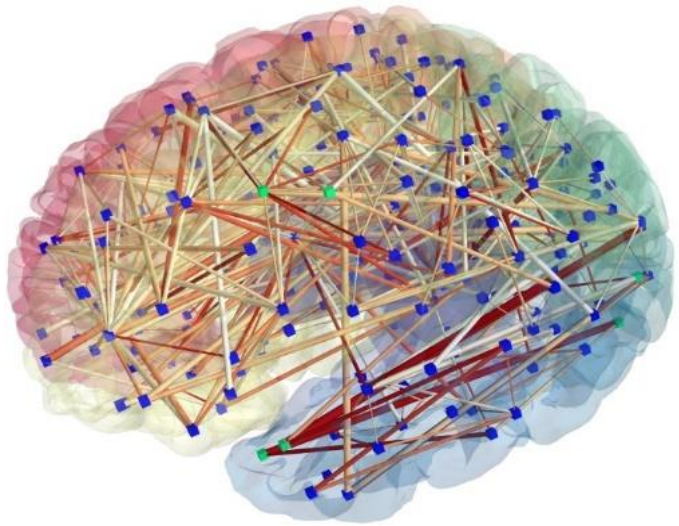
- **Close function – anatomy link**
- **Non invasive and *in vivo***
- **Links behavioral manipulation**

Color code for water molecule main diffusion direction





Human connectome analyses



Molecular Imaging

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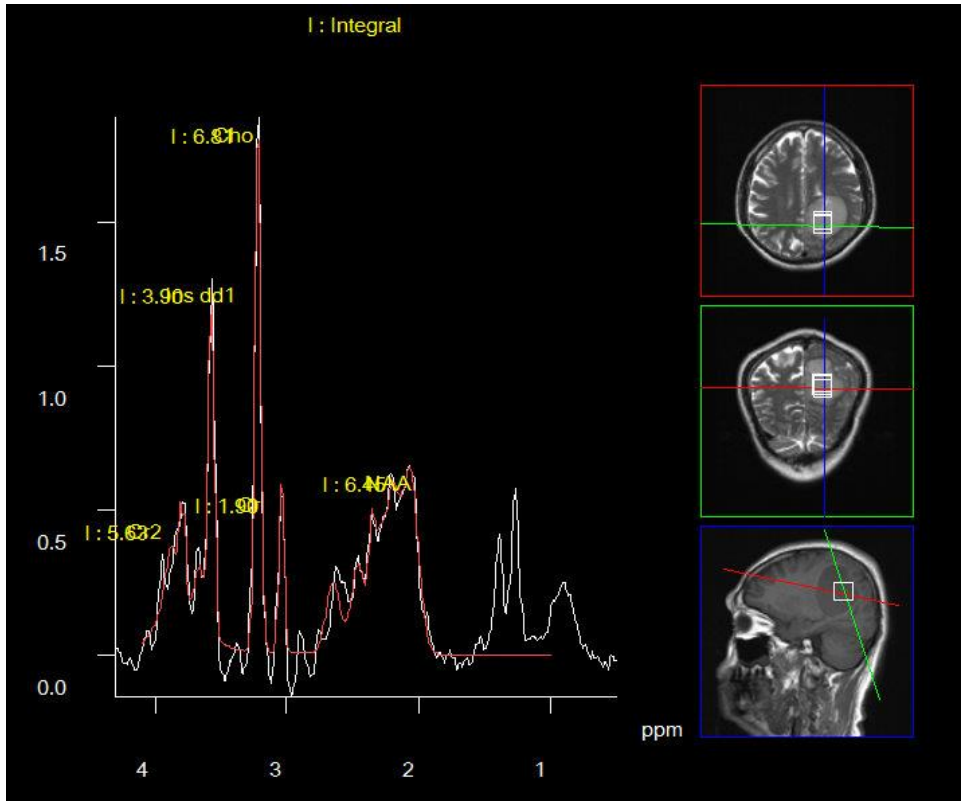
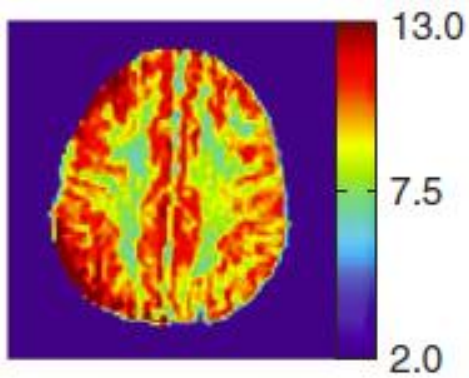
Magnetic resonance spectroscopy (MRS)

- RF induces nuclear magnetic resonance detected with coil.
- Intramolecular magnetic field around an atom in a molecule changes the resonance frequency
- Mainly small volume > whole brain developments



Chemical exchange saturation transfer (CEST)

- Whole brain molecular imaging
- Many molecules accessible – e.g. glutamate, GABA, etc



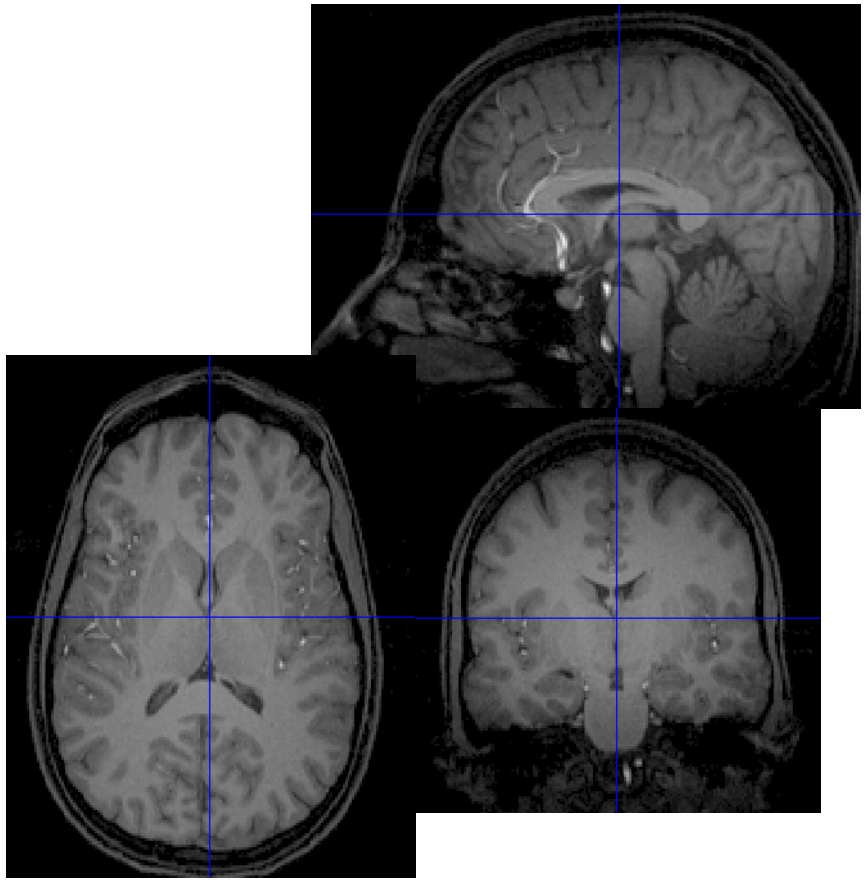
Whole brain glutamate imaging

Cai et al. 2012 Nat. Med.

- **Close function – anatomy link**
- **Non invasive and *in vivo***
- **Links behavioral manipulation**

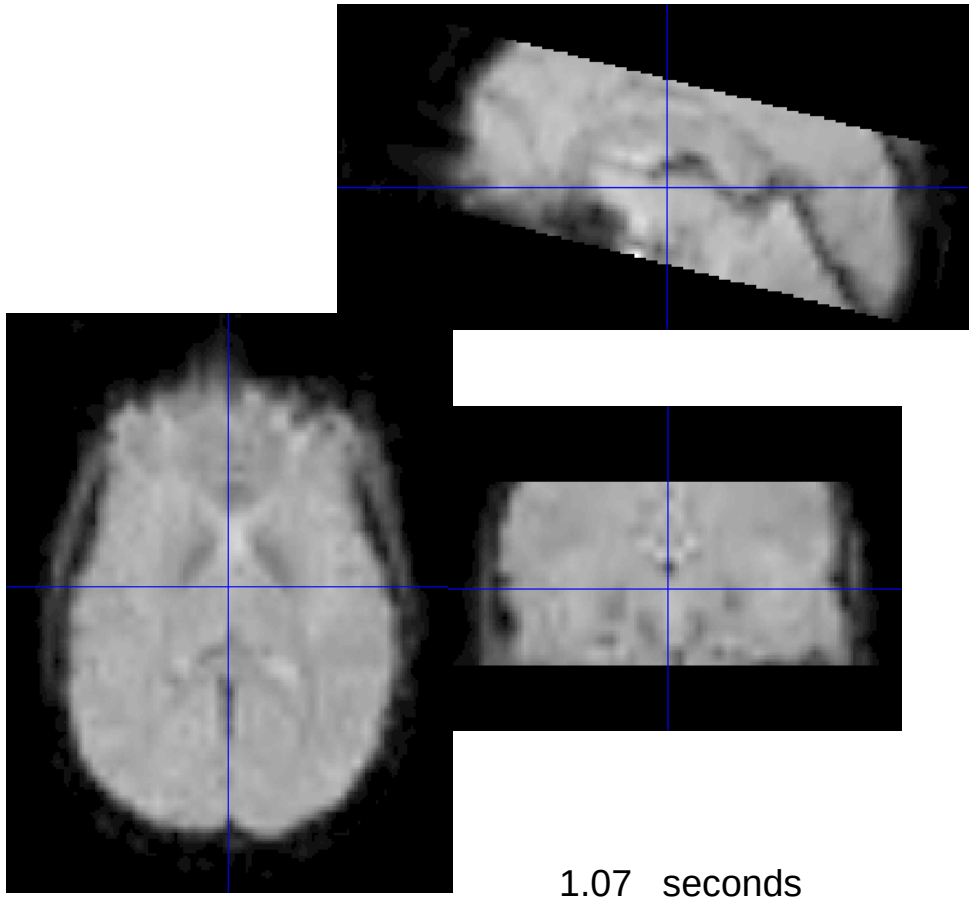
Functional MRI - fMRI

- Short recording (< 3s)
- Poorer spatial resolution than MRI



6 minutes

MRI (MPRAGE sequence)

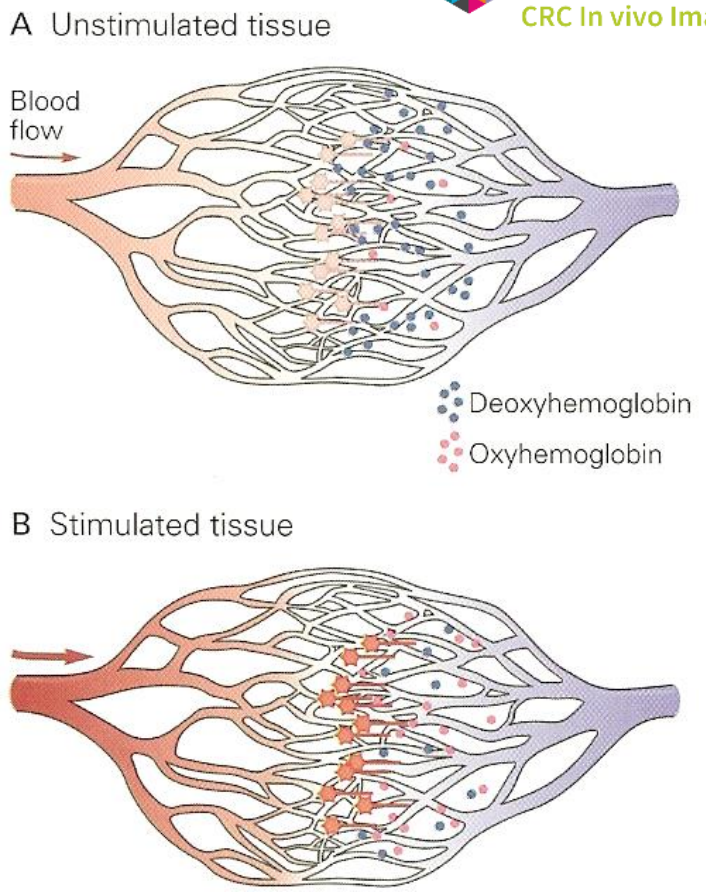


1.07 seconds

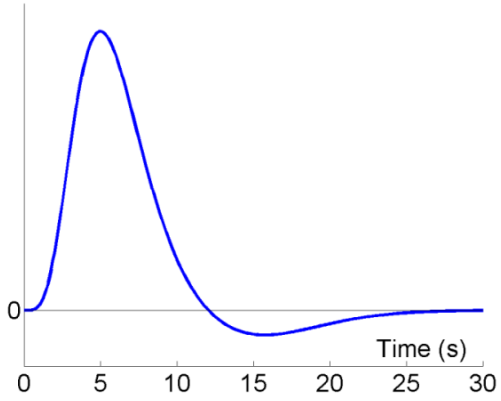
fMRI (EPI sequence)

Functional MRI - fMRI

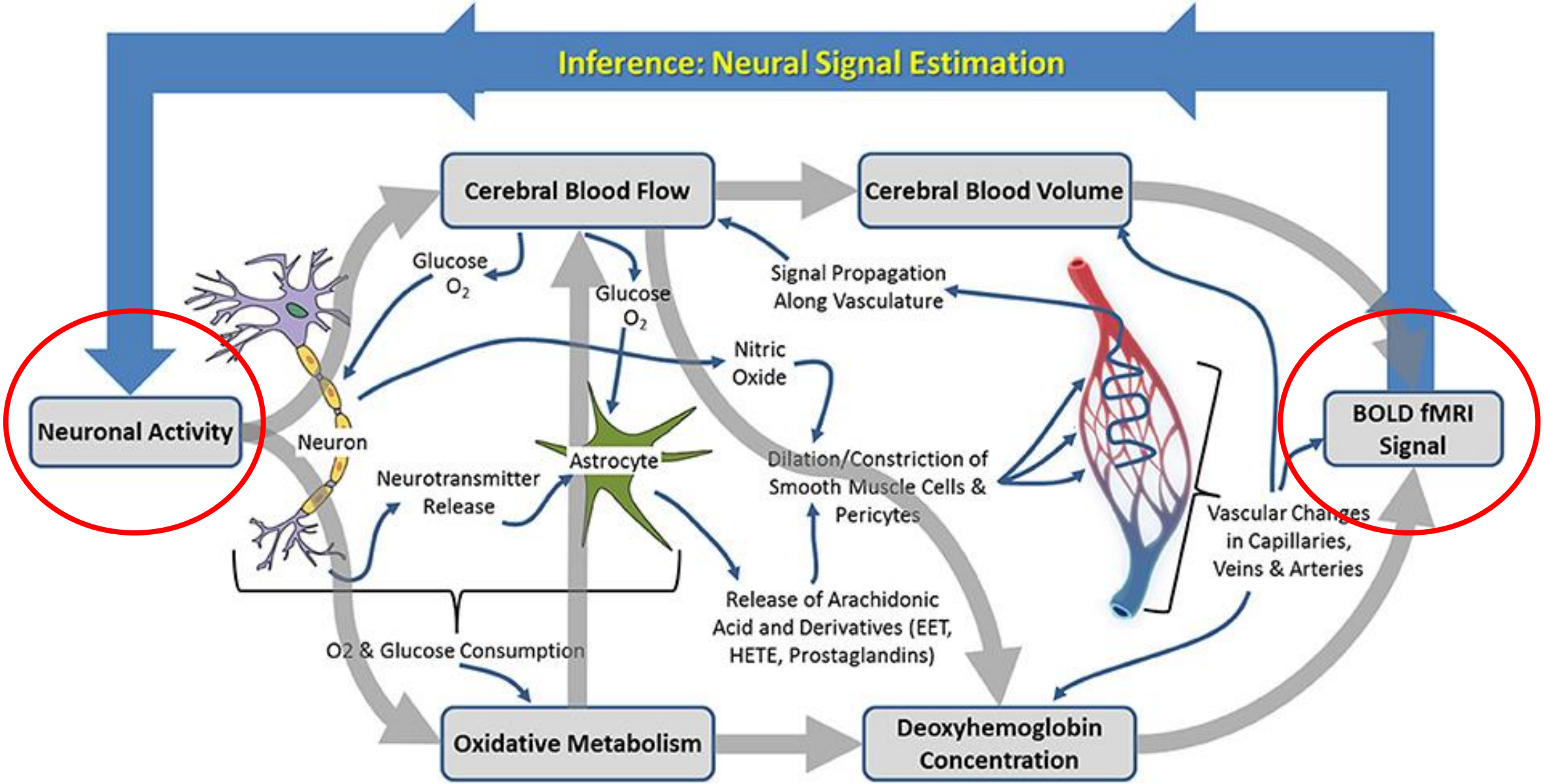
- **BOLD signal**: blood oxygen level dependent
  - Depends on Oxy/Deoxyhemoglobin ratio
  - Model of blood flow changes due to neuronal activity (extensively validated)
  - Event though it is a slow response, it can be applied to short event (e.g. 0.5 seconds)



Hemodynamic response: modeling of blood flow change in response to a stimulation



- ***Functional*** **measure**
- ***Causal*** **manipulation**
- ***Indirect*** **measure of neuronal activity**


Inference: Neural Signal Estimation
Cerebral Blood Flow
Cerebral Blood Volume
Glucose
O_2
Glucose
O_2
Signal Propagation
Along Vasculature
Nitric
Oxide
Neuronal Activity
Neuron
Astrocyte
Neurotransmitter
Release
Dilation/Constriction of
Smooth Muscle Cells &
Pericytes
BOLD fMRI
Signal
Vascular Changes
in Capillaries,
Veins & Arteries
Release of Arachidonic
Acid and Derivatives (EET,
HETE, Prostaglandins)
O2 & Glucose Consumption
Oxidative Metabolism
Deoxyhemoglobin
Concentration

fMRI: activation maps

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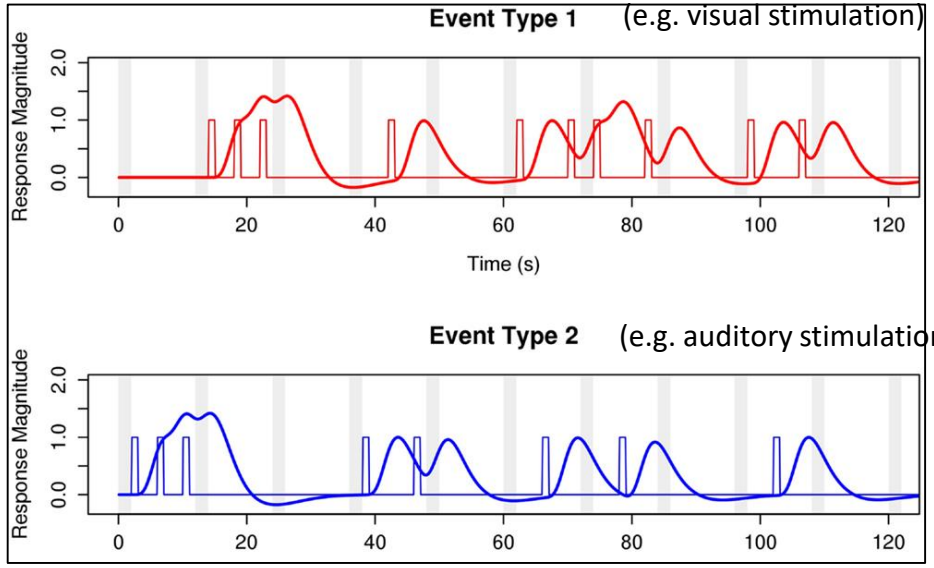
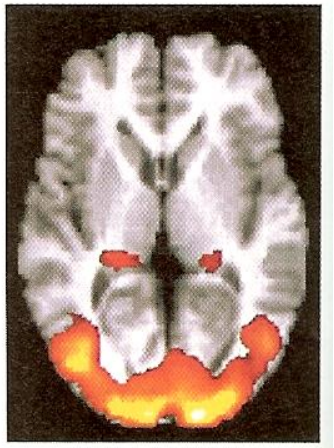
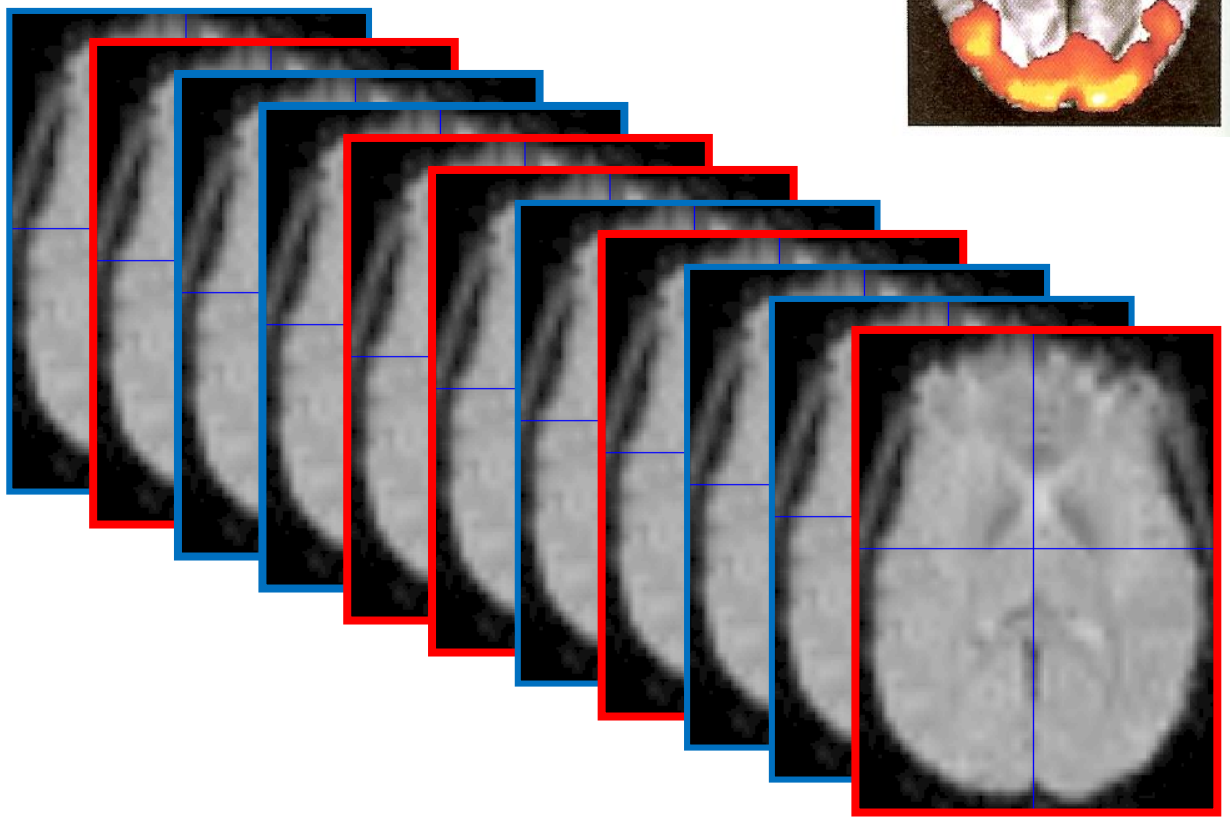
BOLD signal modelling for 2 event types



Difference

1 vs. 2





fMRI: resting state networks

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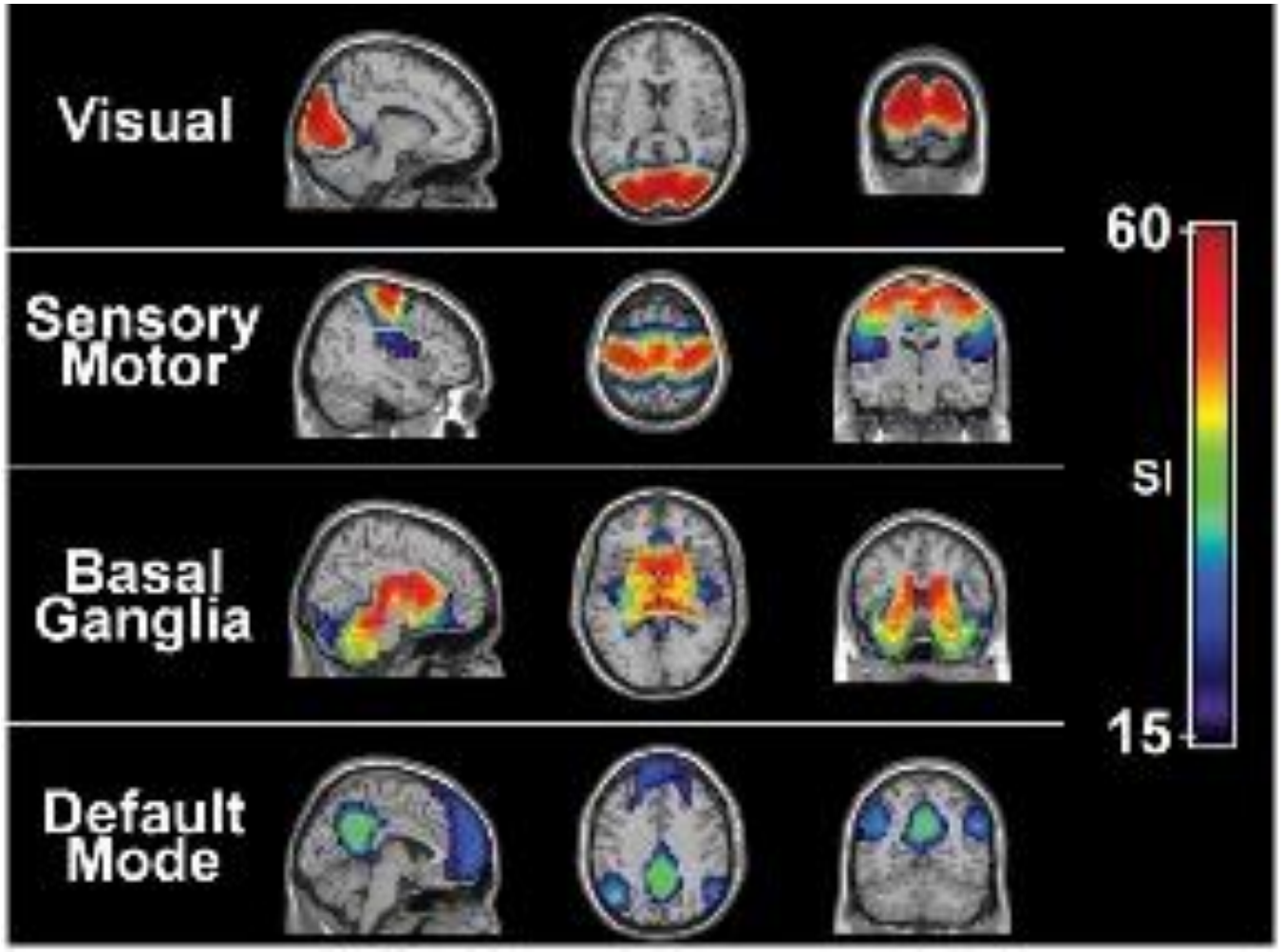
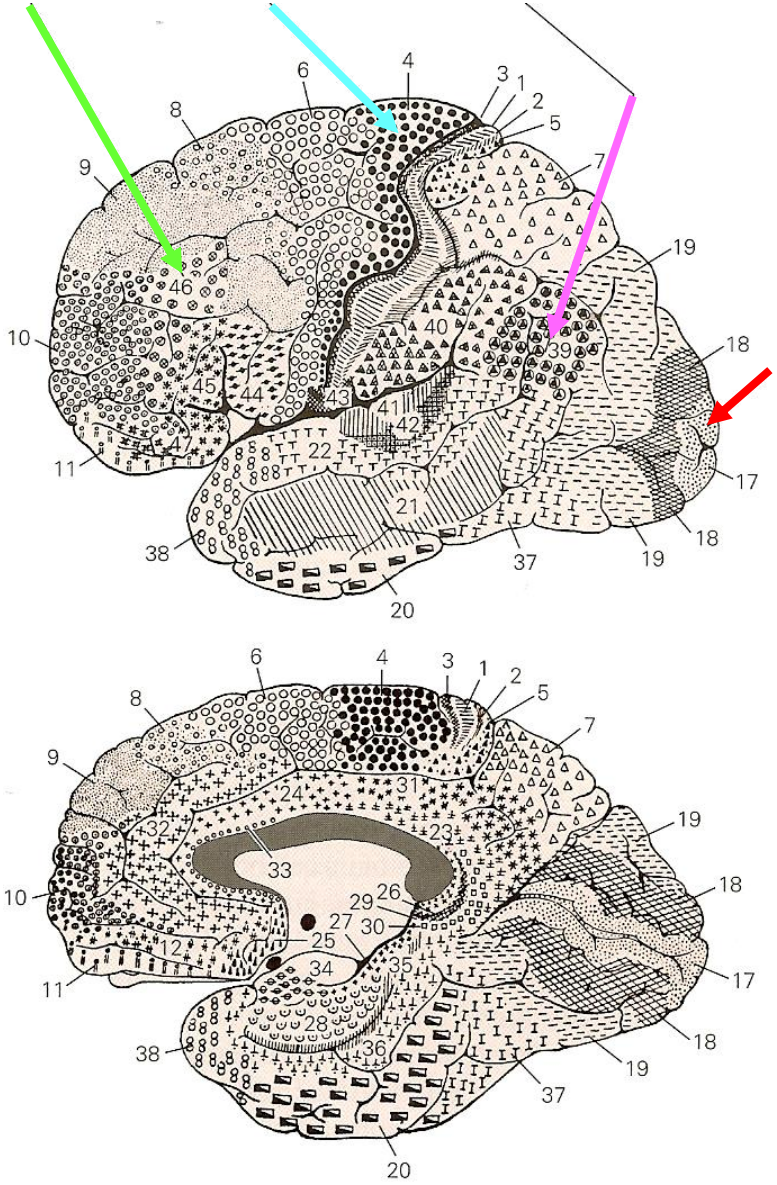
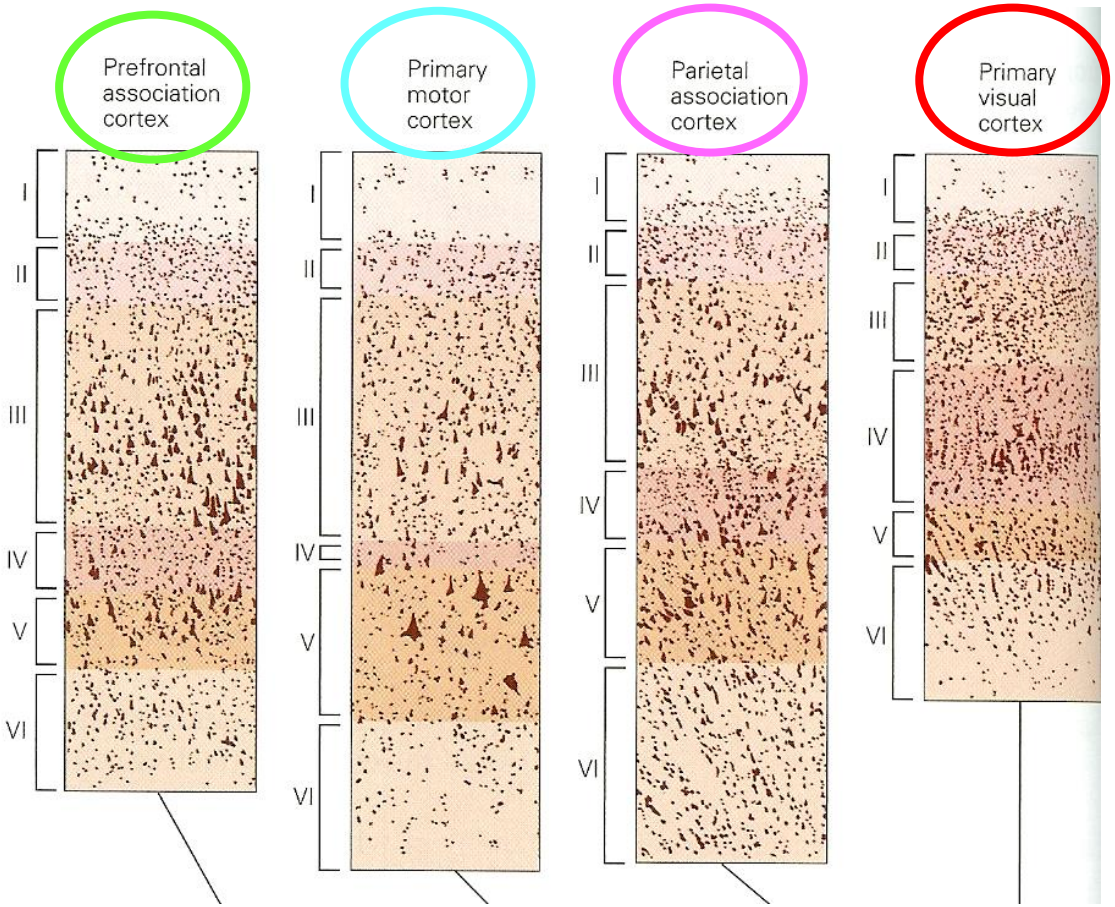
- Spontaneous spatial correlation in BOLD signal
- Correspondence to known functions



Layer fMRI - Cytoarchitecture





- Brodman areas

Layer fMRI

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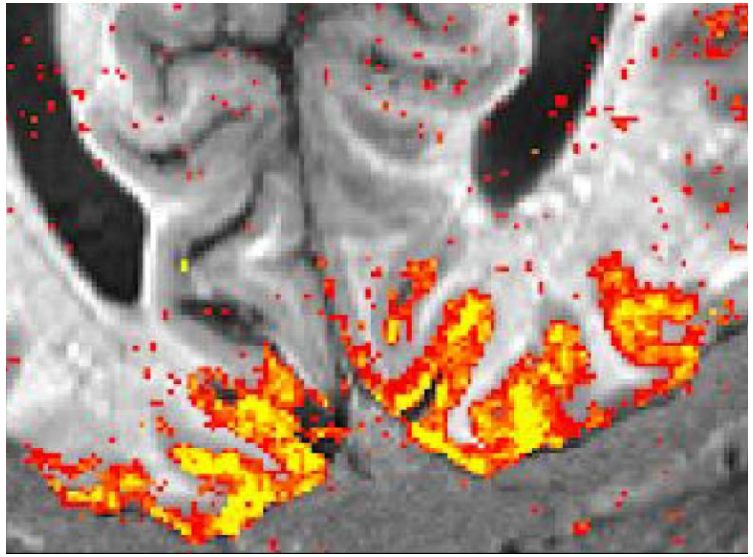
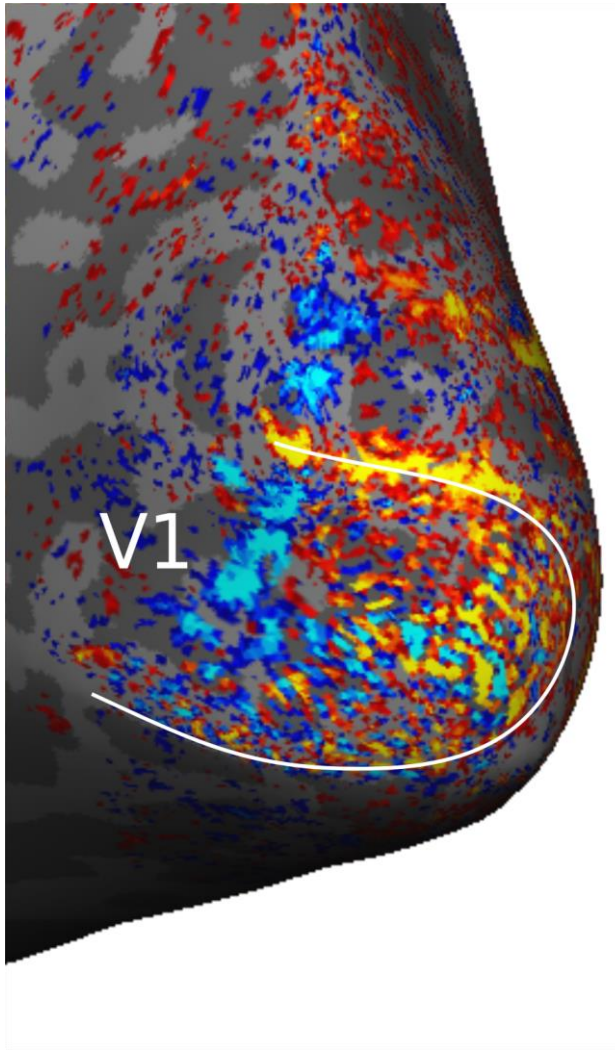
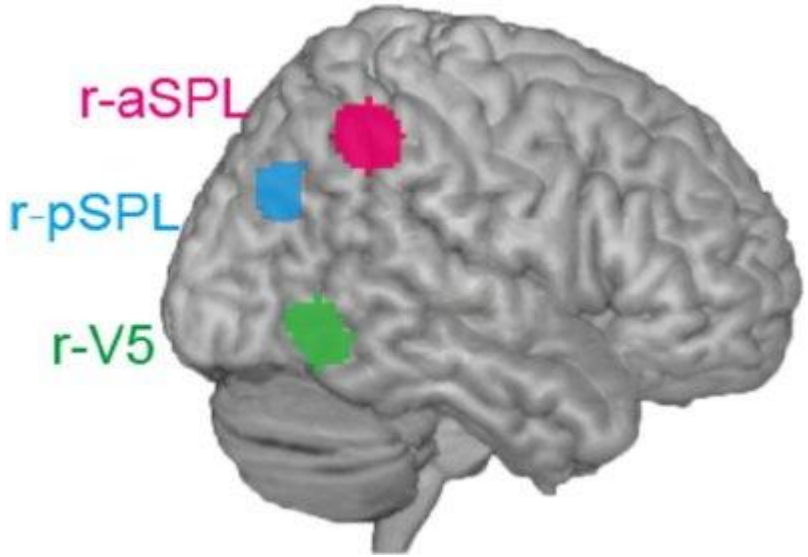
- High resolution fMRI < 1 mm
- Part of the brain
- Computation to infer layer activity



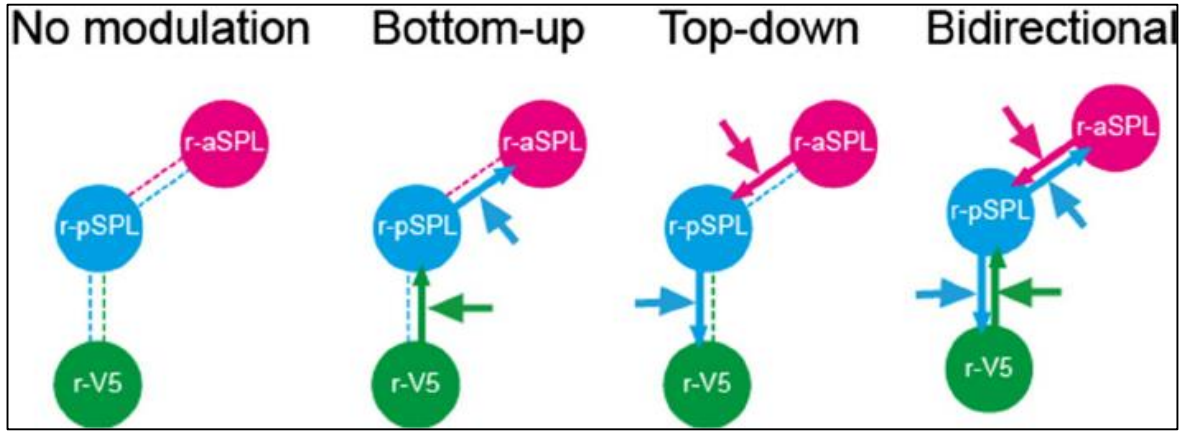


Causal connectivity analyses

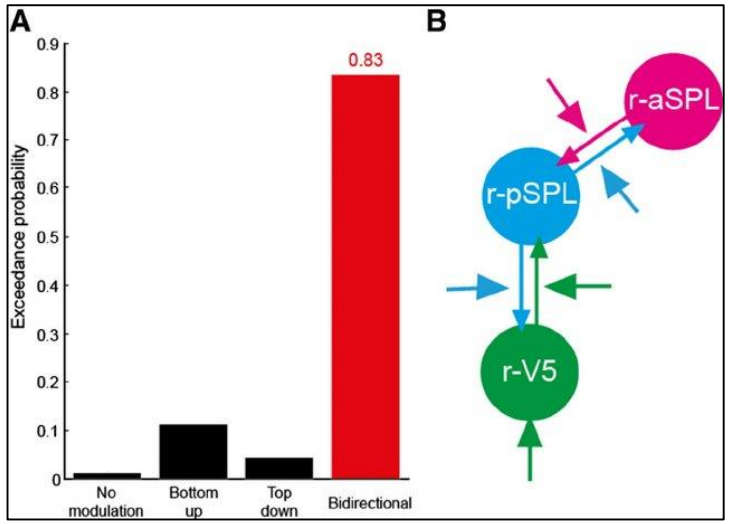
- **Following neural activity inference**
- **Test different plausible models to explain the data**
- **Selects the model with best evidence**



Tested models



Winning model



MRI is a very versatile non-invasive technique

Allowing for *in-vivo* characterisation of brain structure and function

And for* in-vivo *histology