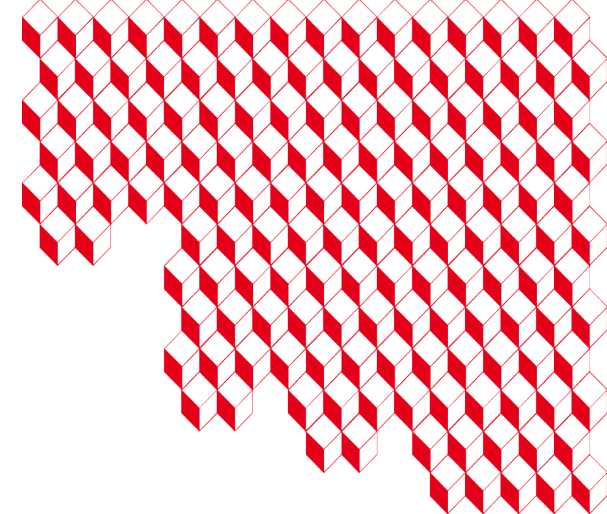




Models and Inference for Neuroimaging Data

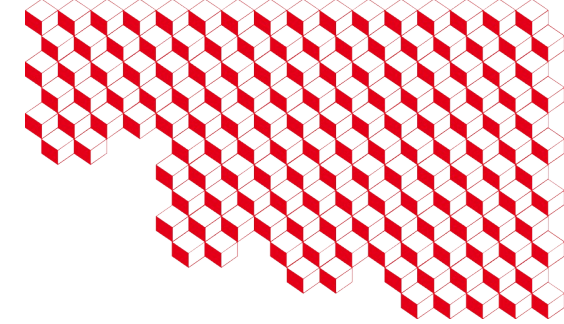
Visite Étudiants ENS 25/04

Pierre-Antoine Comby

Supervisors: Philippe Ciuciu & Alexandre Vignaud

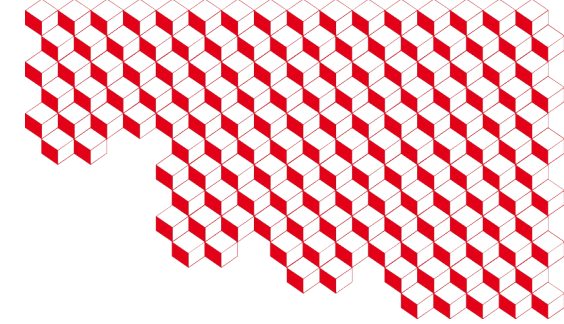


Who am I?



- PCSI/PSI
- ENS (2017 Cachan -2021 Saclay):
 - SAPHIRE
 - M1 EEA
 - ARPE (KIT, Karlsruhe, Germany)
 - M2 ATSI + Stage @Neurospin
- PhD (2021 – April 2025)
 - CDSN (Sept 2021- Sept 2024)
 - Extension (Sept 2024 – April 2025)
- My PhD
 - “From Compressed Sensing Methods to Deep Unsupervised Learning for fMRI Reconstruction at Ultra High Field”
 - **MIND** (Philippe Ciuciu) & **METRIC** (Alexandre Vignaud)
 - Keywords:
 - *Inverse Problem*
 - *Non Uniform Fourier Transform*
 - *Python/CUDA*
 - *Convex Optimization*
 - *Deep Learning*

MIND Team in Summer 2024



Philippe
Ciuciu
DR,
HdR

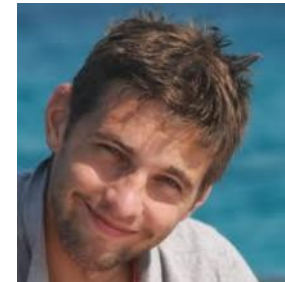
Resp.
Equipe



Bertrand
Thirion
DR, HdR



Demian
Wassermann
DR, HdR



Thomas
Moreau
CR,
PhD



Chaithya GR
CR, PhD



David Degras
Assoc Prof.
Sept 2023- June
2024

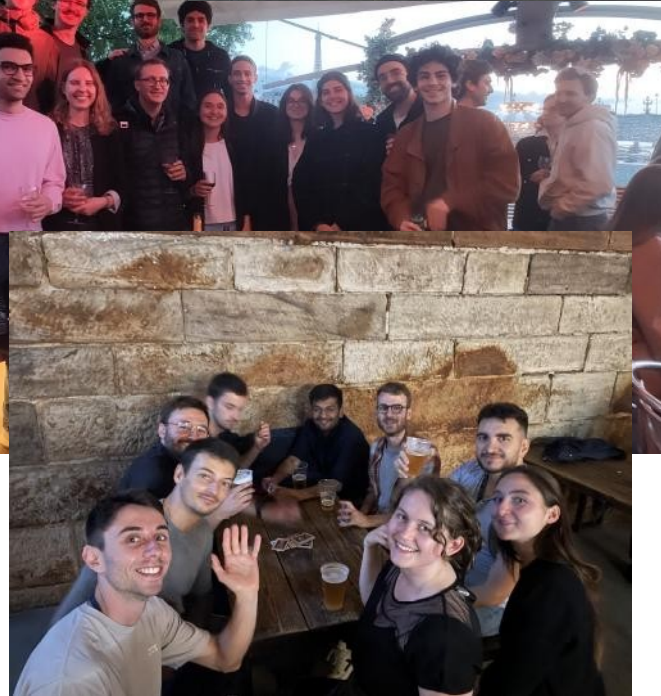


20 PhD students — 5 Post-docs — 5 Engineers (CDD) + Interns

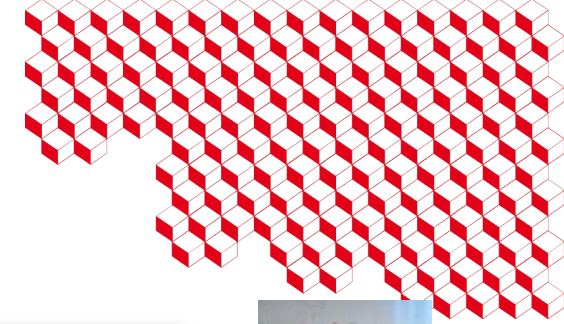


Inc. 2 EEA !

Family Album



MIND : Core Development



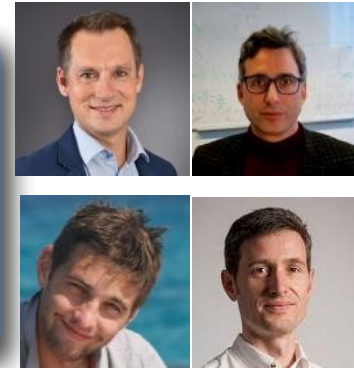
Machine learning for
inverse problems

Heterogeneous Data &
Knowledge Bases

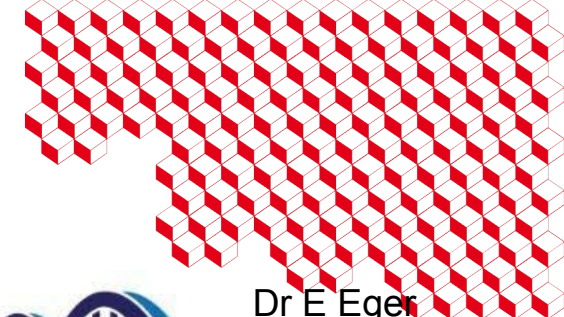


Statistics and causal
inference in high
dimension

Machine Learning on
spatio-temporal signals



MIND: A resonating tryptic organization



MEG/EEG/SEEG
aMRI/fMRI/dwMRI

ML for neuroimaging &
neuroscience



Dr E Eger



Prof. S. Dehaene Dr Ch Pallier



Open source software
development

Applications in cognitive
& clinical neuroscience



Pierre-Antoin

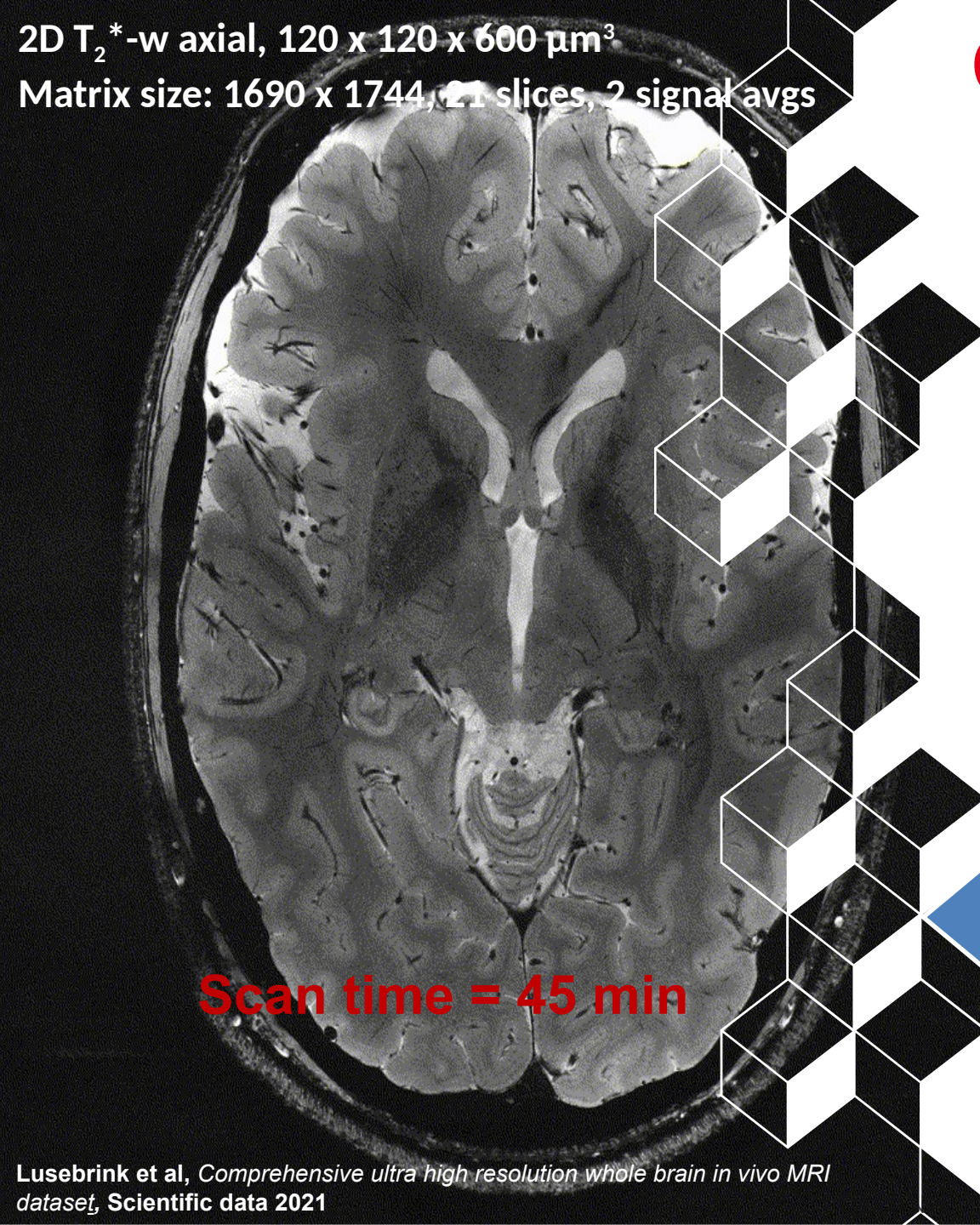


Prof. E. Mandonnet



Dr F. Vallée

26 avril 2024

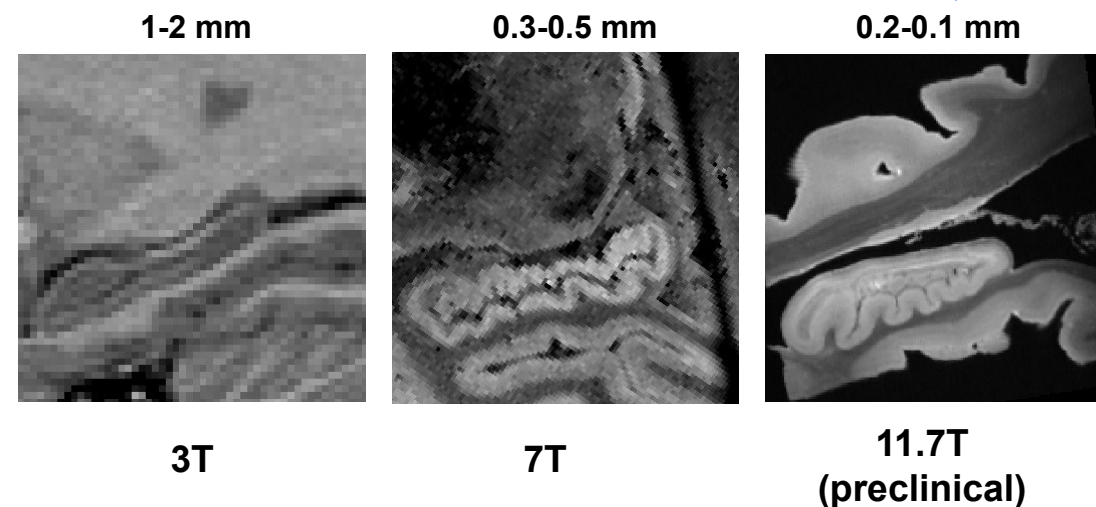


Context

Ultra-high-resolution MR imaging

Human brain Hippocampus

Courtesy C. Poupon (NeuroSpin)



Need for accelerating acquisition

Reduce scan time for a given resolution

reduce costs, patient discomfort, motion

Increase resolution for a given scan time budget

Understand brain structure, morphology and function

SPARKLING

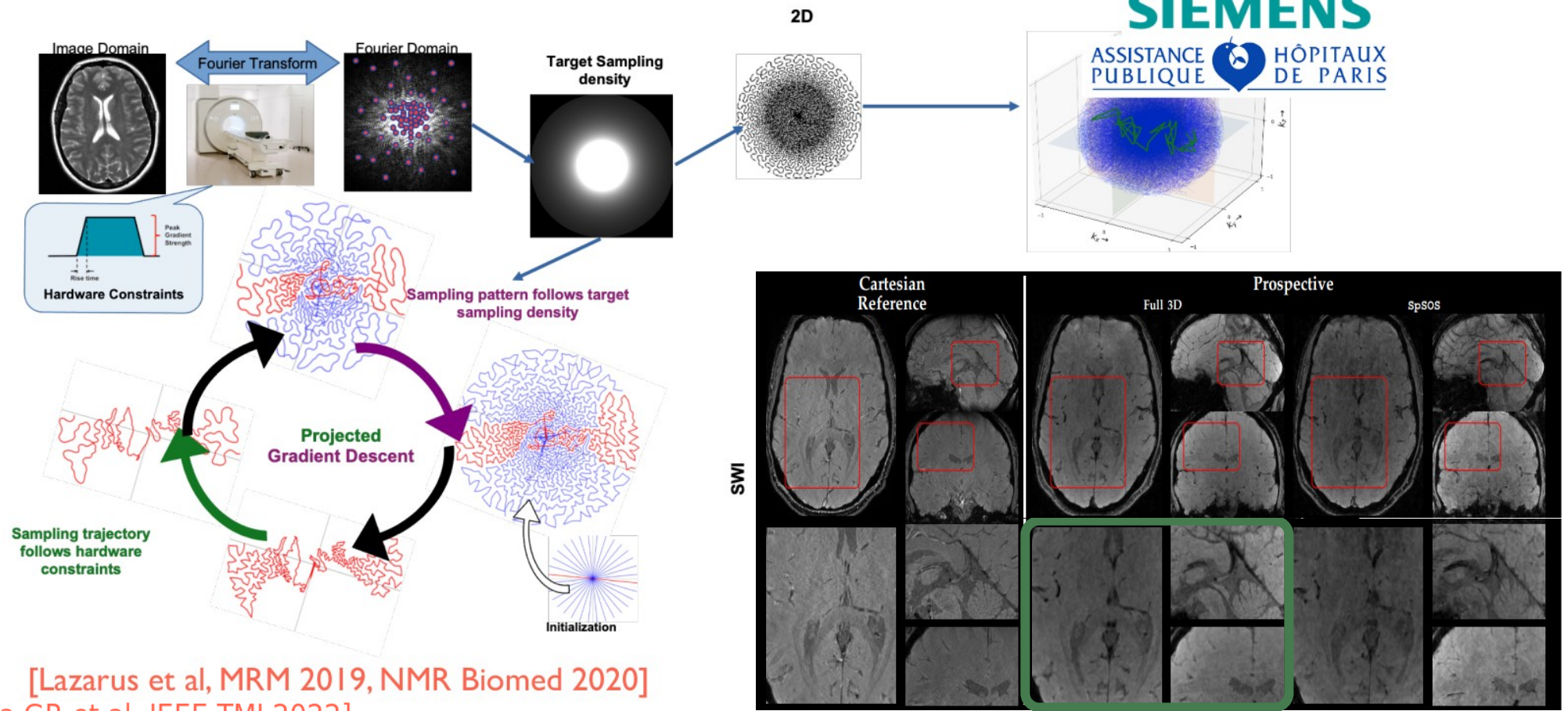
Challenge: Speed up the **acquisition** (less sampling)

SPARKLING method

Collaboration with
NeuroSpin **METRIC**

SIEMENS

ASSISTANCE
PUBLIQUE **HÔPITAUX
DE PARIS**



[Lazarus et al, MRM 2019, NMR Biomed 2020]

[Chaithya GR et al, IEEE TMI 2022]

[Daval-Fr rot et al, MRM 2022]

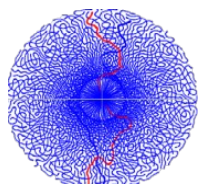
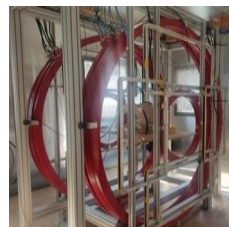
Kick-off MIND team - NeuroSpin - Philippe Ciuciu

Impact of 3D SPARKLING

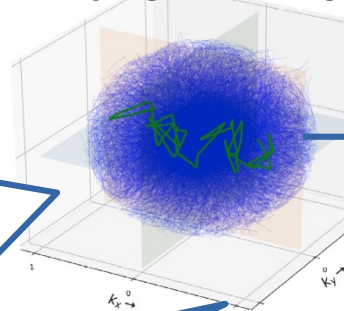
SPARKLING for VLFMRI



P. Kumari



3D SPARKLING

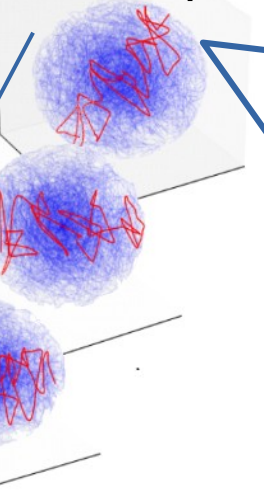


Chaithya G R



Time

Scan & Repeat



fMRI

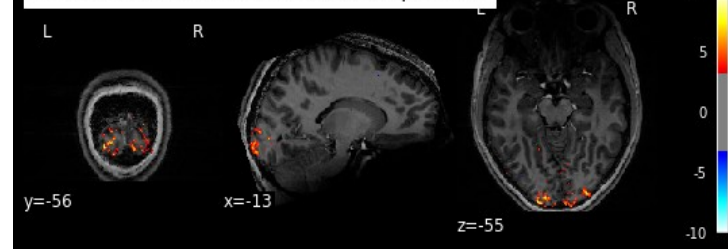
Z. Amor



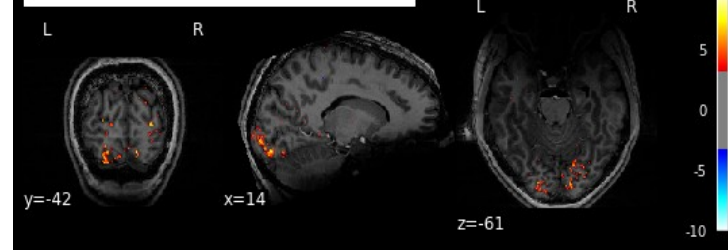
METRIC

Z. Amor, P. Ciuciu,
Chaithya G R et al,
SPARKLING vs EPI
for fMRI, in review
PloSOne 2023

3D-SPARKLING - Effect of interest at $p < 0.001$

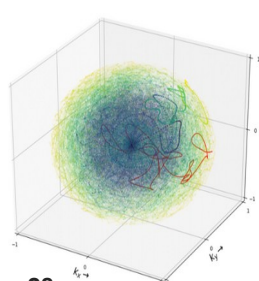
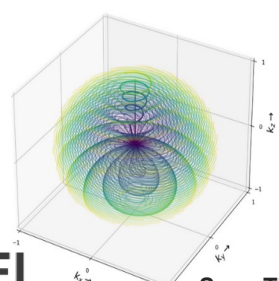


3D-EPI - Effect of interest at $p < 0.001$



SPARKLING

TPI

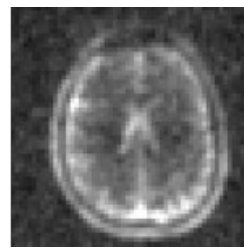
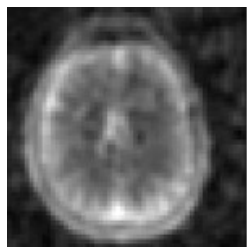


Scan Time: 28s

Sodium Imaging



R. Baptista



R Baptista, M Naudin, Chaithya et al, *IRM cerebrale du sodium rapide avec SPARKLING 3D sous-echantillonnee a 7*, Journal of Neuroradiology 2023

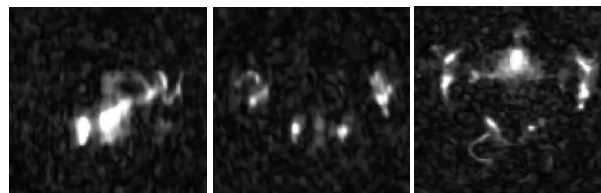
Angiography and Perfusion imaging



Q. Shen
T. Okell



SOTA



SPARKLING



A. Vignaud



G. Daval-Fr rot



A. Massire



F. Mauconduit



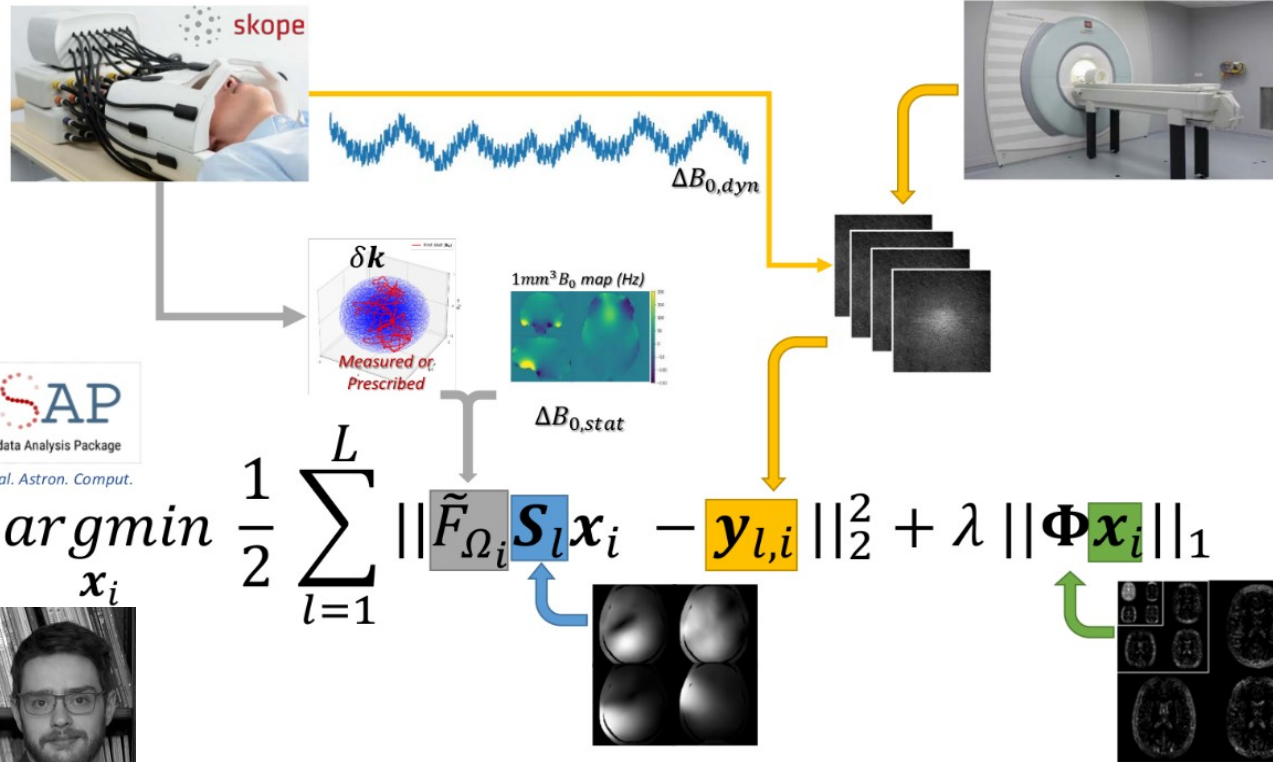
METRIC

3D SPARKLING for fMRI at 7Tesla

	TE (ms)	Unitary TR (ms)	Volumetric TR (s)	Spatial resolution (mm)	FOV (mm)	Number of repetitions	Encoding direction
3D-SPARKLING	20	50	2.4	1mm iso	(192,192,128)	120 - 125	P-A



- ▶ 5 volumes per GPU
- ▶ 25 GPUs for Sone fMRI time series
- ▶ 125 volumes reconstructed in ~3 hours

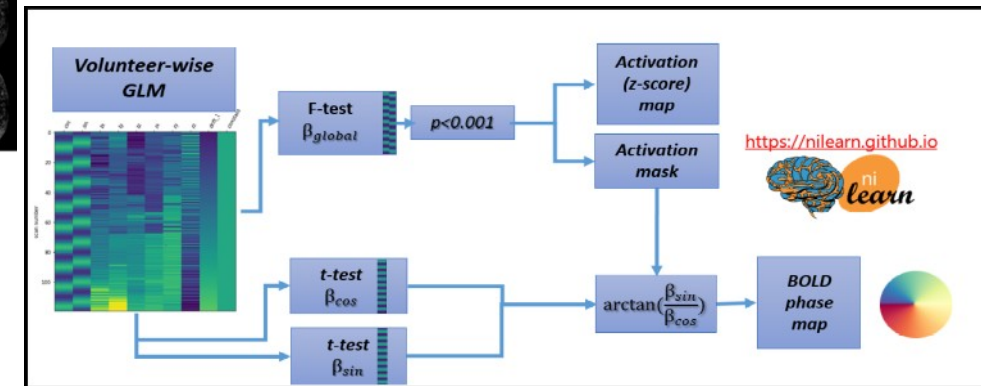


S. Farrens P.A. Comby

<https://github.com/CEA-COSMIC/pysap-mri>

▶ Evaluation:

- ▶ rsfMRI: image quality and tSNR
- ▶ Retinotopic mapping fMRI data: retinotopic maps



[Farrens et al, Astro. Comput., 2020; Amor, et al, MRM under review]

BLUESKY: MULTISCALE UNDERSTANDING OF LEARNING MECHANISMS

Based on existing **short term learning paradigms**
with robust outcomes in **healthy subjects**

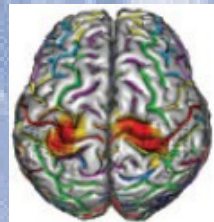
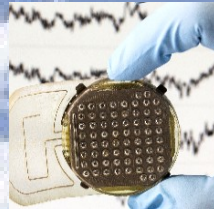
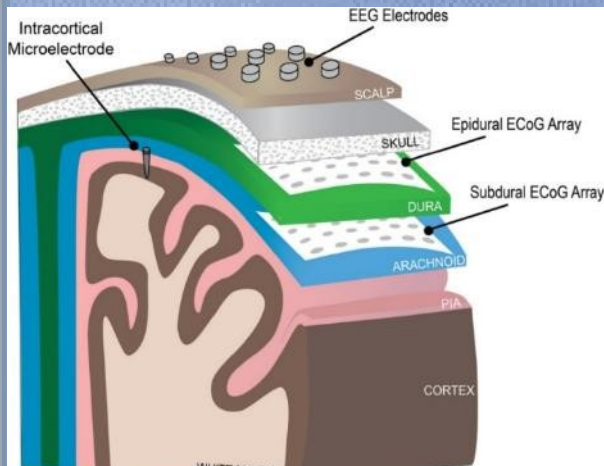
Tools: 7T fMRI and MEG

Based on available clinical datasets from SCI
patients intending motor control

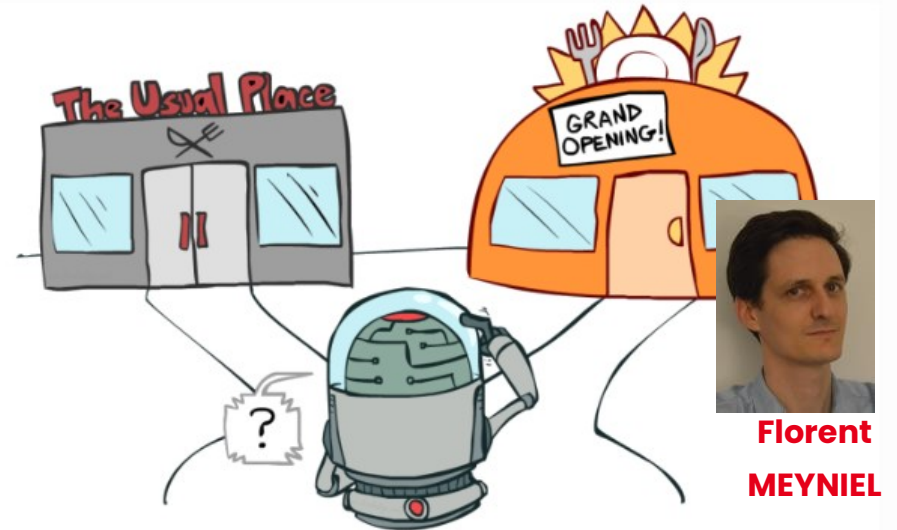
Tools: Epidural ECoG, fMRI and MEG

Study of **brain plasticity mechanisms**
within years of training

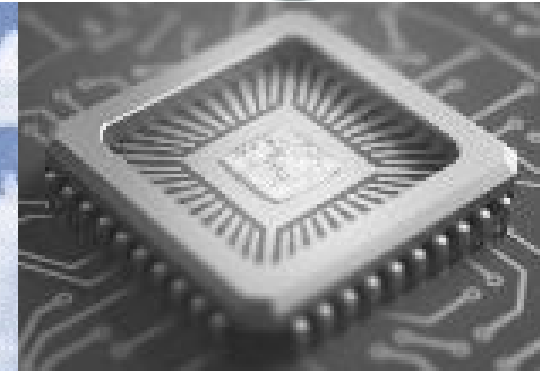
Study of **reinforcement mechanisms**
within training sessions



Do I explore or do I exploit?



**Florent
MEYNIEL**



Inserm CEA
UNICOG

Acknowledgments



Team members

- Aggarwal Himanshu
- Al-shikhley Liza
- Allain Cédric
- Amor Zaineb
- Brosset Serge
- **Chaithya GR**
- Chamma Ahmad
- *Chapalain Thomas*
- Chehab l'Emir Omar
- **Collas Antoine**
- *Comby Pierre-Antoine*
- Dagréou Mathieu
- Dumeur Merlin
- **Ghayyem Fatemeh**
- Lapostolle Benjamin
- Le Bris Alexandre
- Linhart Julia
- Malézieux Benoît

Team members

- Manquat Elsa
- Mellot Apolline
- Meudec Raphaël
- Michel Florent
- Mohamed Ziad Ahmed
- **Moreau Thomas**
- Marzulli Morgan
- Mzayek Yasmin
- Ponce Martinez Ana
- Pooja Kumari
- Rouillard-Odera Louis
- **Staerman Guillaume**
- **Terris Matthieu**
- **Thirion Bertrand**
- Thual Alexis
- **Wang Sheng H**
- **Wassermann Demian**
- *< Your Name Here >*

Collaborators

- Alexandre Vignaud
- Franck Mauconduit
- Caroline Le Ster
- Stanislas Dehaene
- Christophe Pallier
- Evelyn Eger
- Florent Meyniel
- Agnès Malgouyres
- Aurélien Massire
- Mariappan Nadar
- Blanche Bapst
- Emmanuel Mandonnet
- Fabrice Vallée
- Mathurin Massias
- Pedro Rodrigues
- Pierre Ablin
- Matthieu Kowalski
- ...

A PhD thesis at Neurospin

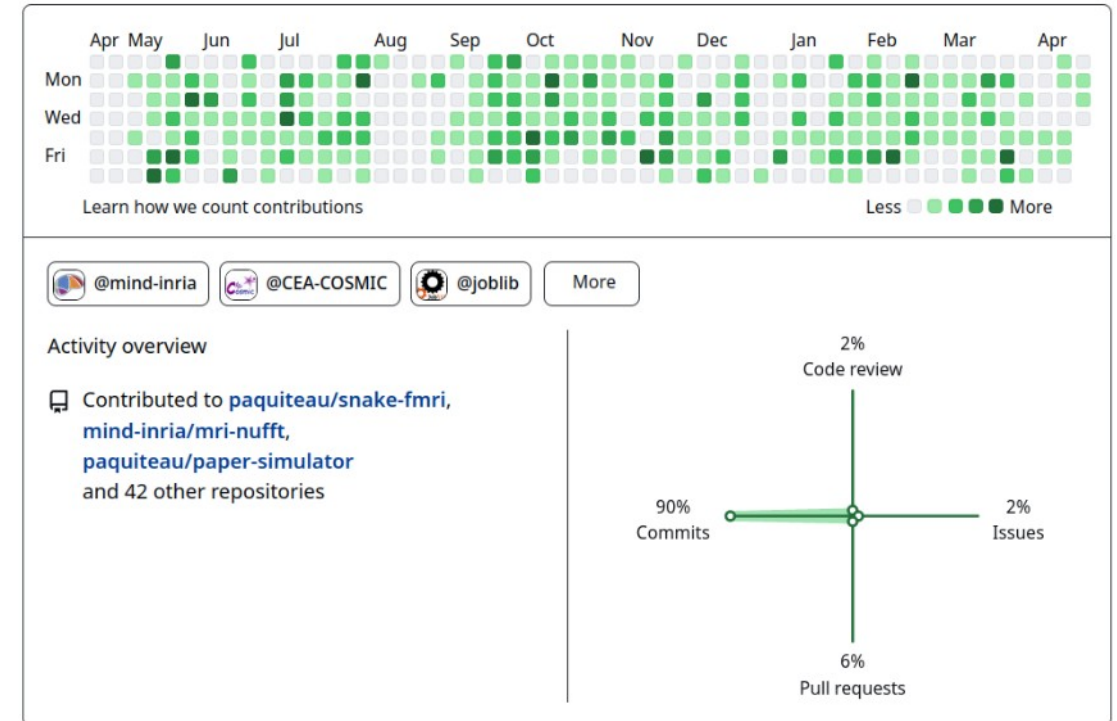
- Free Coffee, Discussion
- Code / Experiments
- Meetings
 - Advisors, Team, ...
- Paper Writing
- Slides, Slides, Slides
- MRI Acquisitions (or not !)
- Conferences
 - Travel !

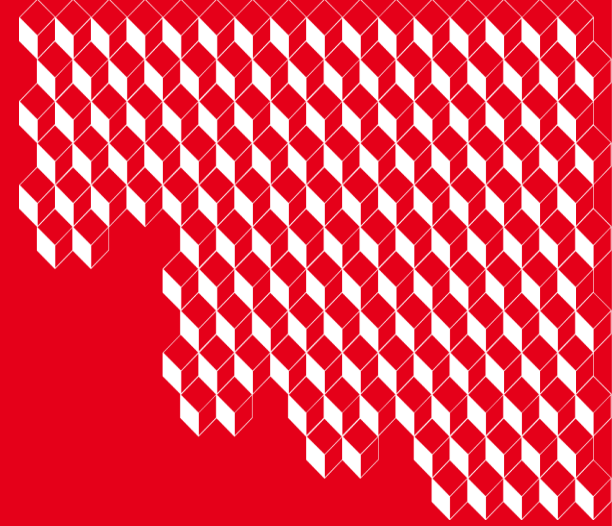
 <https://github.com/paquiteau>

 <https://linkedin.com/in/pierre-antoine-comby>

 pierre-antoine.comby@ens-paris-saclay.fr

 pierre-antoine.comby@crans.org





 <https://github.com/paquiteau>

 <https://linkedin.com/in/pierre-antoine-comby>

 pierre-antoine.comby@ens-paris-saclay.fr

 pierre-antoine.comby@crans.org

Stage, Thèse, etc:

 philippe.ciuciu@cea.fr

