# DRF-impulsion : COSMIC – COmpressed Sensing for Magnetic resonance Imaging and Cosmology

**Projet AAP 2016**


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*Jean-Luc Starck*[2],*Samuel Farrens*[2], *Florent Sureau*[2], *Fadi Namour*[2], *Sophie Starck*[2], *Julien Girard*[2]

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DE LA RECHERCHE À L'INDUSTRIE

3 Février 2020

# COSMIC – Aims

## Projet AAP 2016

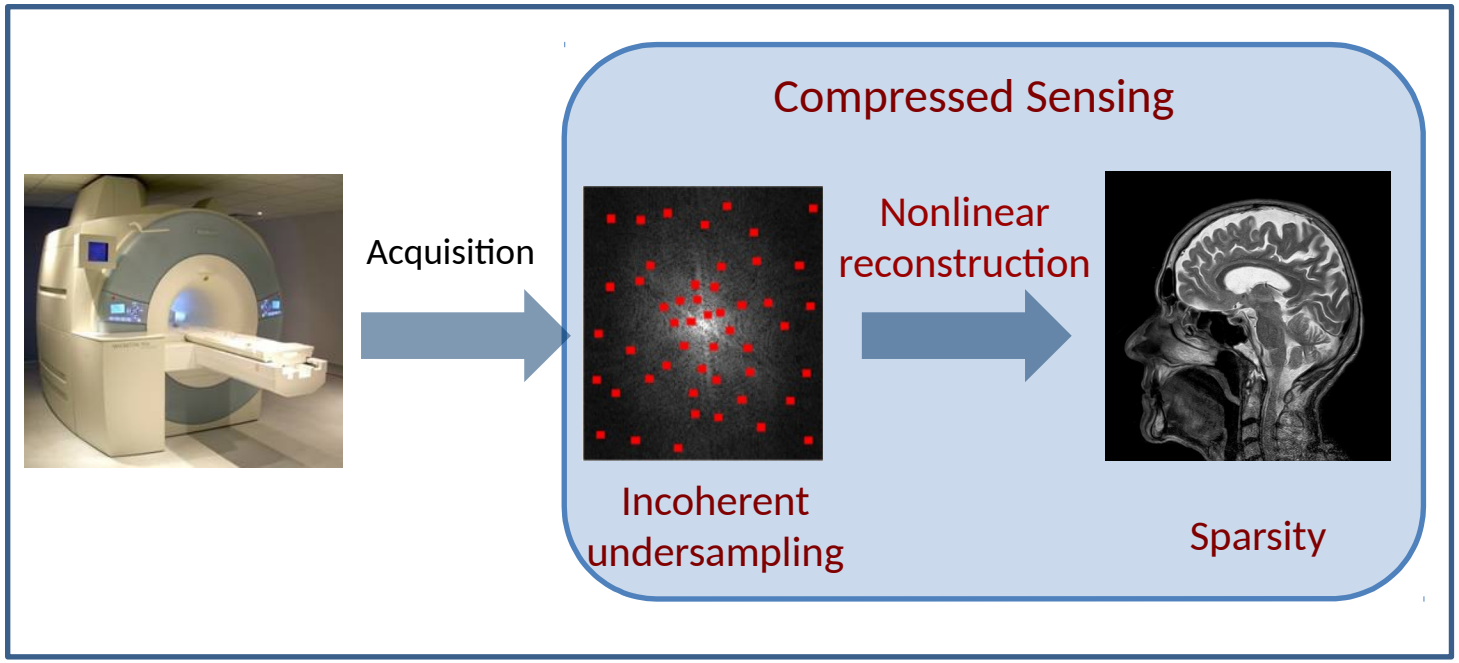
**Context: Large scale instruments & Big data Analytics**

- ✓ Iseult 11.7 Tesla MRI scanner
- ✓ Squared Kilometer Array telescope (radio-interferometry)


cosmic.cosmostat.org

**Goals: Imaging better & faster**

- ✓ Common needs for sparse Fourier sampling
- ✓ Improve MR image representation
- ✓ Speed up image reconstruction
- ✓ Develop common software (PySAP)

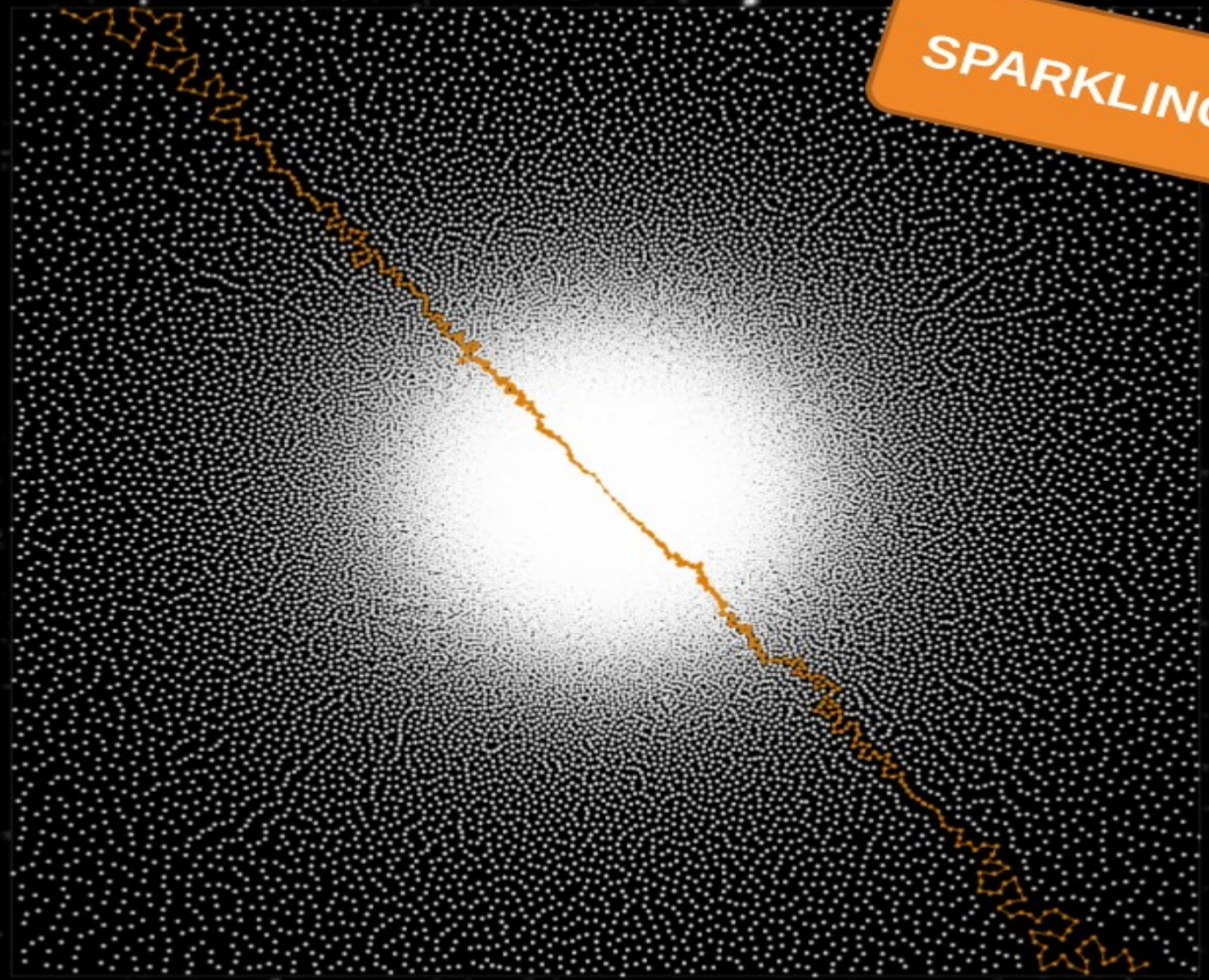


# SPARKLING

## Spreading Projection Algorithm for Rapid K-space sampLING

Carole lazarus *PhD*

*2019 I.I.Rabi ISMRM Young Investigator Award Finalist*
*Best PhD thesis from Chancellor of Paris Universities, 2019, section: Sciences*

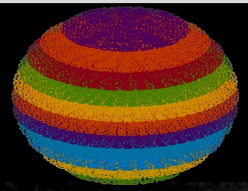



Alexandre *Vignaud, PhD*

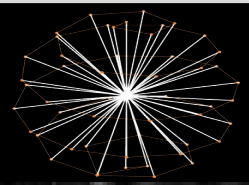
[Lazarus et al. SPARKLING: ISMRM 2017, Magn Reson Med 2019]

# 2.5D SPARKLING Trajectories vs Others

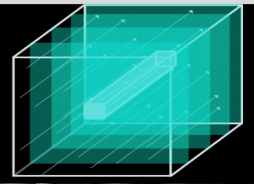
IPAT 4
TA=14'31”



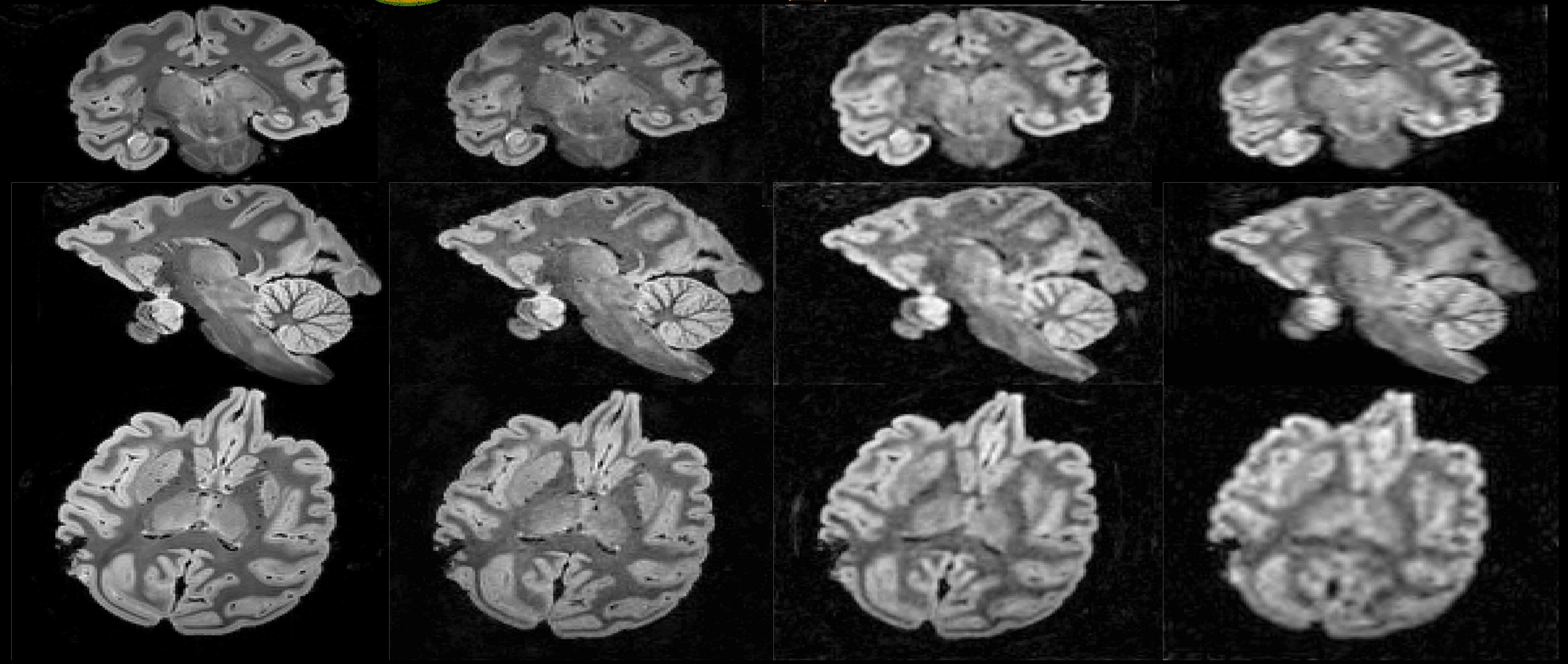
SPARKLING
TA=45”
SSIM=0.86



RADIAL
TA=45”
SSIM=0.72



Poisson disk lines
TA=45”
SSIM=0.58

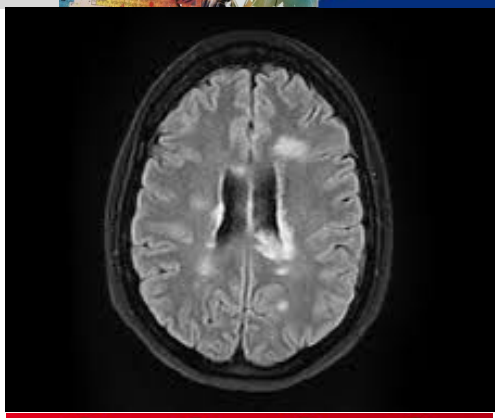


[Lazarus et al, ISMRM 2018, MRM 2019, under review NRM Biomed 2020]

# Multidisciplinary Image Processing Tools

Cosmic

Compressed Sensing for Magnetic Resonance Imaging & Cosmology

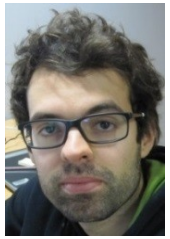


CosmoStat

PySAP: Python Sparse Data Analysis Package

NeuroSpin

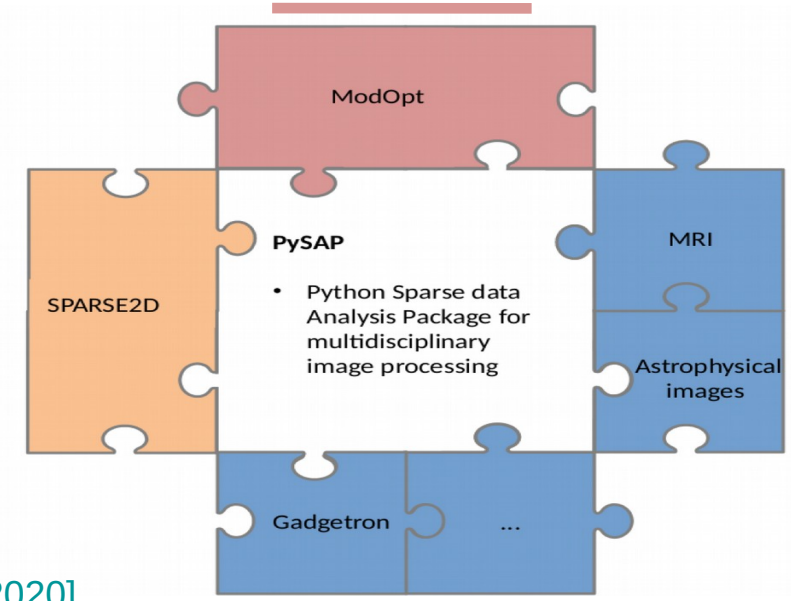
S. Farrens



A. Grigis

## ModOpt

## Sparse2D

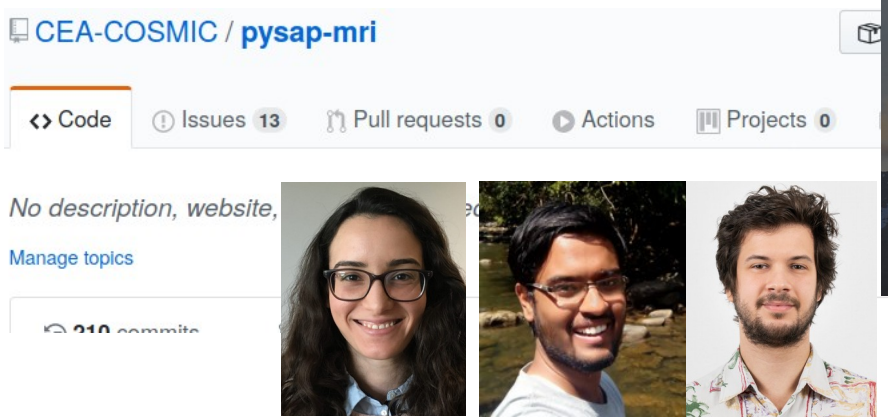



## Plug-Ins

https://github.com/cea-cosmic/pysap

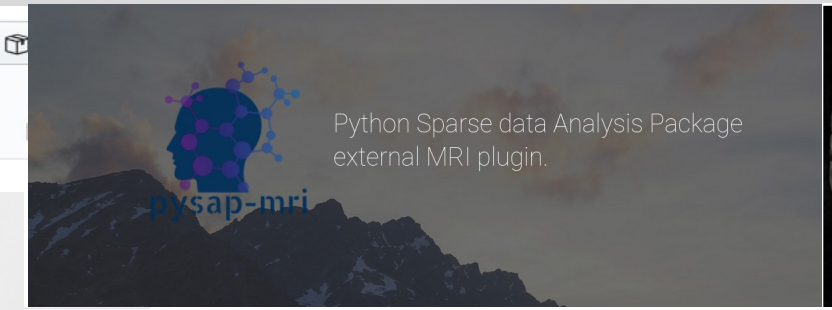
[Farrens et. al., Astronomy & Computing, 2020]

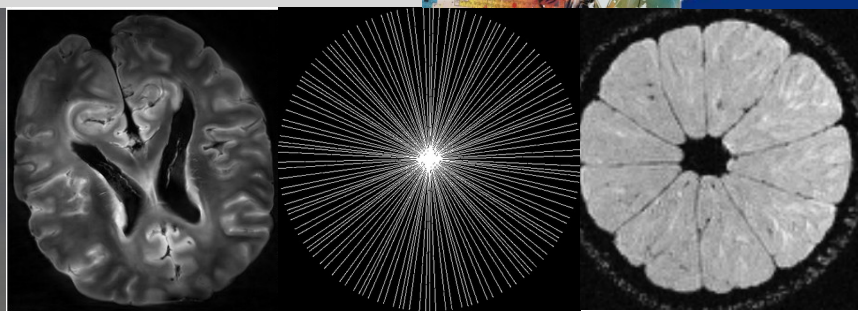
# PySAP – MRI: https://github.com/CEA-COSMIC/pysap-mri

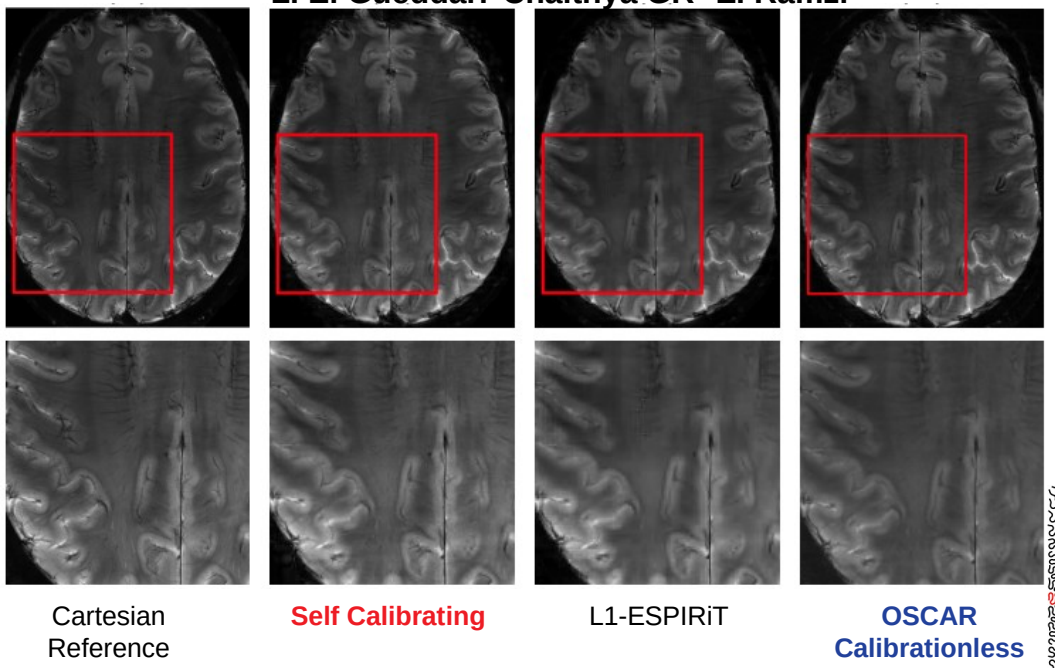





L. El Gueddari Chaithya GR Z. Ramzi

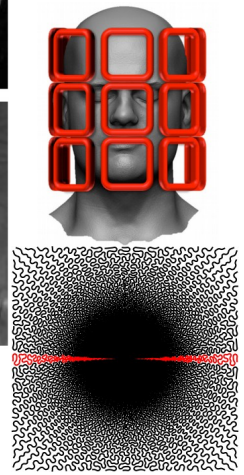





[El Gueddari et. al., IEEE ISBI 2019, ISMRM WS 2020]

[El Gueddari et. al., sub to IEEE TCI 2020]



20x accel.

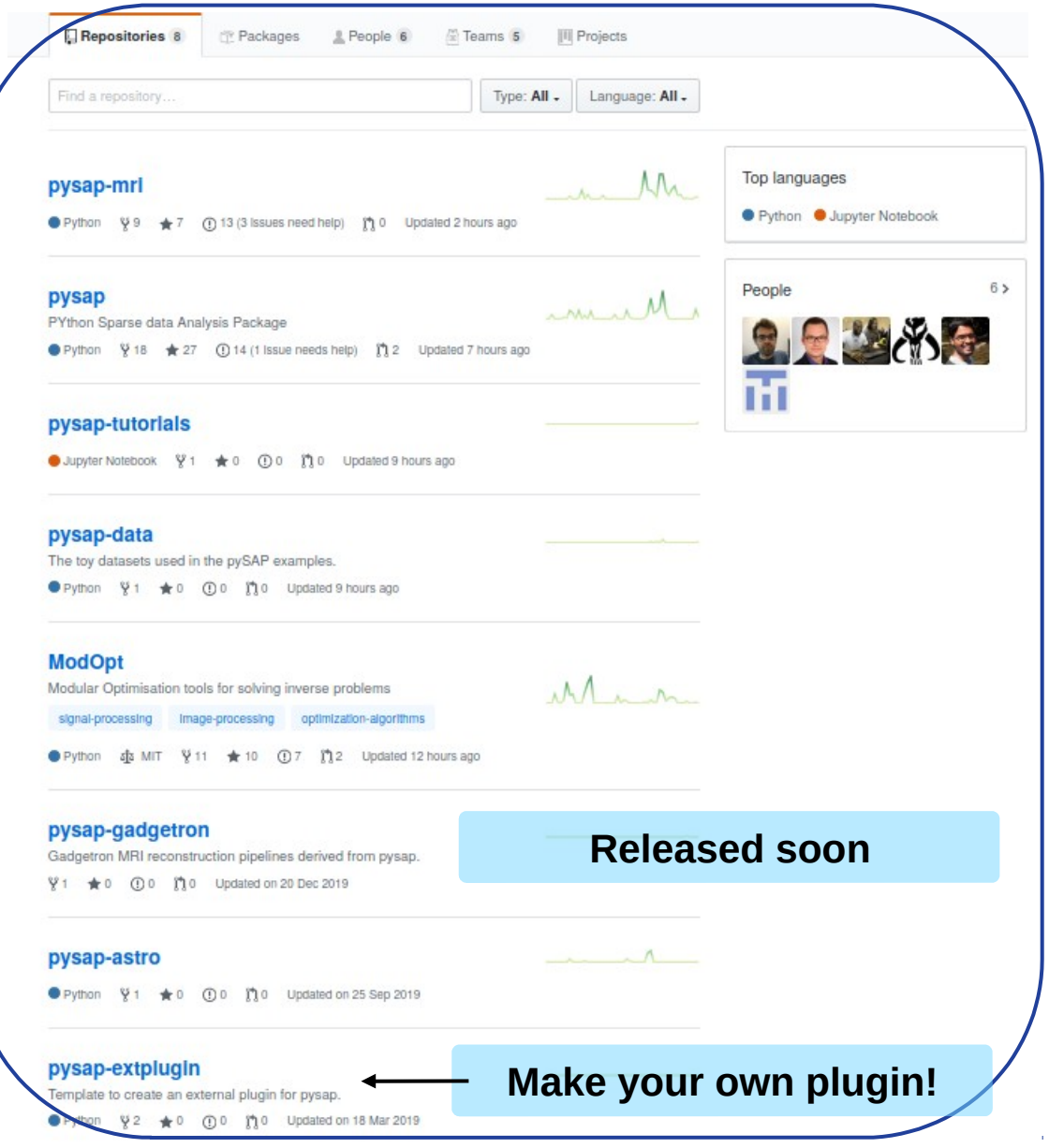
## Goal : Implement various MRI reconstruction models

- **Modeling Features**
  - Cartesian and non-Cartesian sampling schemes in **operators API**
  - Various image acquisition models in **reconstructors API**:
    - 2D vs 3D imaging
    - single vs multiple channels
    - **self-calibrating** vs **calibrationless**

$$\widehat{\boldsymbol{x}} = \underset{\boldsymbol{x}\in\mathbb{C}^{N\times N}}{\arg\min} \sum_{\ell=1}^{L} \frac{1}{2\sigma_\ell^2} \|\boldsymbol{F}_\Omega \boldsymbol{S}_\ell \boldsymbol{x} - \boldsymbol{y}_\ell\|_2^2 + \lambda \|\boldsymbol{\Psi}\boldsymbol{x}\|_1$$

$$\widehat{\underline{\boldsymbol{x}}} = \underset{\underline{\boldsymbol{x}}\in\mathbb{C}^{N^2\times L}}{\arg\min} \sum_{\ell=1}^{L} \frac{1}{2\sigma_\ell^2} \|\boldsymbol{F}_\Omega \boldsymbol{x}_\ell - \boldsymbol{y}_\ell\|_2^2 + \lambda\, g_{\mathrm{OSCAR}}(\boldsymbol{\Psi}\underline{\boldsymbol{x}})$$

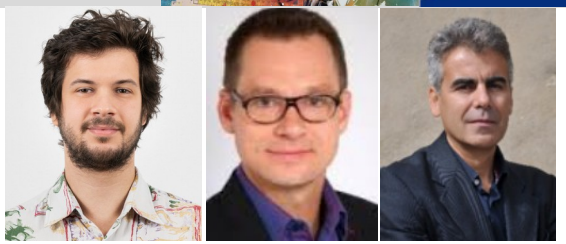
# Open to the Computational Imaging Community




https://github.com/cea-cosmic

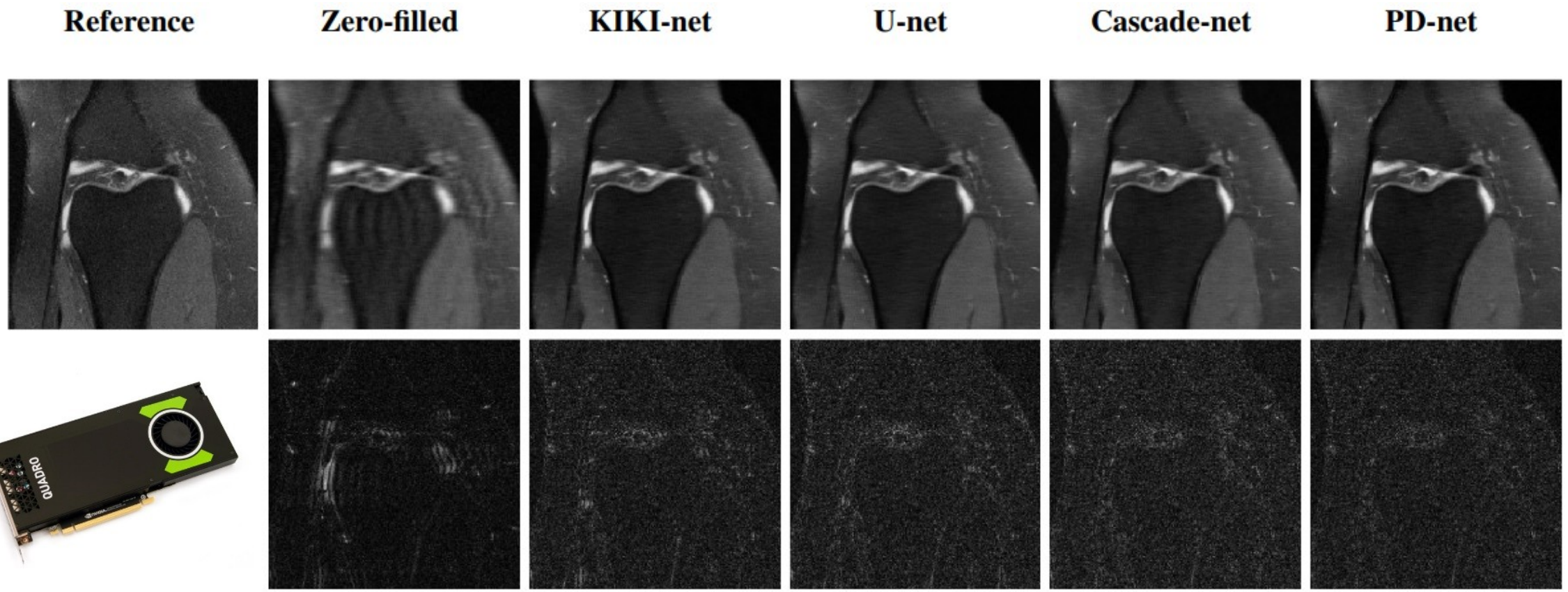
- **Software Features**
  - Continuous integration with Travis
  - Automated build of documentation
  - Integration with pyNUFFT for GPU implementation of NFFT
  - Parallelization over multiCPU for calibrationless recon.
  - GPU support in progress
- **Dissemination**
  - Test data sets & Jupyter notebooks provided (Binder support)
  - Connection to pysap-data and pysap-tutorials
- **Upcoming plug-ins**
  - Electron tomography & microscopy

# Deep learning for MR image reconstruction: a new benchmark on the fastMRI dataset



Z. Ramzi P. Ciuciu J.-L. Starck

Qualitative results, implemented in : https://github.com/zaccharieramzi/fastmri-reproducible-benchmark




[Ramzi et. al. ISBI 2020, paper submitted to a special issue “CS for Biomed Signal & Image Analysis” ]

# Scientific Outcomes

- **Permanent position:** 1 computational scientist (S. Farrens)
- **PhD theses: 3** defended (Ming Jiang, Carole Lazarus and Loubna El Gueddari)
- **2 awards for Carole Lazarus**
- **Pending patent:** 1 (in Jan 2019, ICT)
- **Journal papers:** 4 accepted, 2 under review, 1 in revision
- **Conference proceedings:** 15
- **Invited conferences:** 12 (1 at Collège de France, April 23rd 2019)
- **Teaching responsabilities @ UPSay:** M2 ATSI, L2S/CentraleSupélec 2020/21

# Giving rise to interdisciplinary projects in CEA

**CEA Compressed Sensing day** (on 31st Jan 2018@Saclay)

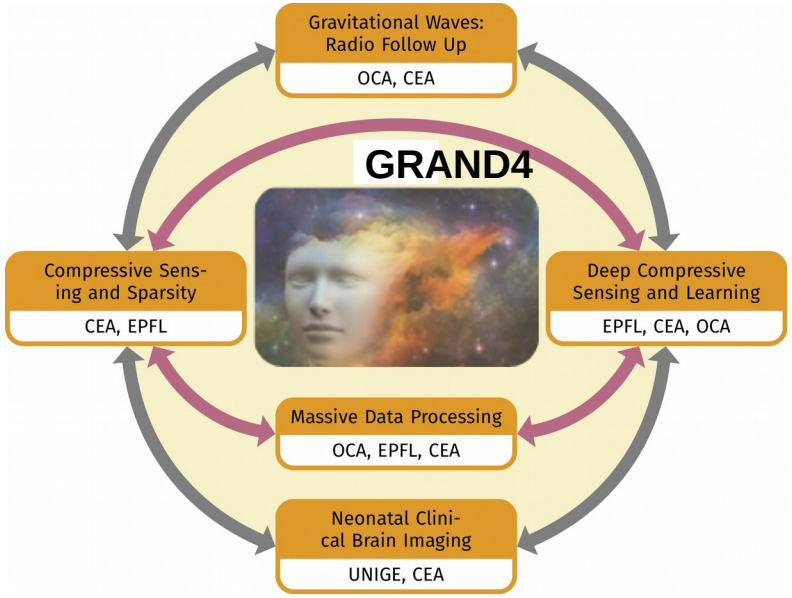
- **Objectives**: foster the cross-fertilization between imaging fields where CEA is proactive
  - DRF Impulsion **Fast FIB-SEM** (DRF Inac, PI: **P.H. Jouneau**, 70 k€) → **Electron Microscopy**
  - DRF Invention **MANIAC** (NeuroSpin, PI: **A. Vignaud**, 70 k€) → **Transfer to clinical application**
  - PTC **ComSET** (DRT/LETI, PI: **Z. Saghi**, 70 k€) → **Electron Tomography**
  - PTC **SILICOSMIC** (DRF, PI: **P. Ciuciu**, 130 k€) → COSMIC's Follow-up
    - NeuroSpin
    - CosmoStat
    - Maison de la Simulation (Pierre Kestener)

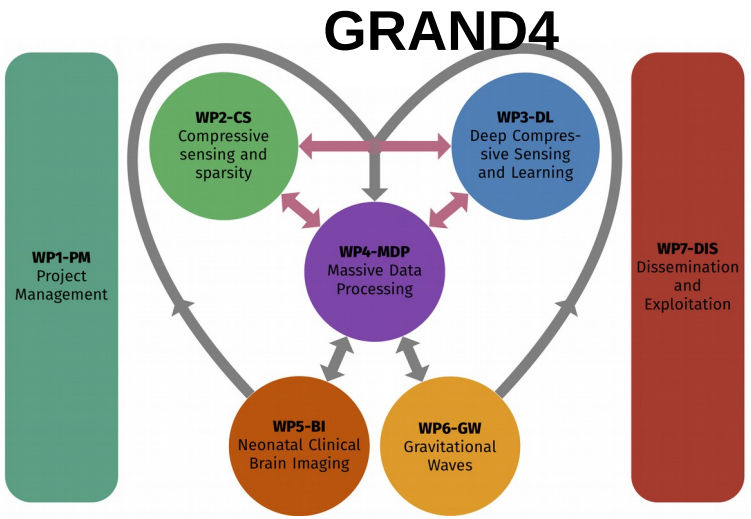
# COSMIC Perspectives

## COSMIC follow-up: next funding mechanisms

✓ **European level (H2020)**

- Nov 2019 *ERC Synergy* **GRAND4** (PI: **J.-L. Starck,** CEA, EPFL, CHU Geneva, Observatoire Nice Côte d'Azur), **under review**
- May 2020 FET Open **BaBAR** (PI: **P. Ciuciu,** CEA, UNIGE, UMA, FORTH, Icometrix), **to be submitted**




✓ **Industrial agreement**

- Siemens-Healthineers CIFRE PhD thesis: **G. Daval Frérot**