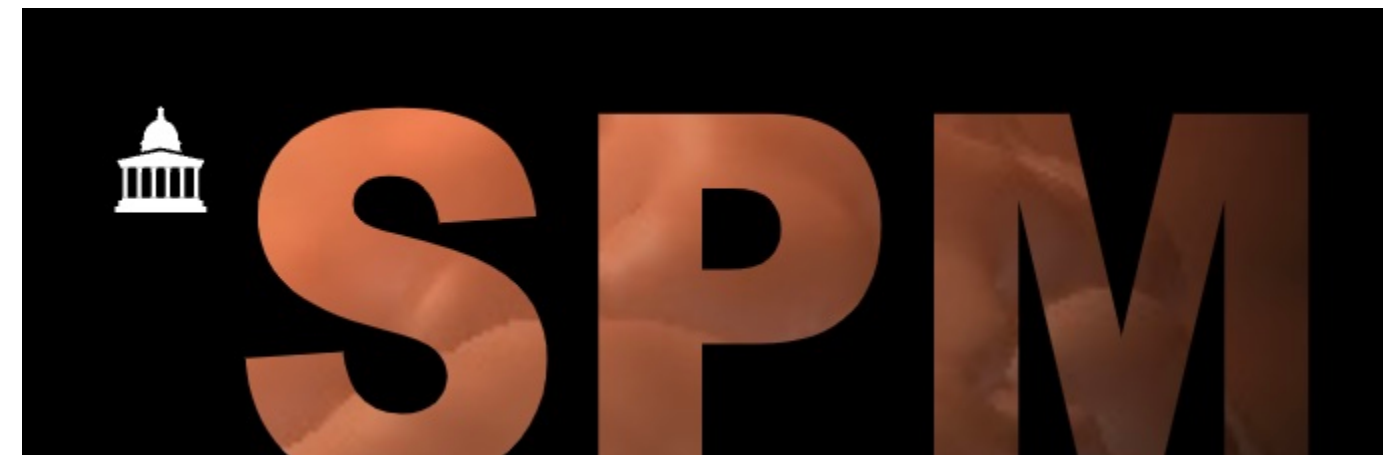


The NiPreps ecosystem for reproducible neuroimaging

Russ Poldrack
Stanford University

The standard design (anti-)pattern for fMRI preprocessing

- Pick a single software package
 - Usually based on considerations other than performance



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- String together the tools from that package into a script to run the preprocessing workflow

```
#!/bin/bash

# Generate the subject list to make modifying this script
# to run just a subset of subjects easier.

for id in `seq -w 1 26` ; do
  subj="sub-$id"
  echo "====> Starting processing of $subj"
  echo
  cd $subj

  # If the brain mask doesn't exist, create it
  if [ ! -f anat/${subj}_T1w_brain_f02.nii.gz ]; then
    echo "Skull-stripped brain not found, using bet with a fractional intensity thresh"
    # Note: This fractional intensity appears to work well for most of the subjects in
    # Flanker dataset. You may want to change it if you modify this script for your own
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  fi

  # Copy the design files into the subject directory, and then
  # change "sub-08" to the current subject number
  cp ../design_run1.fsf .
  cp ../design_run2.fsf .

  # Note that we are using the | character to delimit the patterns
  # instead of the usual / character because there are / characters
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  sed -i '' "s|sub-08|${subj}|g" \
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  # Now everything is set up to run feat
  echo "====> Starting feat for run 1"
  feat design_run1.fsf
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  feat design_run2.fsf
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  # Go back to the directory containing all of the subjects, and repeat the loop
  cd ..
done
```


The standard design (anti-)pattern for fMRI preprocessing

- Pick a single software package
 - Usually based on considerations other than performance
- String together the tools from that package into a script to run the preprocessing workflow
 - Generally written by a student or postdoc with little software engineering experience
- Hope it keeps working over time...
- Trust that it does the right thing...

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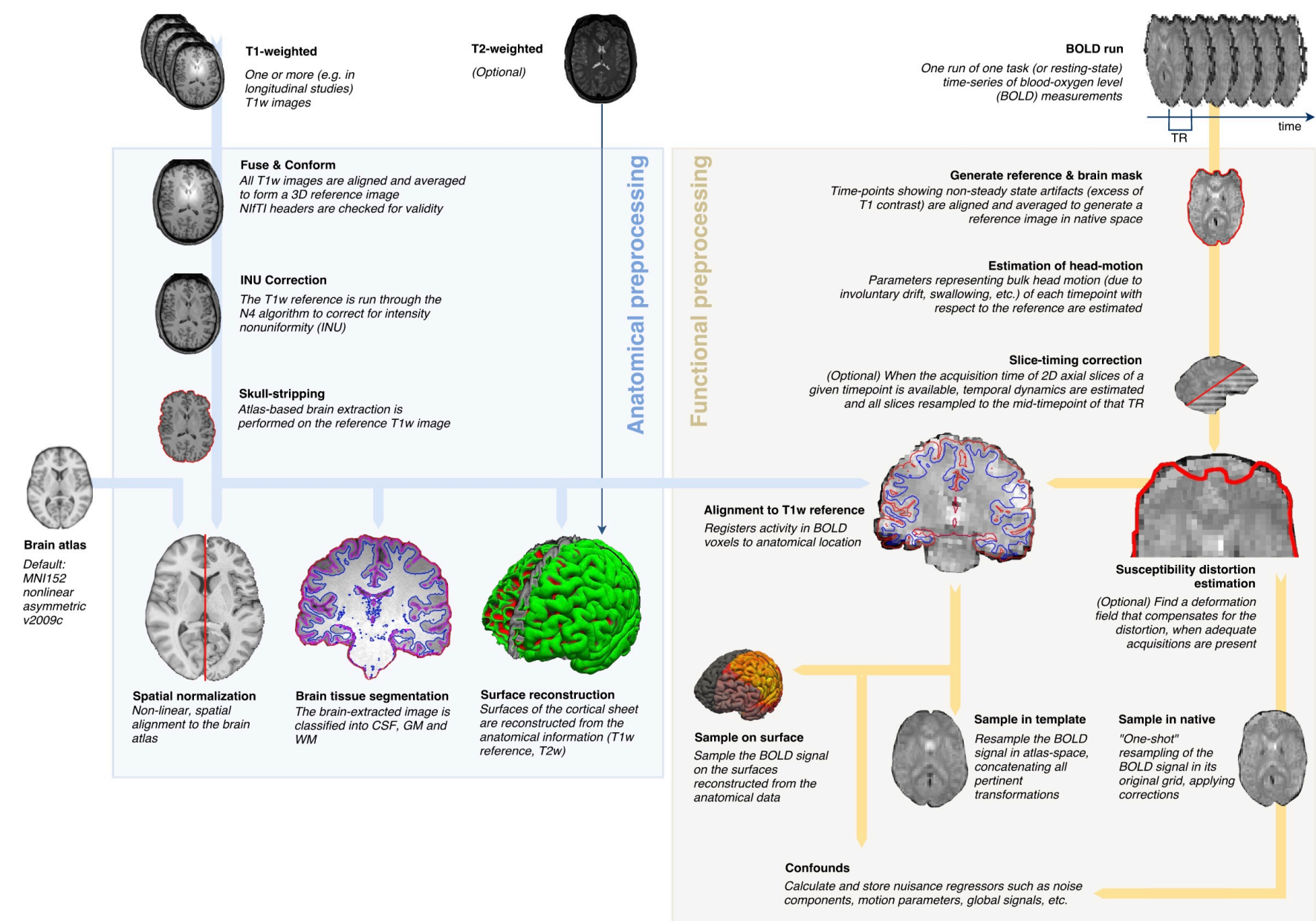
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Towards a new design pattern for preprocessing: fMRIPrep

- A robust workflow for preprocessing fMRI data
 - Tested on a large number of fMRI datasets from OpenNeuro
 - Adapt to each dataset and processes it in the best way possible
 - Outputs to BIDS-Derivatives format
 - Provides powerful visualizations :
 - to help identify problems
 - allowing glass-box access to training researchers
 - Currently averaging ~5000 successful runs per week



Esteban et al., 2019, *Nature Methods*

RF1MH121867: NiPreps (NeuroImaging PREProcessing tools)

... the overarching **objective of this project is to develop NiPreps**, a software framework to perform standardized preprocessing of diverse neuroimaging data.

- Aim 1: solidify the foundations of the NiPreps integration.
- Aim 2: enable integrative analysis approaches of heterogeneous data.
- Aim 3: accelerate the dissemination of NiPreps to the neuroscience community through hackathons and “docusprints”.

Why?

In developing fMRIPrep, we learned about critical aspects of neuroimaging workflows. NiPreps is envisioned as a generalization of fMRIPrep.

RF1MH121867: Sites



Poldracklab (Stanford)



Satterthwaite Lab (Penn)



Ariel Rokem
Research Associate Professor
email: arokem@uw.edu
[Website](#)



McKenzie Hagen
Graduate student, started 2021



Ezgi Yucel
Graduate student (with [Ione Fine](#)), started 2017

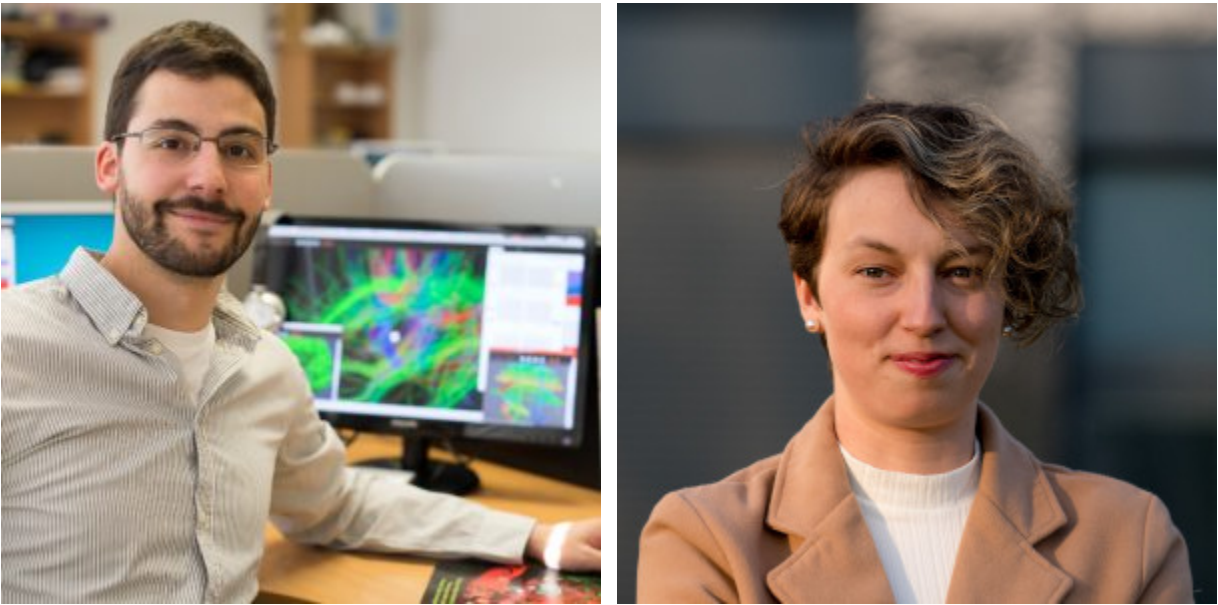


John Kruper
Post-bacc student, started July 2020

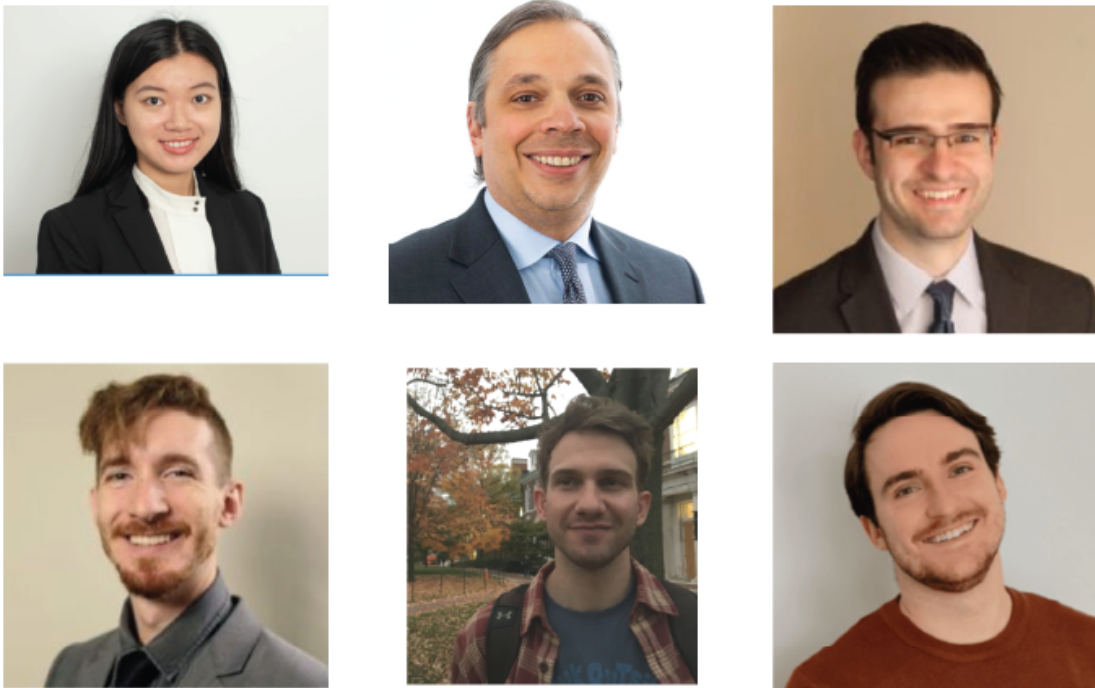


Teresa Gomez
Post-bacc student, started January 2022

Rokem Lab (UW)



Esteban Lab (CHUV Lausanne)



Milham Lab (Child Mind Inst)

The NiPreps community

- NiPreps
- Home
- NiPreps >
- BIDS-Apps >
- Community >
 - Welcome
 - Membership
 - New features
 - Contributing
 - Code of Conduct
 - Licensing
 - Developers >

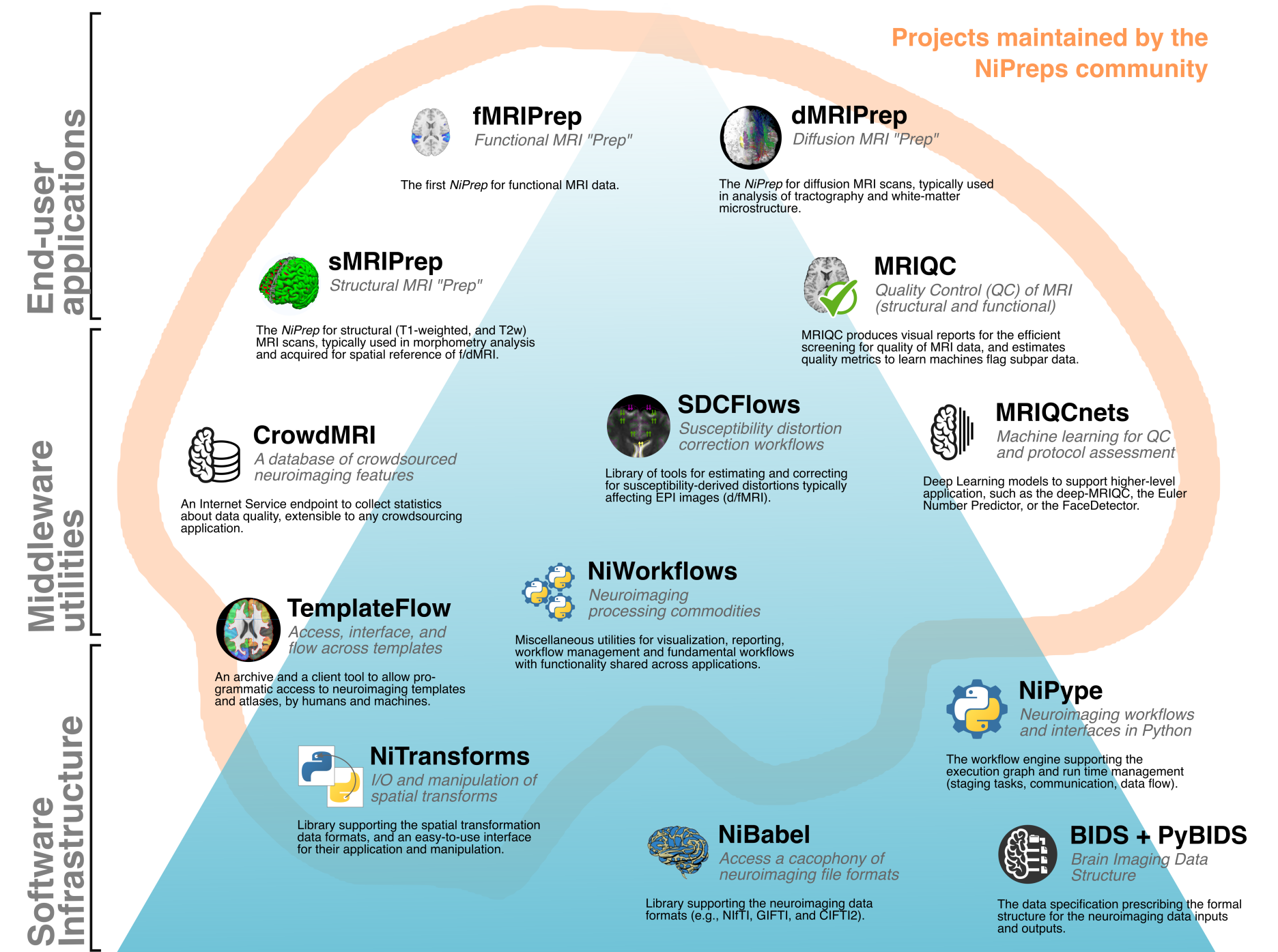
Current members of the GitHub organization

A total of 90 neuroimagers have already joined us. Becoming a member will give you access to additional forums for discussion, subscribing notifications for events and meetings, etc. You can request you are added to the organization by [creating a new issue here](#).



Aim 1: Developing and refining reusable infrastructure/middleware components

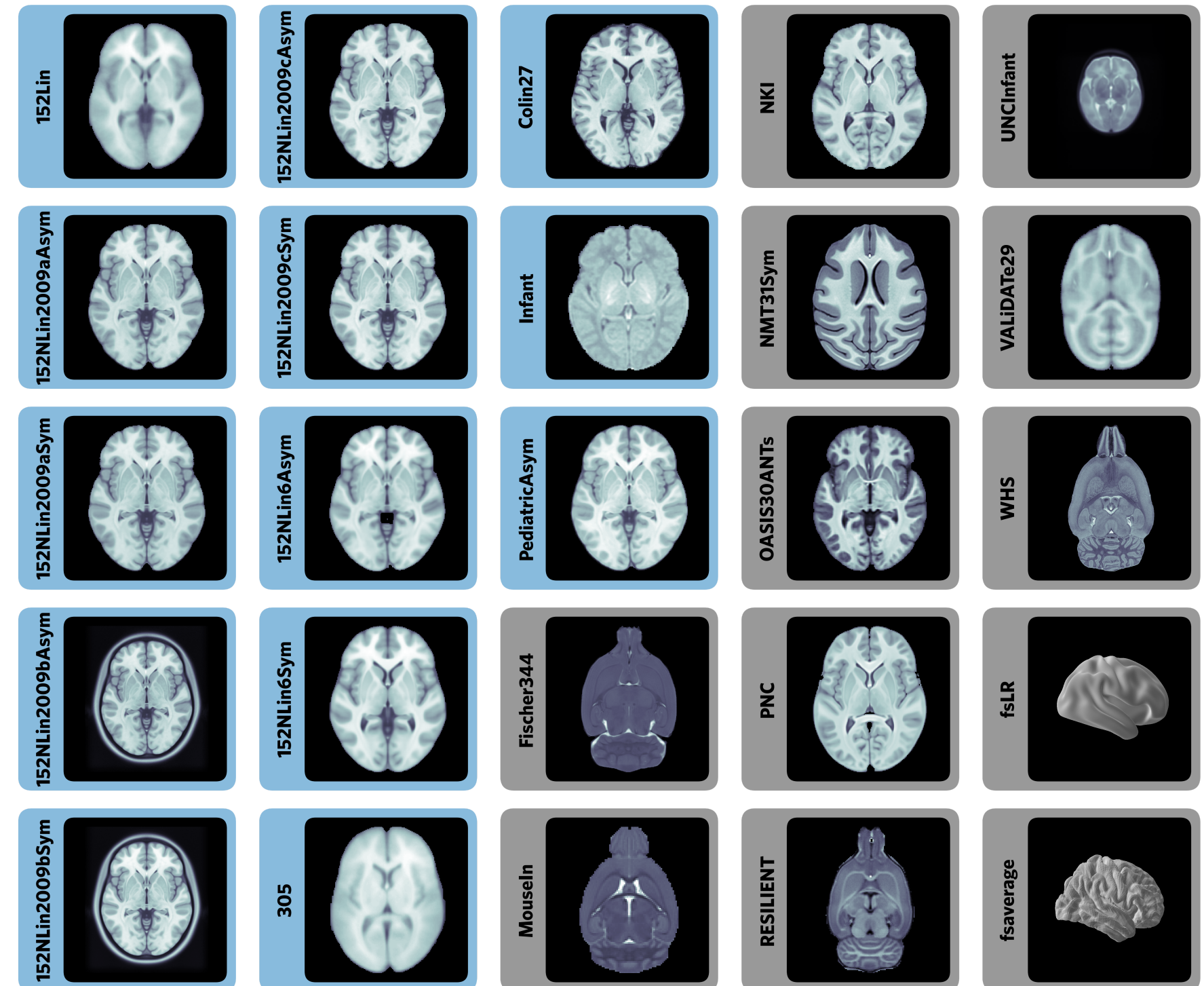
- *TemplateFlow*: FAIR Sharing and management of neuroimaging templates and atlases
- *SDCflows*: Integrating susceptibility distortion correction (SDC)
- *NiReports*: A modular visual reports system
- *NiTransforms*: Spatial transforms integration



TemplateFlow: FAIR sharing of neuroimaging templates and atlases

- Templates and atlases are commonly used in neuroimaging research
- There is significant lack of clarity in the use of these templates
 - There are numerous versions of the widely used “MNI template”
- Templateflow provides programmatic access to a database of templates and mappings between them
- Easy to use for humans and machines:

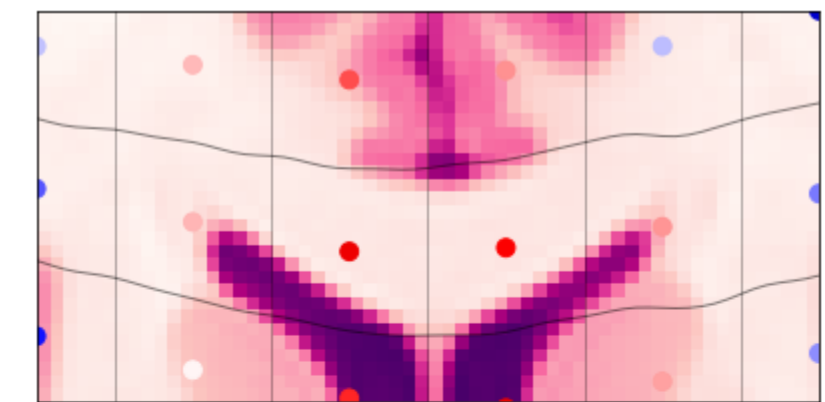
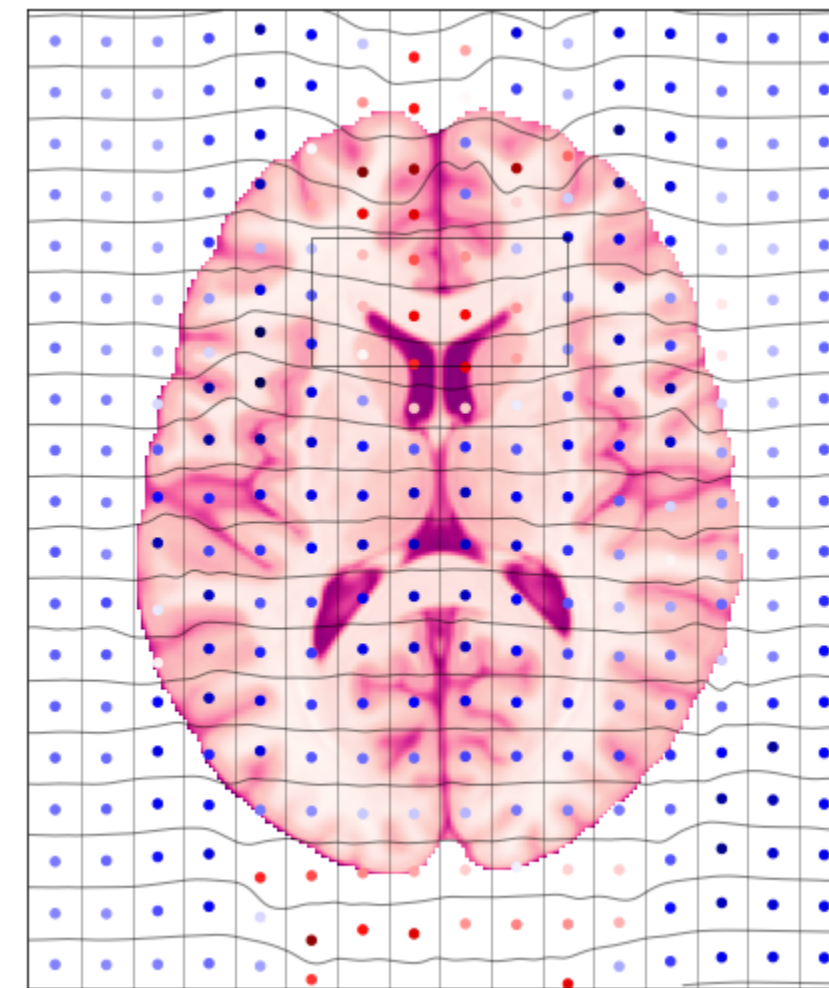
```
>>> from templateflow import api as tf
>>> tf.get("MNI152NLin2009cAsym",
...       suffix="T1w")
```



Ciric et al., 2022, *Nature Methods*

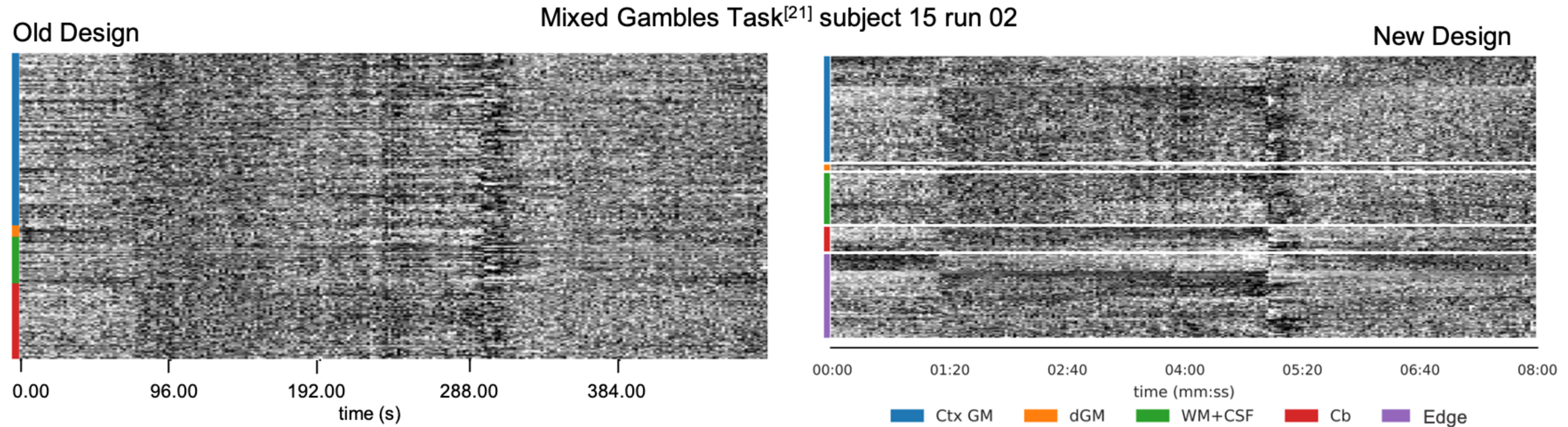
SDCFlows: Susceptibility Distortion Correction workflows

- SDCflows aims to provide a unified interface to susceptibility distortion correction methods
 - Defines a shared representation model (B-Spline) for the field map
 - “decouples” estimation and application steps (increasing modularity)
- Overhaul started early 2021 ([Esteban et al., OHBM 2021](#))
 - Faced many technical challenges
 - Requiring numerous bugfixes and “edge” cases
 - Developed new educational materials & Jupyter notebooks



Jupyter Notebook
on GitHub:
[nipreps/sdcflows](https://github.com/nipreps/sdcflows)

NiReports: New visualization tools from MRIQC



(Provins et al., ISMRM 2022)

- *MRIQC* is a quality control workflow for structural/functional MRI
- Developing a number of visualizations that will go into *NiReports*
 - Added visualization of voxels at the edge of the brain (“crown”)
 - Added hierarchical sorting of rows (voxels) to enhance patterns (Aquino et al. 2019)

Infrastructure: Architectural redesign

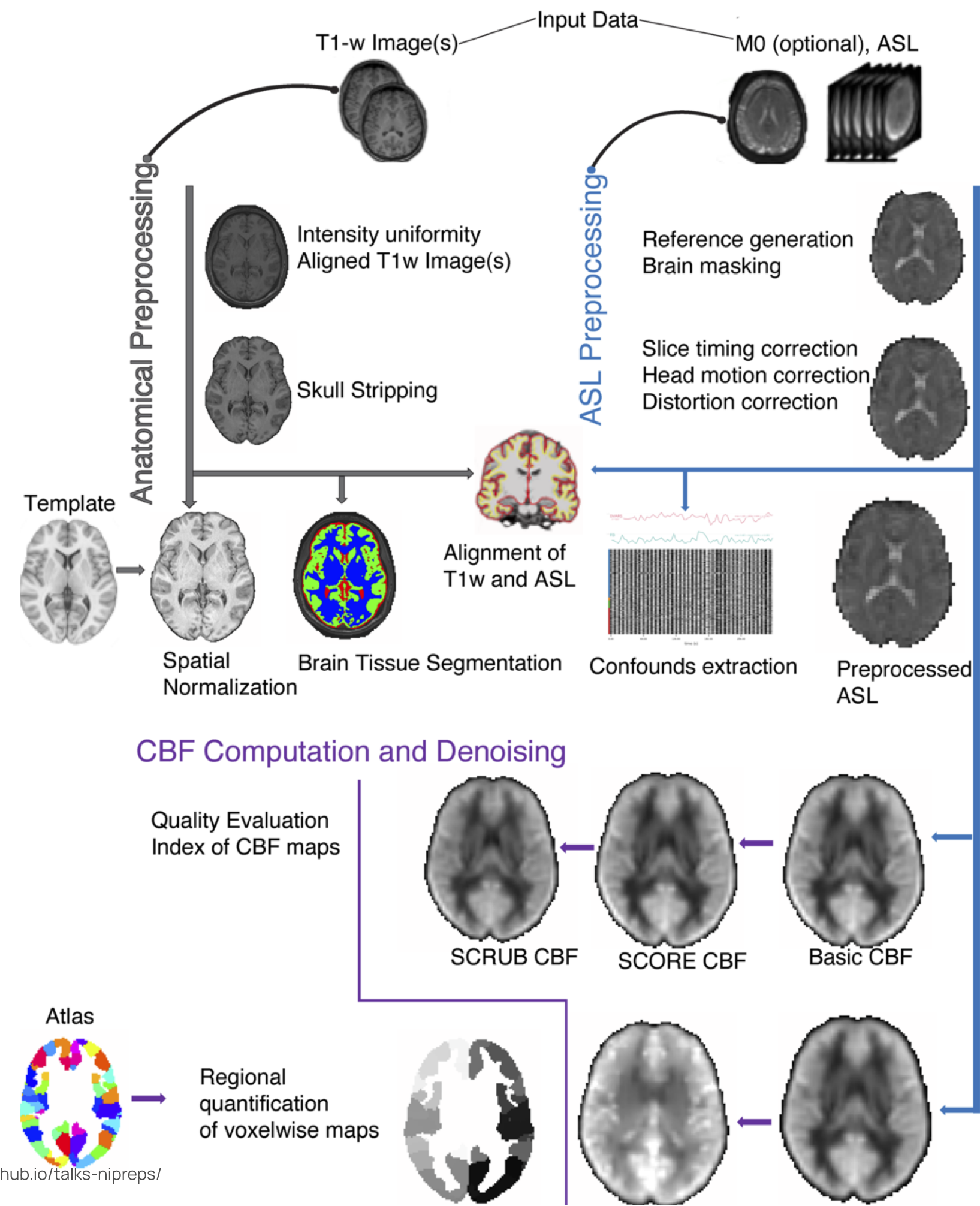
- Problem: fMRIPrep’s “one size fits all” design has limitations for emerging use cases
 - Archiving preprocessing results requires balancing storage costs against possible use cases.
 - Including alternative algorithms requires custom code to integrate.
- Solution: Accept pre-computed derivatives and defer computationally cheap operations
 - E.g., Deep learning segmentations and masks can be accepted, skipping fMRIPrep defaults.
 - Multiple template registrations can be archived, analysts may resample BOLD series to different spaces on demand.
- This approach is implemented in SDCFlows and is being generalized to other components.

Aim 2: Expand the portfolio of end-user NiPreps

- ASLPrep
- dMRIPrep
- PETPrep
- fMRIPrep-infants (aka *NiBabies*)
- fMRIPrep-rodents (aka *NiRodents*)

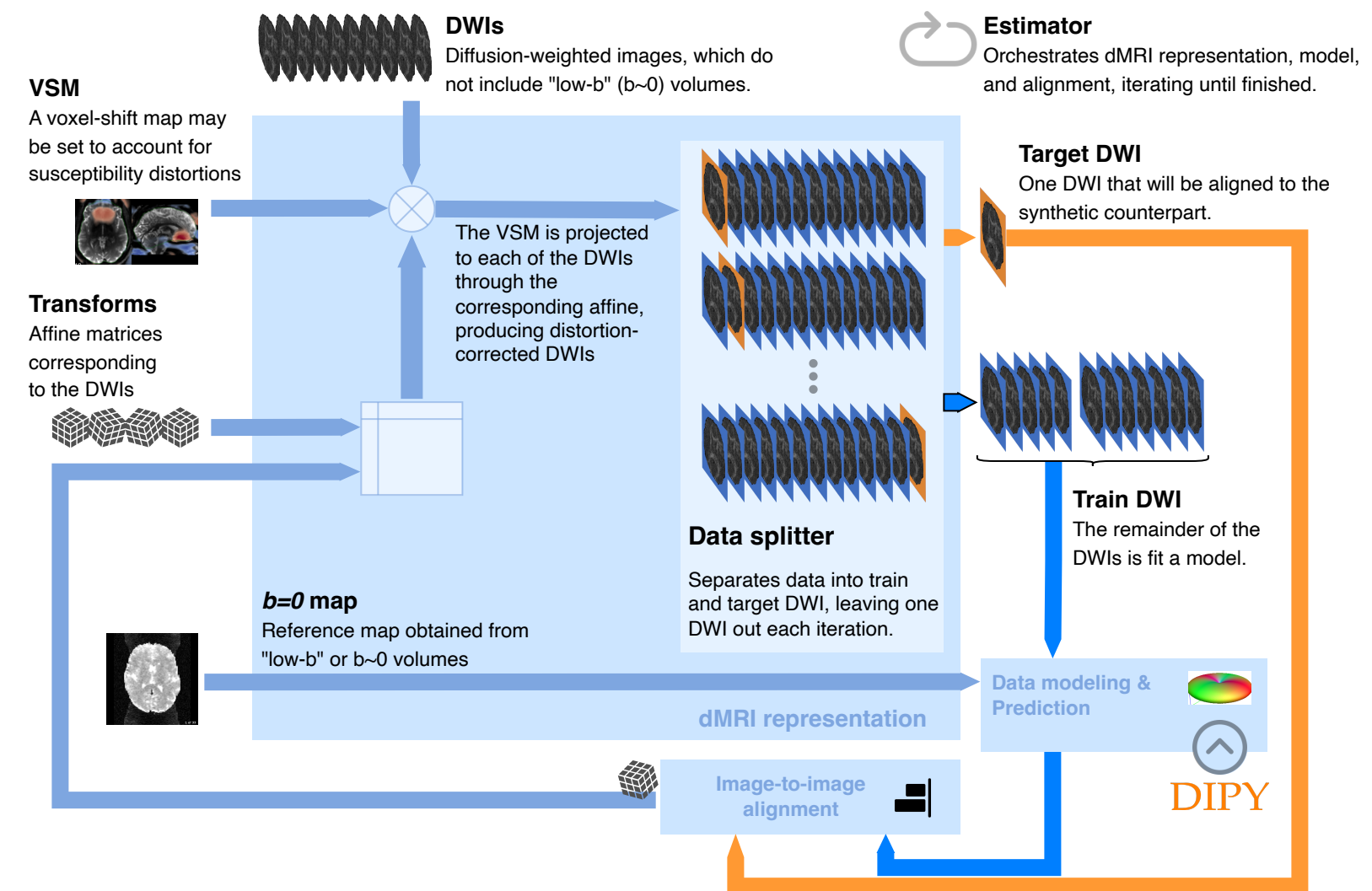
Workflows: ASLPrep (cerebral blood flow quantification)

- A robust workflow for preprocessing arterial spin labeling (ASL) data
 - Including cerebral blood flow (CBF) quantification
 - Provides quality evaluation for CBF maps
 - Provides CBF quantification at the regional level using atlases



Workflows: dMRIPrep (diffusion MRI)

- A workflow for preprocessing of diffusion MRI data
- Development currently focused on *eddy* motion
 - an algorithm to estimate head-motion (modality-agnostic) and modality-specific artifacts (eddy currents in the case of dMRI)

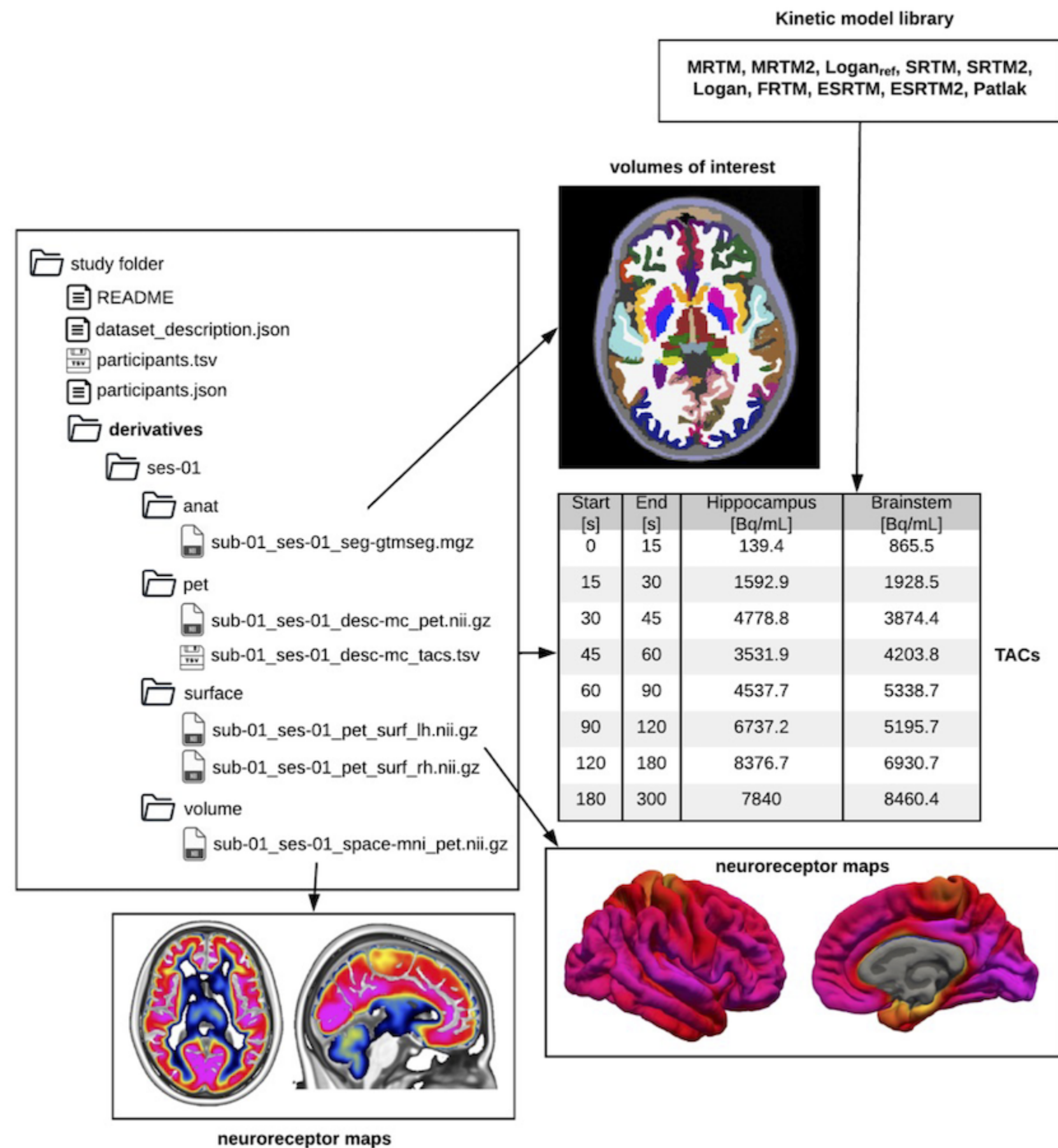


Preprint: Pisner et al., 2022.

Workflows: PETPrep (positron emission tomography)

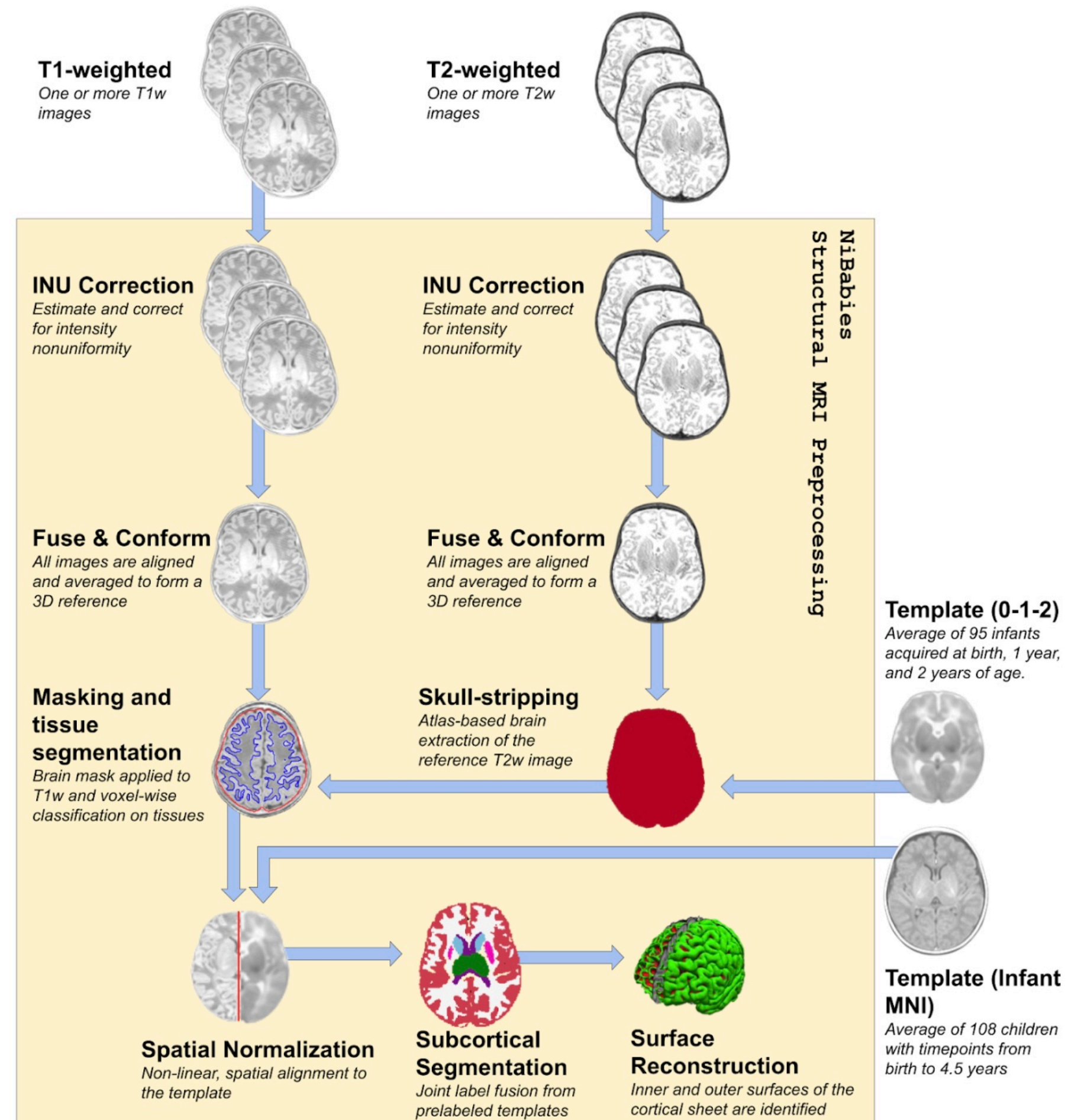
- A NiPreps workflow for PET preprocessing

- Successfully merged petsurfer into nipyne (1.8.0)
- Incorporated nipyne implementation of a robust head motion correction workflow (petprep_hmc)
- Developing a BIDS-Derivatives standard for PET derivatives
- Model-based head-motion correction leveraging *eddy* motion in progress



Workflows: fMRIPrep for infants

- Collaboration with Damien Fair & HBCD team
- **New developments**
 - Support for pre-computed derivatives (mask, segmentations).
 - Improved robustness and validity of CIFTI-2 outputs.
- **Upcoming developments**
 - Morphometric outputs (cortical thickness, curvature)
 - Improvements to susceptibility distortion correction versatility
 - T2 assisted surface generation

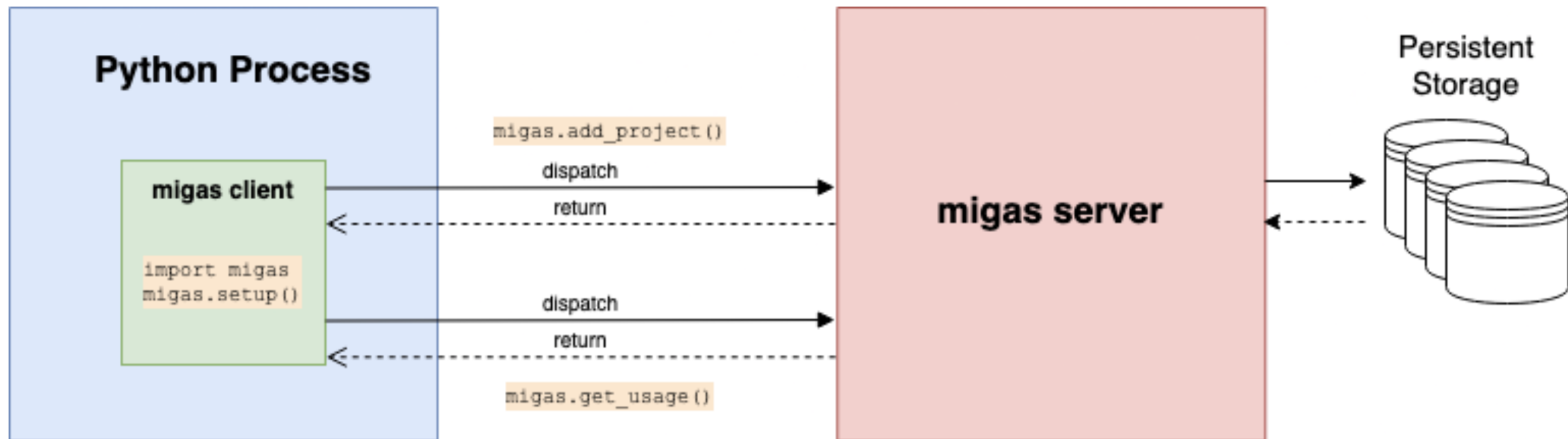


Aim 3: Consolidate the NiPreps community

- Project monitoring infrastructure: MIGAS
- Evaluation of cross-workflow reproducibility
- Hackathons and documentation
- Best practices and educational resources
- NMIND: Building common standards for software development

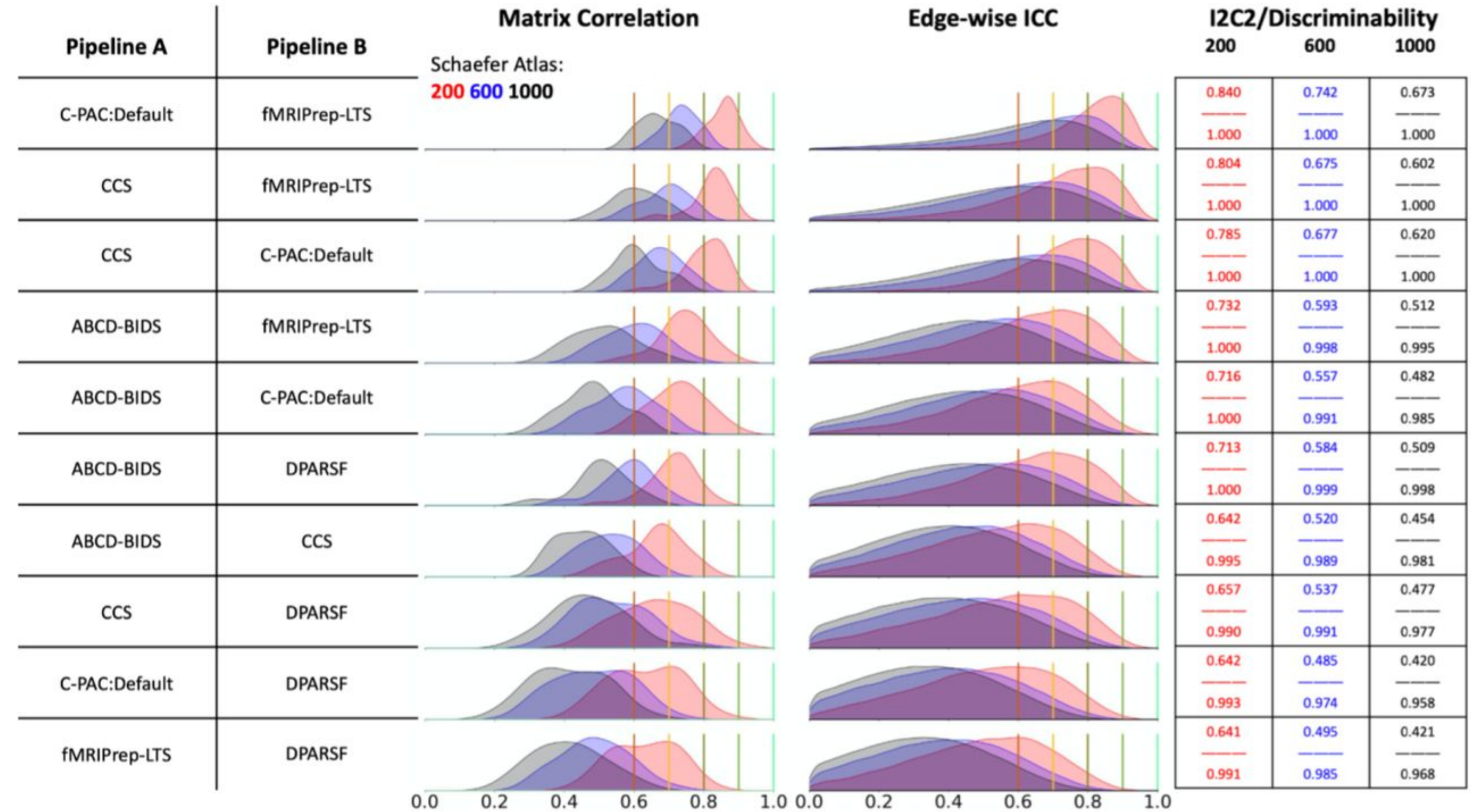
Project monitoring: MIGAS

- An open-source, customizable telemetry solution
- Allows collecting usage information, errors, and status throughout a process's lifetime
- Easy to deploy with various cloud providers (Heroku / GCP / AWS)
- Available as a Python package: <https://pypi.org/project/migas/>



Reproducibility: Cross-workflow evaluation

- CMI team developed a CPAC implementation of fMRIPrep
 - Able to achieve high levels of reproducibility in connectivity metrics between harmonized workflows
 - Helped identify causes of divergence, such as use of different versions of MNI template



Hackathons and documentation

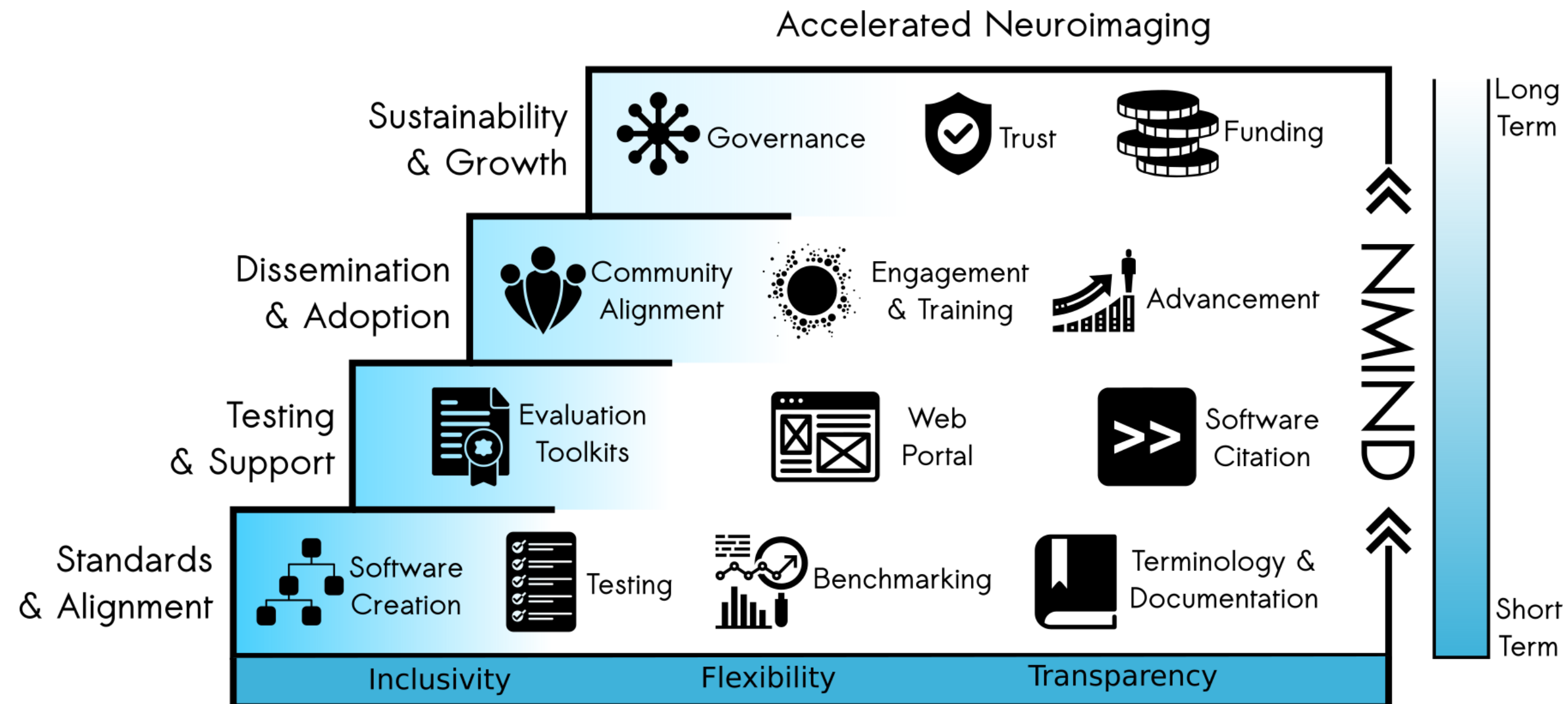
- Held a hackathon/documentation sprint in Glasgow following OHBM 2022
- Will participate in Brainhack Global 2022
- Planning to hold a hackathon/documentation sprint in Montreal in association with OHBM 2023

Best practices and educational resources

- Collaborative QC-Book (educational, ISMRM 2021): <https://nipreps.org/qc-book>
- MRIQC-SOPs (standard operating procedures)
 - A GitHub template-repository to create and maintain versioned SOPs documentation and checklists.
 - Example: <https://nipreps.org/mriqc-sops/>
- MRIQC Protocol report (Hagen et al., in preparation)
- Frontiers' research topic on QC of fMRI (Provins et al., under review)
- Biases introduced by defacing in QC (Provins et al., pre-registered report under review)

NMIND: Building common standards for software development

- **NMIND:** Nevermind, this Method Is Not Duplicated
 - *Alignment:* development and adoption of standards for critical software component
 - *Testing:* accessible and (semi-)automated mechanisms for evaluating standards compliance
 - *Engagement:* widespread promotion and adoption of the NMIND collaborative standards



Thank you!