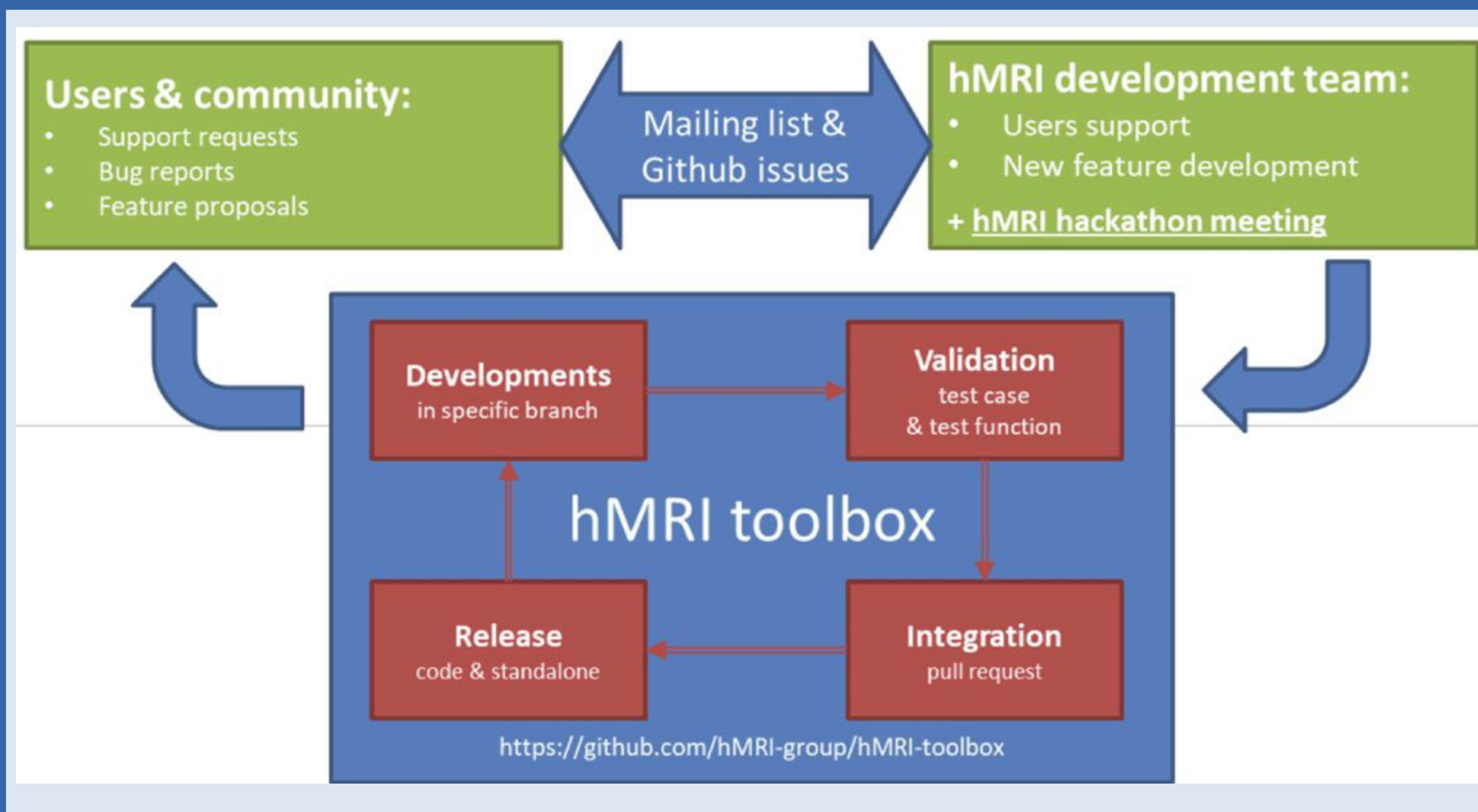# *In vivo* MRI histology revisited: en route to hMRI toolbox 1.0

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- internationally developed SPM-based framework for creation and statistical analysis of quantitative MRI maps sensitive to myelin and iron content (https://hmri.info) [4,9]
- collaborative software development workflow which includes: collecting user queries through issues and mailing list, organized coding and test development structured by pull requests, careful code review and testing of the new features before getting merged to the master branch.
- since its initial release (v0.2) in 2018, acquired several new functionalities.
- new functionalities in upcoming major public release 1.0: denoising module, errormaps, QUantitative Imaging data using a Quality Index (QUIQI).

Compilation of the toolbox:

- standalone version: cross-platform use without requiring a Matlab license.
- available in Neurodesk: https://www.neurodesk.org
- can be accessed via the SPM batch GUI or executed through command-line batch jobs.
- main functionalities accessible with the (free) "Matlab Runtime" environment.
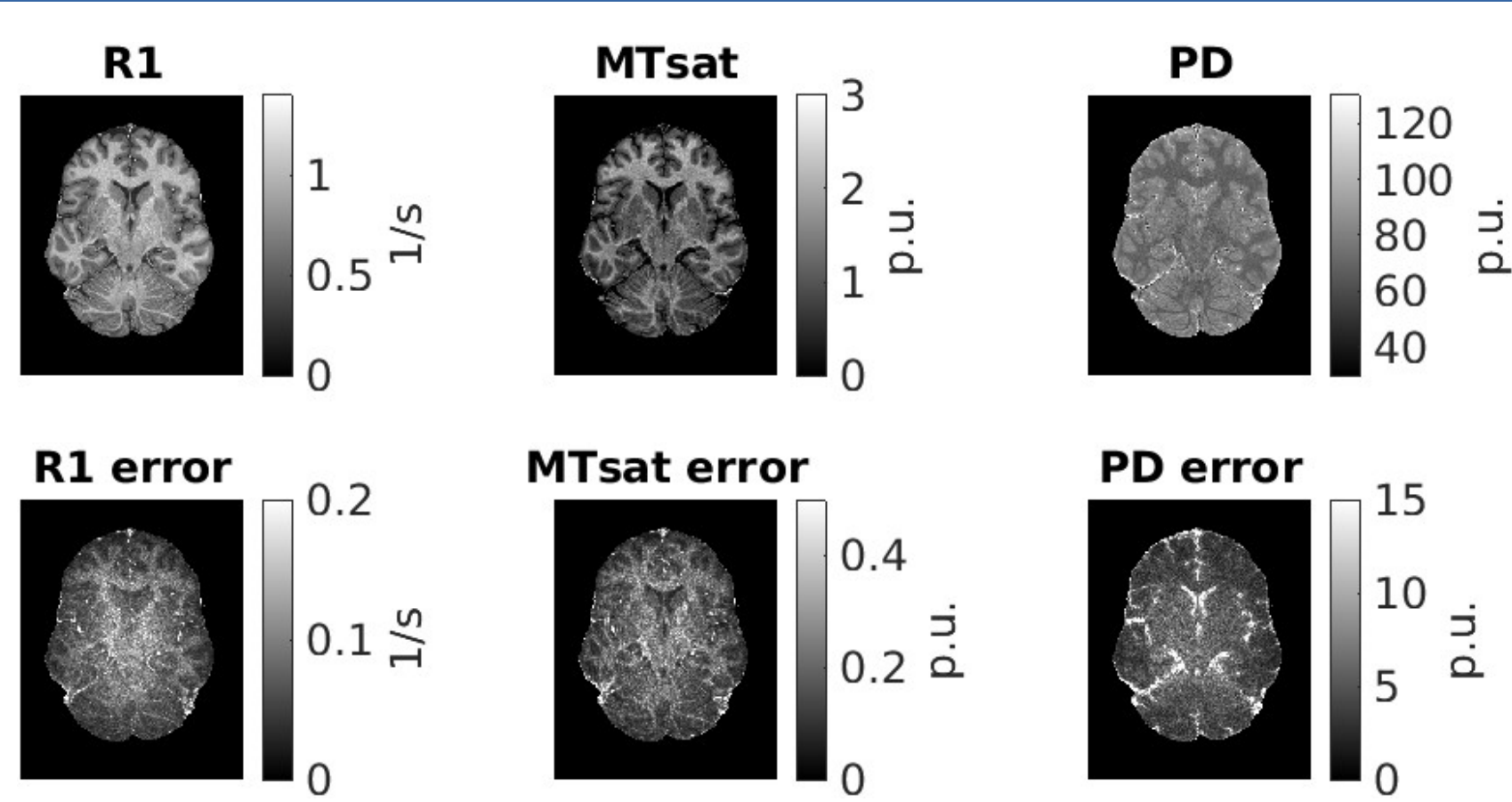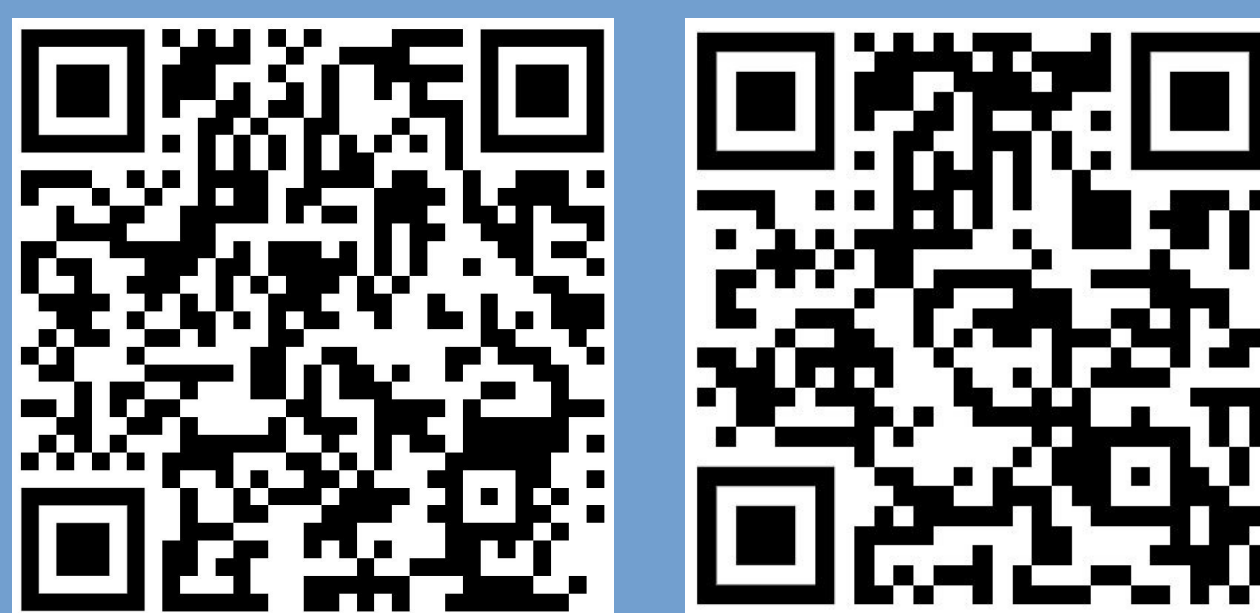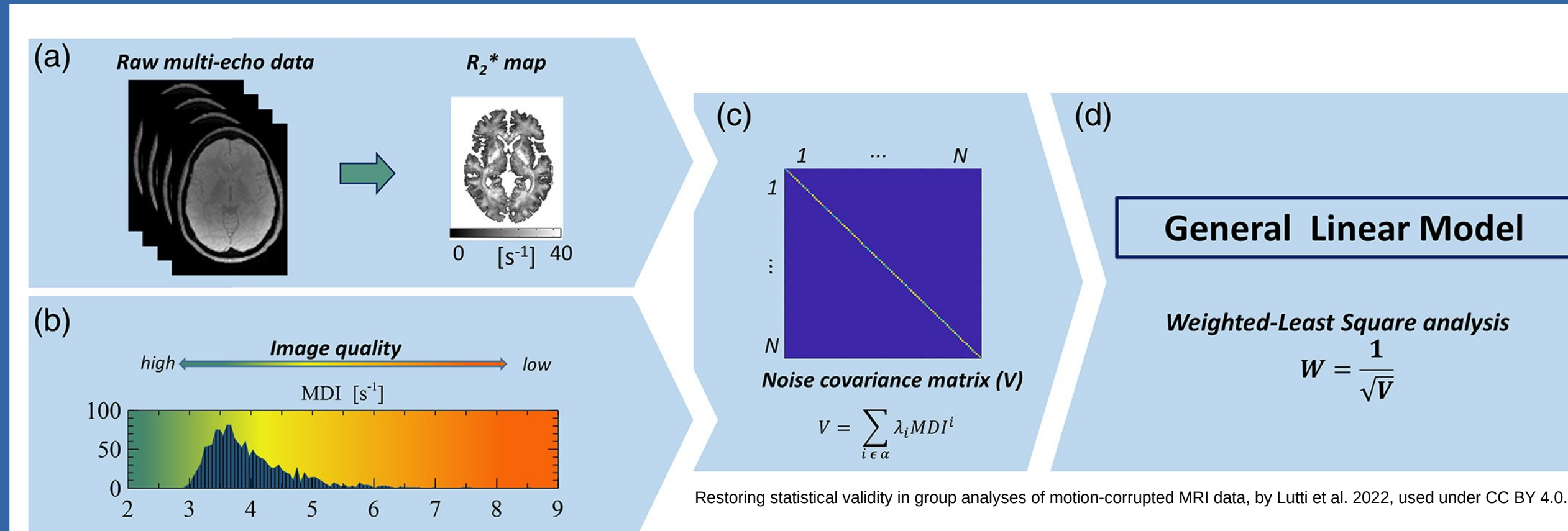
Contact & Discover:
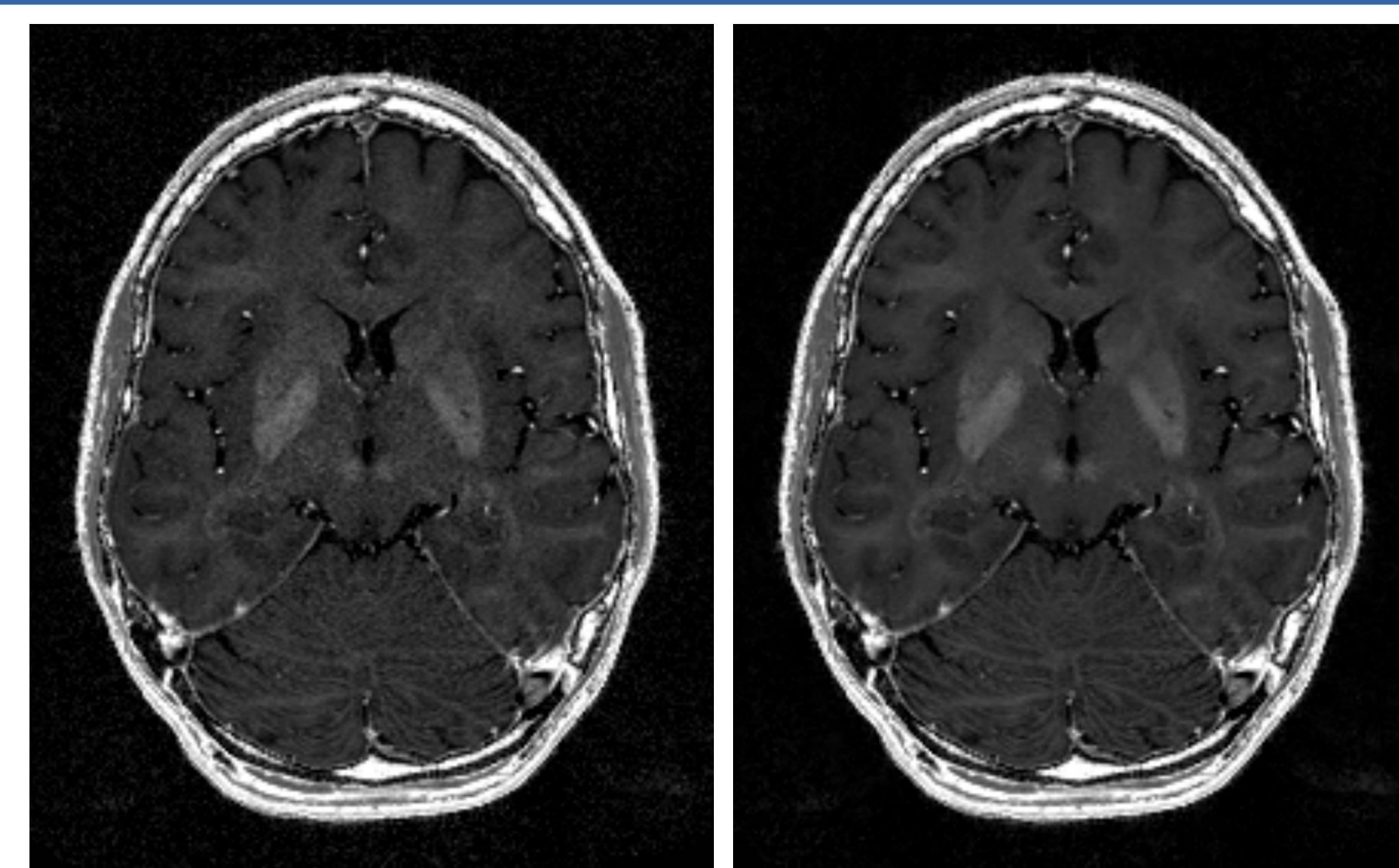
R2s output: the left figure obtained from PDw, T1w, MTw of toolbox demo data (Callaghan et al. 2019) and the right from demo data which is first denoised in the built-in denoising module with the options 'LCPCA-denoising', 'window size=4', 'std_cutOff=1.05'.

Denoising module [5]:

- wrapped publicly available implementations of the state-of-the-art denoising methods [1,3,10] within our toolbox through our own GUI, pre-processing modules and a Java-Matlab interface.
- meta-data capabilities which outputs JSON sidecar files for further processing.
- seamless configuration and piping with other main processing steps through the SPM batch dependencies.
- LCPCA-denoising, originally written in Java, can now be invoked also within/from Matlab through an advanced custom developed Java-Matlab interface.

The error maps module (Mohammadi et al. 2022) associates an error estimate to each quantitative map voxel that can be used to evaluate data quality. Error maps created from demo dataset (Callaghan et al. 2019) using example error map configuration file.

- **Error Maps [8]** give the voxel-wise error of the quantitative maps for quality assurance.
- additional submodule ('Combine two successive hmri datasets') can use these error maps as weights to robustly combine quantitative maps from two successive acquisitions.
- enable evaluation of both local data quality variations and artifacts without requiring additional data.
- resulting robust MPM parameters show reduced variability at the group level compared to the single-repeat or averaged counterparts.

Restoring statistical validity in group analyses of motion-corrupted MRI data, by Lutti et al. 2022, used under CC BY 4.0.

Analysis of QUantitative Imaging data using a Quality Index (QUIQI)[7]:

- mitigates the effect of image degradation due to head motion on group comparison/regression statistical analyses (GLM).
- data-driven solution that assigns image-specific weights in an analysis based on an index of image quality.

The new developments demonstrate the toolbox's dedication to cross platform efforts (inclusion of the compiled-standalone toolbox in Neurodesk), advanced software techniques (custom developed Java-Matlab interface and user focused GUI developments) and high quality image processing modules offering built-in denoising, error quantification, and motion mitigation. The hMRI toolbox 1.0 has been developed as a self-sufficient, easily configurable, cross platform and well-documented software, which will further support developments in MRI-based *in vivo* histology.

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