# FANSI Toolbox

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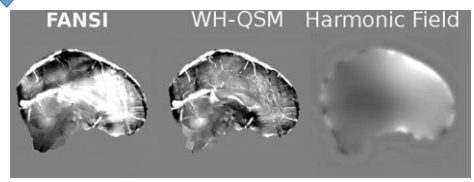
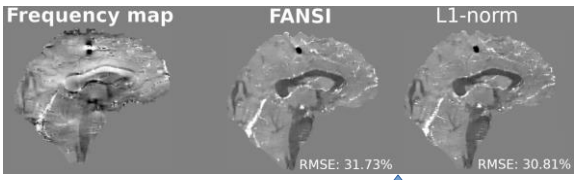
Toolbox developed at Pontificia Universidad Catolica de Chile, Chile and University College London, UK

***Matlab* toolbox for Quantitative Susceptibility Mapping and Phase processing**

**Dipole inversion:**

- **Closed form solvers:** TKD, direct Tikhonov, L2-norm (gradient penalty)
- **FANSI:** Linear and nonlinear - TV and TGV regularized QSM (*MRM 2018*)
- **Weak Harmonics QSM (WH-QSM):** Joint QSM and residual background field estimation (*MRM 2018*)




- **L1-norm QSM:** L1-norm **data fidelity** terms to suppress streaking artifacts (*ISMRM 2020 3257*).
- **Early Stopping Nonlinear Dipole Inversion (NDI):** fast conjugate gradient solver for parameter-free QSM (*ISMRM 2021 3982*)

Here is a brief overview of the FANSI Toolbox.
It is written by Carlos Milovic, previously at Pontificia Universidad Catolica de Chile and currently at University College London.
This Matlab toolbox focuses mainly on state-of-the-art dipole inversion algorithms, but also incorporates solutions for phase preprocessing steps such as unwrapping, multiecho combination, and background field removal.
The dipole inversion tools include:
Closed form solvers such as TKD, direct Tikhonov, and a L2-norm gradient penalty.
FAst Nonlinear Susceptibility Inversion – FANSI: Linear and nonlinear fast ADMM solvers using TV or TGV regularizations, with spatially variable weights
Weak Harmonics QSM (WH-QSM): this is an extension of FANSI which jointly estimates susceptibilities and residual background fields
L1-norm QSM: another variation of FANSI, this time using L1-norm data fidelity terms to suppress streaking artifacts
And finally, a reimplementation of the Nonlinear Dipole Inversion (NDI) using a fast Conjugate Gradient descent solver. This enables robust ultrafast non-regularized and parameter-free reconstructions *in vivo*.

# FANSI Toolbox

**Phase processing tools:**

- **Unwrapping:** Laplacian-based algorithms (with different data consistency formulations)
- **Multi-echo Combination:** Regularized nonlinear fitting
- **Background Field Removal:** Multiscale Spherical Mean Value (MSMV, *ISMRM 2019 4940*) and Nonlinear PDF (*ISMRM 2018 2203*)

**Relaxometry:** Regularized R2* mapping tools (Tikhonov, TV and TGV)

**Experiment design and evaluation tools:**

- Numerical Phantom data (based on Wisnieff NeuroImgage 2014 and Langkammer MRM 2017)
- Analytic Models: Spheres and cylinders plus Intravoxel effects
- Error metrics: RMSE, SSIM, XSIM (SSIM metric redesigned for QSM), HFEN, Mutual Information, Correlation Coefficient, Mean Absolute Difference, Gradient domain errors

**Parameter optimization tools:** L-curve and Fourier-based analysis (*MRM 2021*)

***Many sample scripts!***

**Links:** http://gitlab.com/cmilovic/FANSI-Toolbox Contact: c.milovic@ucl.ac.uk

We have included code to perform tasks throughout the QSM pipeline for completeness and for academic or research purposes. This includes Laplacian-based unwrapping algorithms, regularized nonlinear multiecho fitting tools, and background field removal tools including a Multiscale Spherical Mean Value method, and a Nonlinear Projection onto Dipole Fields method for enhanced noise robustness.

Nonlinear R2* mapping tools are included with many regularization options.

To facilitate evaluation of QSM tools, we include synthetic brain phantom datasets, code to build synthetic fields and susceptibility ground-truths based on the analytic solutions for spheres and cylinders (including simulation of intravoxel effects) and scripts to calculate various error metrics.

Lastly, the FANSI toolbox includes tools to calculate and display L-curves, and to analyze the Fourier coefficients of the solutions, which can help you find optimal QSM reconstruction parameters.

To find out how to use all these techniques, please have a look at the many sample scripts included.

Please download our latest release from GitLab and send any questions or suggestions to Carlos

at this email address.