

T₁ Mapping ISMRM Reproducibility Challenge

A joint collaboration between the Reproducible Research and Quantitative MR Study Groups

Challenge Leader: Mathieu Boudreau, PhD

Research Fellow, Montreal Heart Institute

Software Developer, NeuroPoly, Polytechnique de Montréal



Introduction

Challenge Pitch

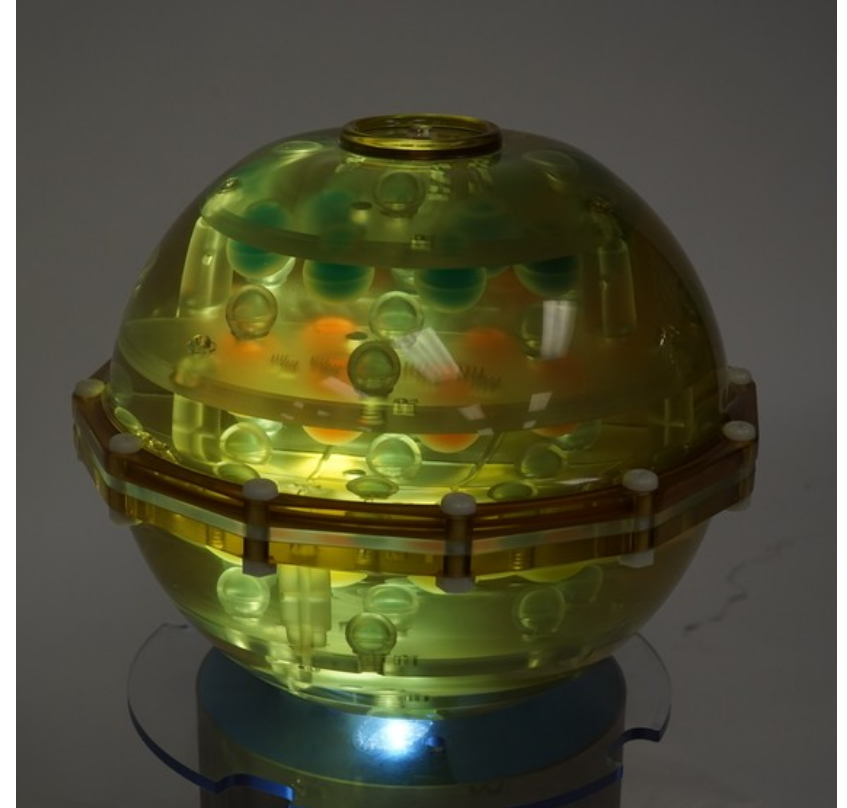
Will an imaging protocol **independently-implemented** at multiple centers reliably measure what is considered one of the fundamental MR parameters (T_1) using the most robust technique (**inversion recovery**) in a standardized phantom (**ISMIRM/NIST system phantom**)?

Material

Quantitative MRI NIST phantom

- Produced and sold by CaliberMRI
- Two versions
 - Version 1: SN < 0042
 - Version 2: SN $\geq$ 0042

If inaccessible, participants were encouraged to submit human data with institutional ethics approval and consent for open data sharing.



Imaging Protocol

Pulse sequence	Spin-echo inversion recovery
Repetition time	2550 ms
Inversion times	50, 400, 1100, 2500 ms
Echo time	14 ms
In-plane resolution	1 mm x 1 mm
Slice thickness	2 mm

Barral, J.K., Gudmundson, E., Stikov, N., Etezadi-Amoli, M., Stoica, P. and Nishimura, D.G. (2010), *A robust methodology for in vivo T_1 mapping*. Magn. Reson. Med., 64: 1057-1067.

Data Processing:

T₁ fitting code

Gold Standard T1 Mapping

[Joëlle Barral](#), Erik Gudmundson, Maryam Etezadi-Amoli, Nikola Stikov

- [Introduction](#)
- [Motivation](#)
- [Pitfalls and Confounds](#)
- [Gold Standard](#)
- [Fitting Procedure](#)
- [Fitting Code](#)
- [Simulations](#)
- [Simulations Code](#)
- [T1 Values of Specific Tissues](#)
- [Download](#)
- [References](#)

Introduction

The purpose of this page is to provide some guidance for T1 mapping and a methodology to evaluate new techniques.

Almost everybody in MR does T1 mapping at one point or another. There is a huge body of literature about different T1 mapping methods. However, the published T1 values of specific tissues in healthy subjects vary well-beyond the expected inter-subject variability. We have two objectives: first, provide the tools to perform reliable T1 mapping and avoid common pitfalls; second, provide a gold standard method and a framework to evaluate new methods. This is a work in progress and your feedback will be greatly appreciated: [jbarral AT mrsrl DOT stanford DOT edu](mailto:jbarral@mrsrl.stanford.edu).

Motivation

You may want to do T1 mapping to:

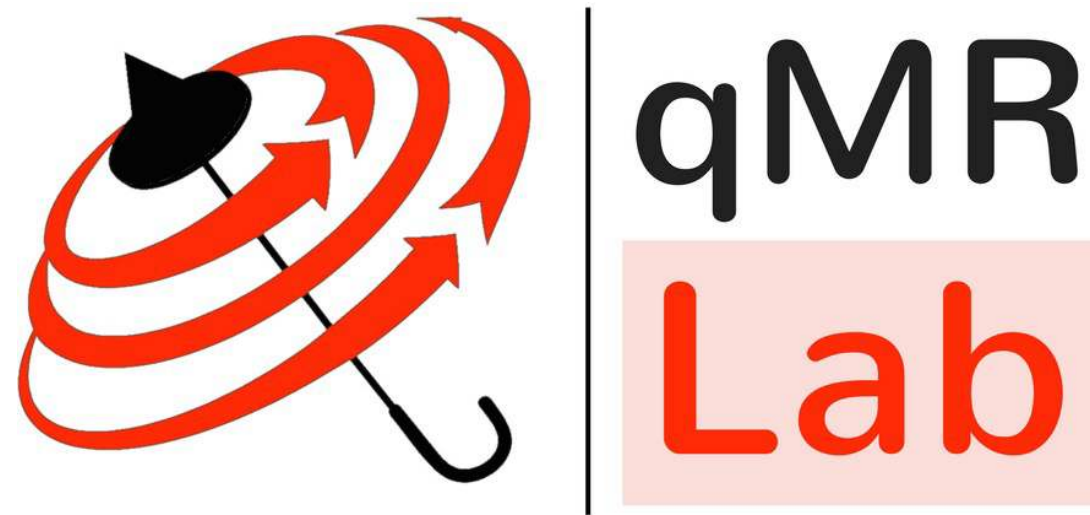
- optimize parameters for a sequence (e.g., Ernst angle is $\arccos(\exp(-TR/T1))$)
- monitor diseased tissue
- measure Ktrans in DCE-MRI
- derive other quantitative parameters (e.g., bound pool fractions)

Pitfalls and Confounds

$$S(TI) = a + be^{-\frac{TI}{T_1}}$$

Data Processing:

T_1 fitting code



Quantitative MRI. Under one umbrella.

Data Processing:

Data sharing

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RRSG2020

Contributors: [Mathieu Boudreau](#), [Agah Karakuzu](#)
Date created: 2019-08-22 04:15 PM | Last Updated: 2020-08-06 11:21 AM
Category:  Project

Files

Filter

Name ^ v	Modified ^ v
 RRS2020	
-  OSF Storage (Canada - Montréal)	
+  challenge_rois	
+  challenge_submissions	
+  challenge_t1_maps	
+  challenge_t1_maps_general_fitting_model	
+  rois	
+  sample_submission	

Citation

Recent Activity

 Mathieu Boudreau added file
challenge_t1_maps_general_fitting_model/3T/NIST_phantom/20200309_near_douglas_NIST.zip to OSF Storage in RRS2020
2020-08-06 11:21 AM

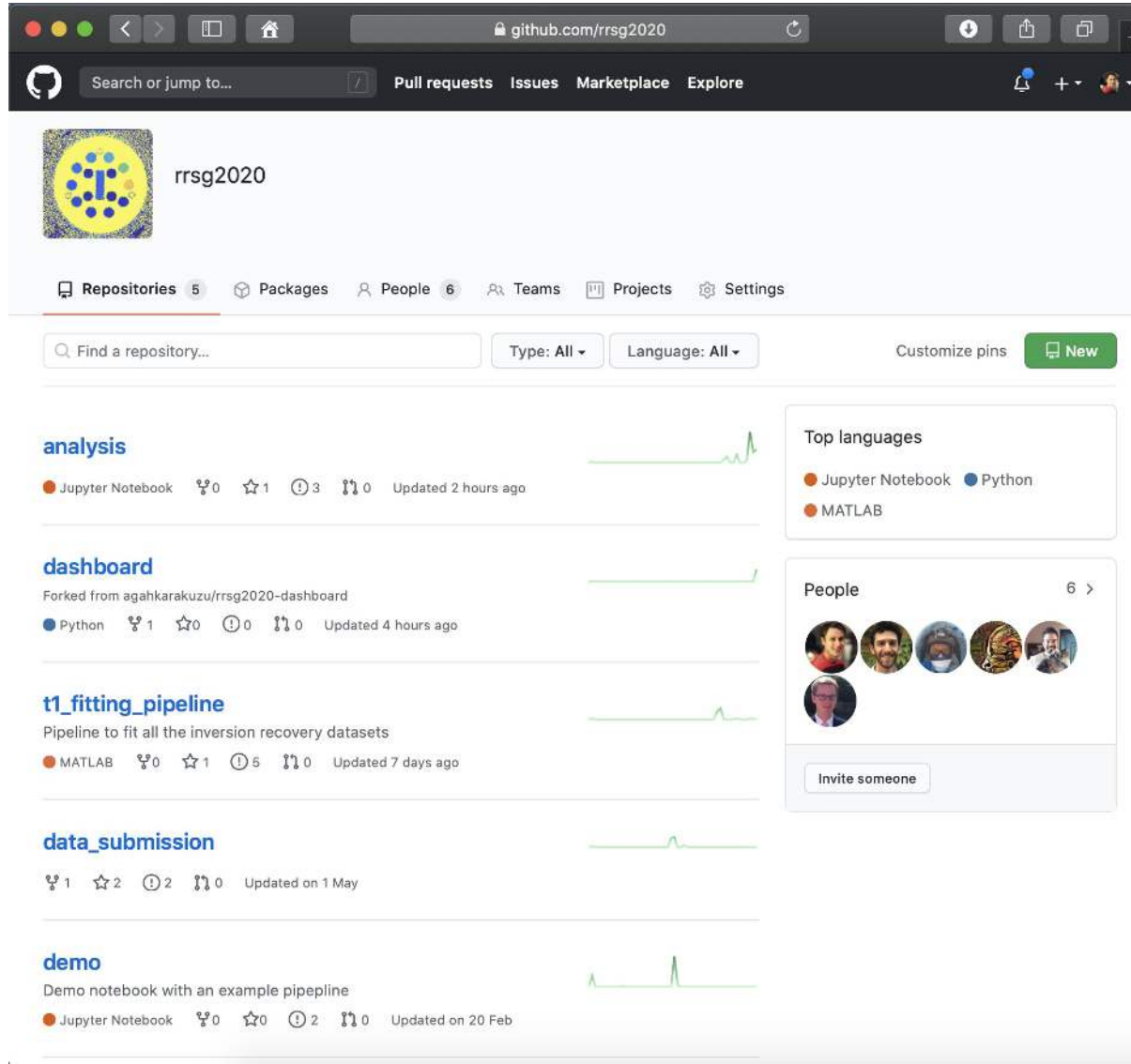
 Mathieu Boudreau added file
challenge_t1_maps_general_fitting_model/3T/NIST_phantom/20201802_jalnejford_sahlgrenska_NIST.zip to OSF Storage in RRS2020
2020-08-06 11:21 AM

 Mathieu Boudreau added file
challenge_t1_maps_general_fitting_model/3T/NIST_phantom/20200305_ngmaforo_ucla_NIST.zip to OSF Storage in RRS2020
2020-08-06 11:21 AM

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challenge_t1_maps_general_fitting_model/3T/NIST_phantom/20200302_wang_MDA_anderson_NIST.zip to OSF Storage in RRS2020
2020-08-06 11:21 AM

Data Processing:

Collaborative coding & analysis



The screenshot shows the GitHub profile page for the user 'rrsg2020'. The page header includes the GitHub logo, a search bar, and navigation links for Pull requests, Issues, Marketplace, and Explore. The user's profile section displays a repository grid with five items: 'analysis', 'dashboard', 't1_fitting_pipeline', 'data_submission', and 'demo'. Each repository entry includes its name, description, language, and statistics (forks, stars, issues, pull requests). The 'analysis' repository is a Jupyter Notebook with 0 forks, 1 star, 3 issues, and 0 pull requests, updated 2 hours ago. The 'dashboard' repository is a Python project, forked from 'agahkarakuzu/rrsg2020--dashboard', with 1 fork, 0 stars, 0 issues, and 0 pull requests, updated 4 hours ago. The 't1_fitting_pipeline' repository is a MATLAB project, described as a 'Pipeline to fit all the inversion recovery datasets', with 0 forks, 1 star, 5 issues, and 0 pull requests, updated 7 days ago. The 'data_submission' repository has 1 fork, 2 stars, 2 issues, and 0 pull requests, updated on 1 May. The 'demo' repository is a Jupyter Notebook, described as a 'Demo notebook with an example pipeline', with 0 forks, 0 stars, 2 issues, and 0 pull requests, updated on 20 Feb. On the right side of the repository grid, there are two sidebars: 'Top languages' showing Jupyter Notebook, Python, and MATLAB; and 'People' showing six user avatars and an 'Invite someone' button.

github.com/rrsg2020

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rrsg2020

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Find a repository... Type: All Language: All Customize pins New

analysis
Jupyter Notebook 0 forks 1 star 3 issues 0 pull requests Updated 2 hours ago

dashboard
Forked from agahkarakuzu/rrsg2020--dashboard
Python 1 fork 0 stars 0 issues 0 pull requests Updated 4 hours ago

t1_fitting_pipeline
Pipeline to fit all the inversion recovery datasets
MATLAB 0 forks 1 star 5 issues 0 pull requests Updated 7 days ago

data_submission
1 fork 2 stars 2 issues 0 pull requests Updated on 1 May

demo
Demo notebook with an example pipeline
Jupyter Notebook 0 forks 0 stars 2 issues 0 pull requests Updated on 20 Feb

Top languages
Jupyter Notebook Python MATLAB

People 6 >
Invite someone

Final Advice to Participants

We encouraged participants to go further and explore other questions that interested them.

Summary of Submissions

Challenge Participants

(NIST phantom data)

Imperial College London

Matthew Grech-Sollars*
Simran Kukran
Ben Statton

McGill University

Alex Ensworth
Veronique Fortier
Anastasia Kolokotronis
Ives Levesque*

University of Gothenburg

Oscar Jalnefjord*

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Douglas Brain Imaging Centre

Jamie Near*

*People listed as contacts for submitted datasets

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Summary of Submissions

Datasets

Total # of submissions: **19**

CaliberMRI/NIST phantom

- # of T_1 datasets: **41**

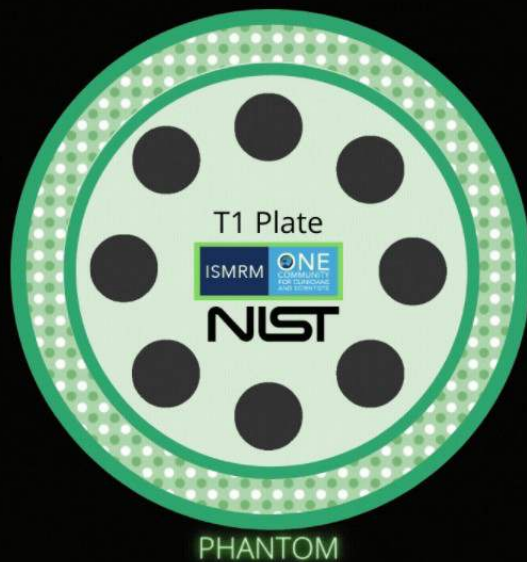
Human subjects

- # of T_1 datasets: **56**

All at **3.0 T** (except for one phantom @**350 mT**)

Vendors: **GE, Philips, Siemens.**

About
Phantom
Data

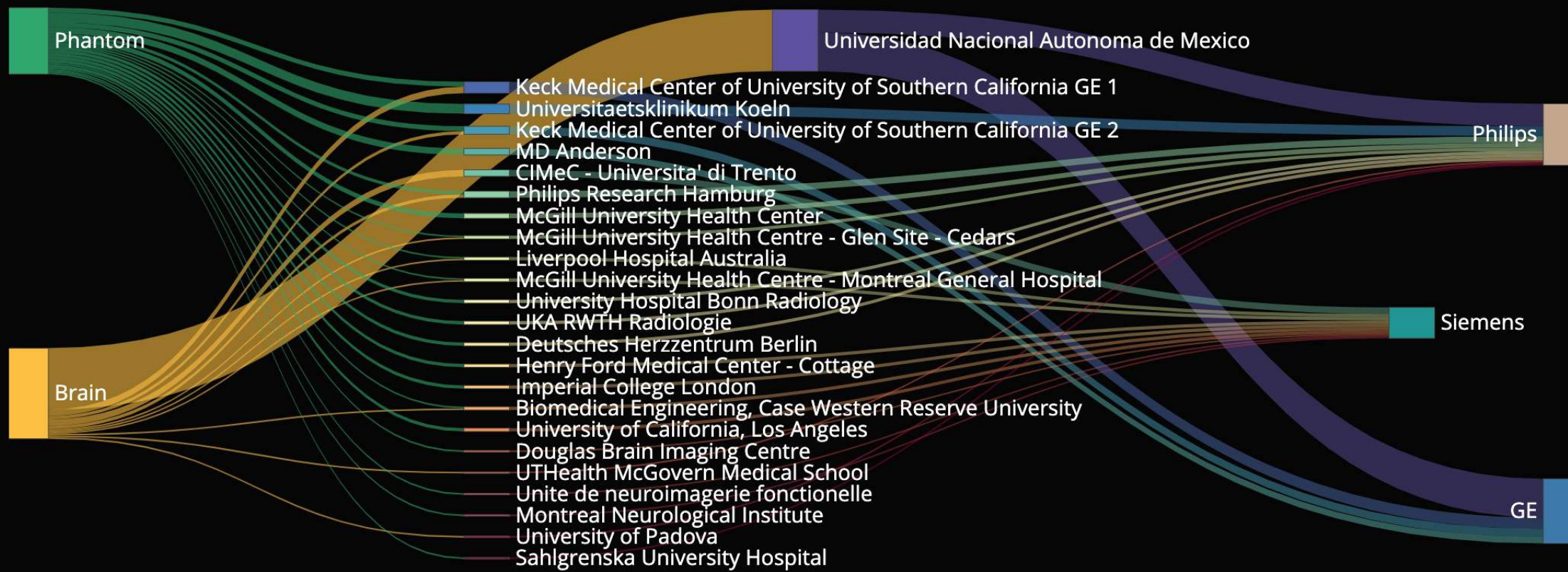
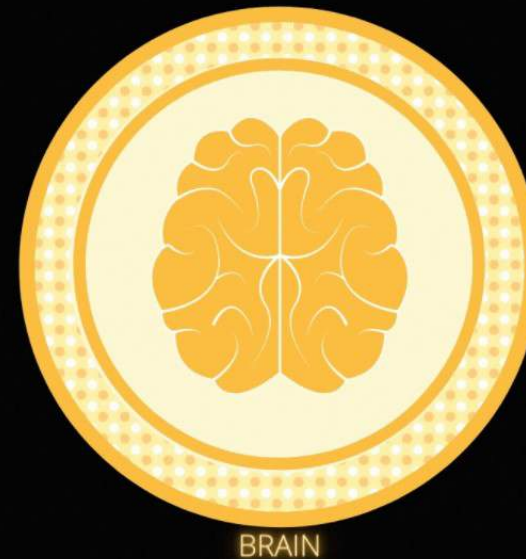


RRSG 2020 CHALLENGE



DASHBOARD

About
Human
Data





Agah Karakuzu

<http://rrsg2020.herokuapp.com/>

Summary of Submissions

“Custom” Subdatasets

NIST

Philips, Germany

- Traveling-phantom, 7 scanners

University of Southern California

- Scan-rescan (day 1 vs. day 2)
- Same-day scans on two MRIs
- Short TR vs. long TR

Henry Ford Health System

- 4 point vs. 14 point scans

MD Anderson

- Scan-rescan (day 1 vs. day 2)

University of California, Los Angeles

- Prisma vs. Skyra

Human

University of Southern California

- 6 subjects

University of Trento

- 20 channels vs. 64 channels

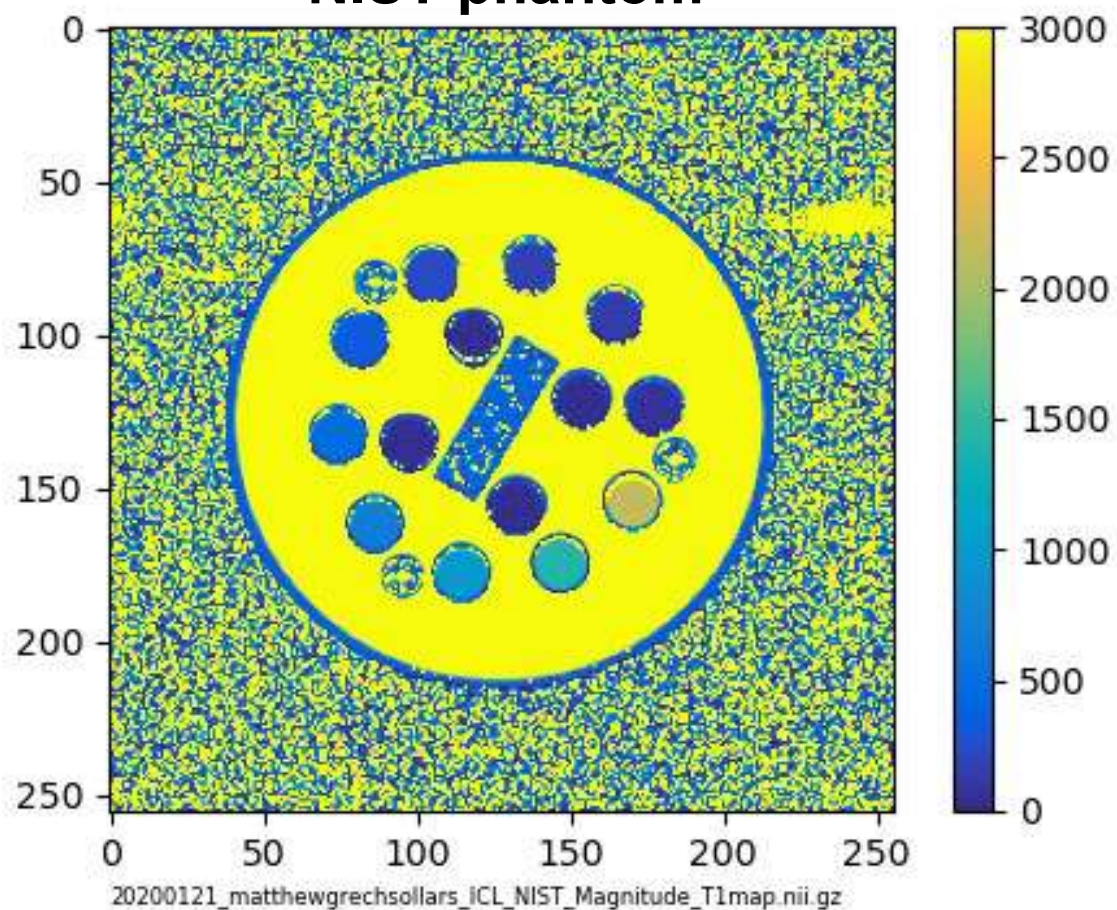
National Autonomous University of Mexico

- 13 subjects, GE vs. Philips

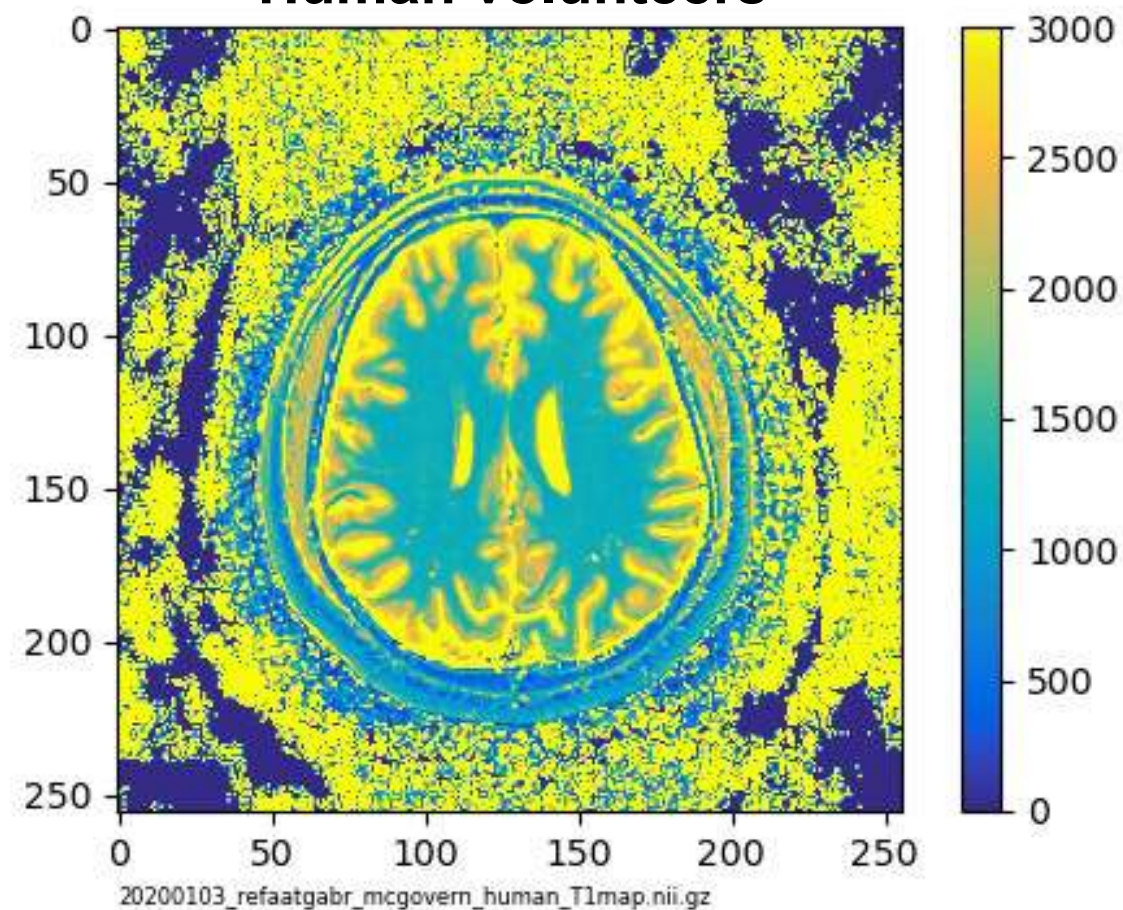
Preliminary Results

Raw T_1 Maps

NIST phantom



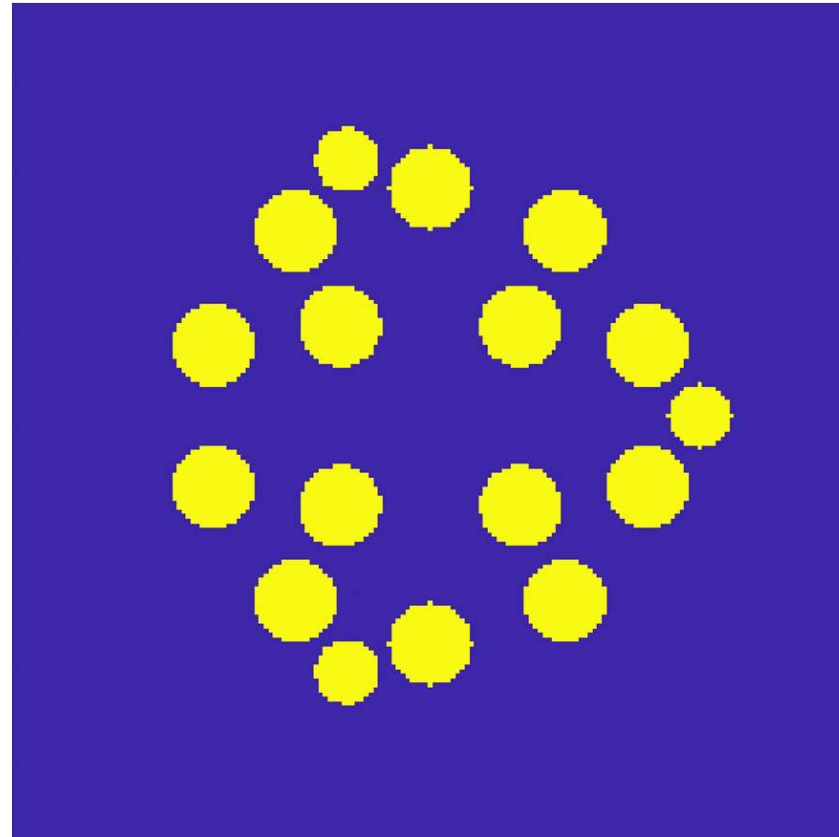
Human volunteers



NIST Phantom

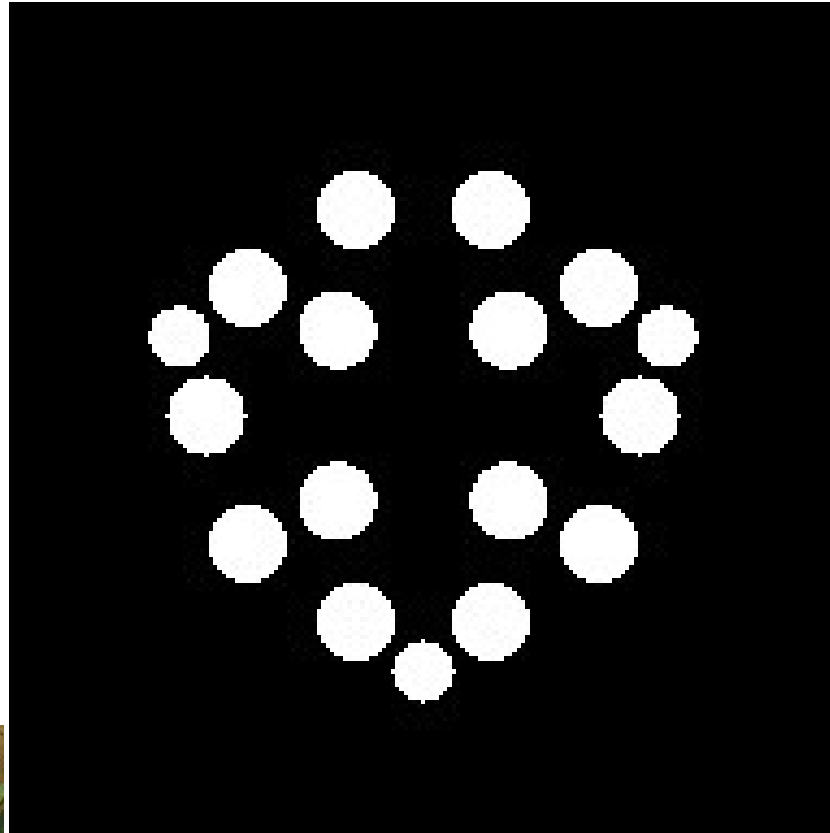
ROI Selection

ROI template and labels



Registration

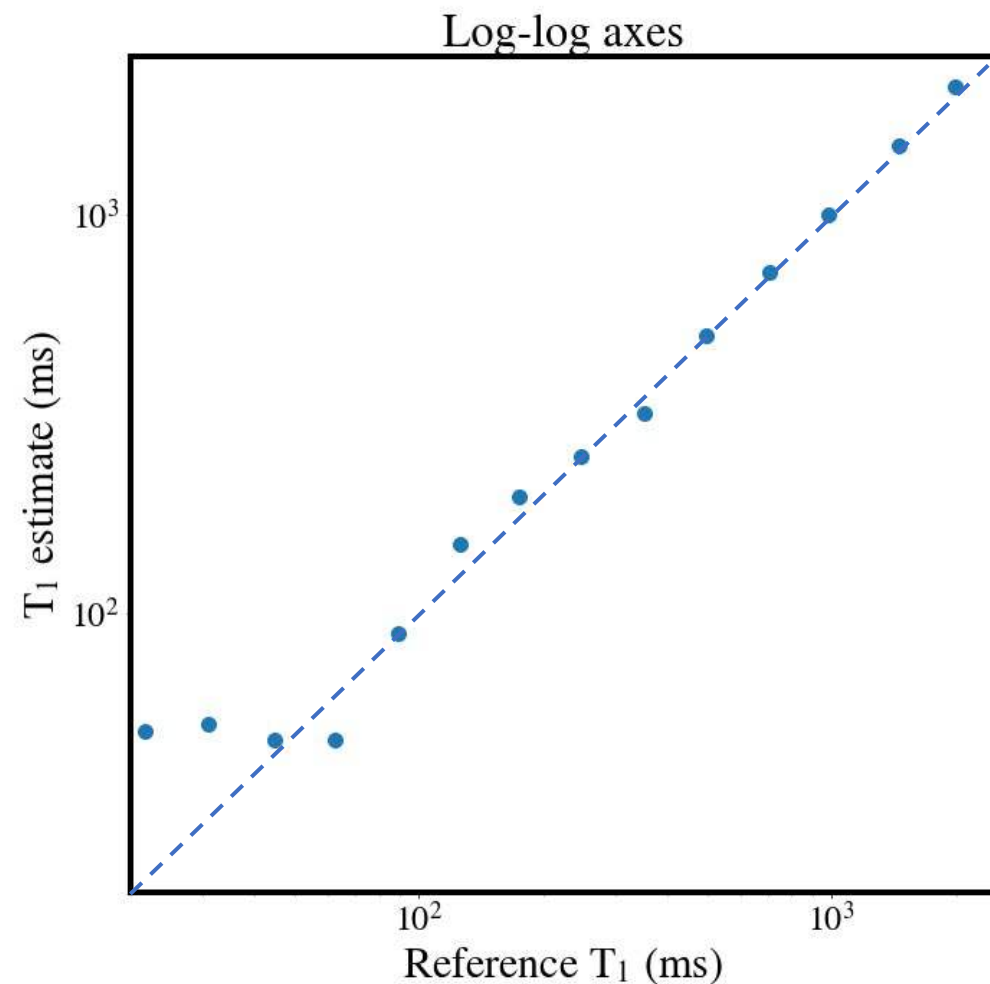
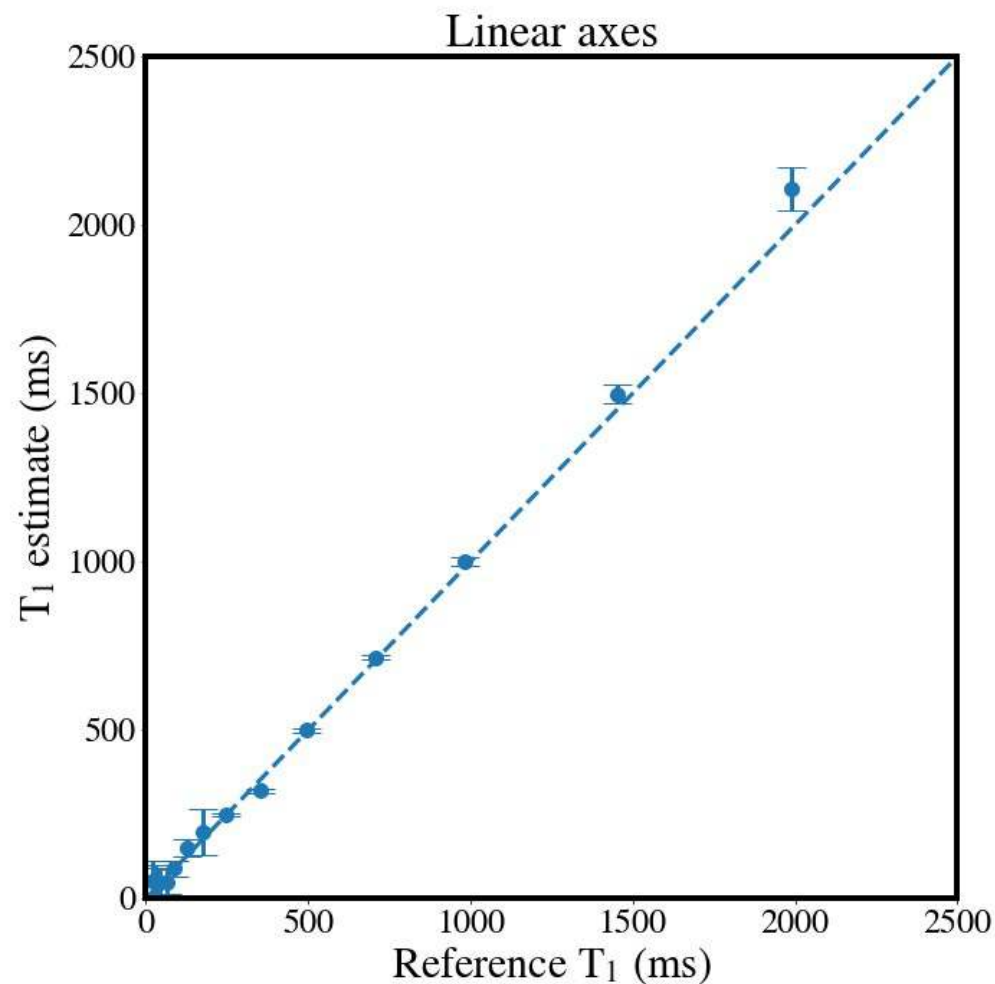
Intermediate registration step



Automatic registration pipeline contributed by **Julien Cohen-Adad** from NeuroPoly at Polytechnique Montréal.

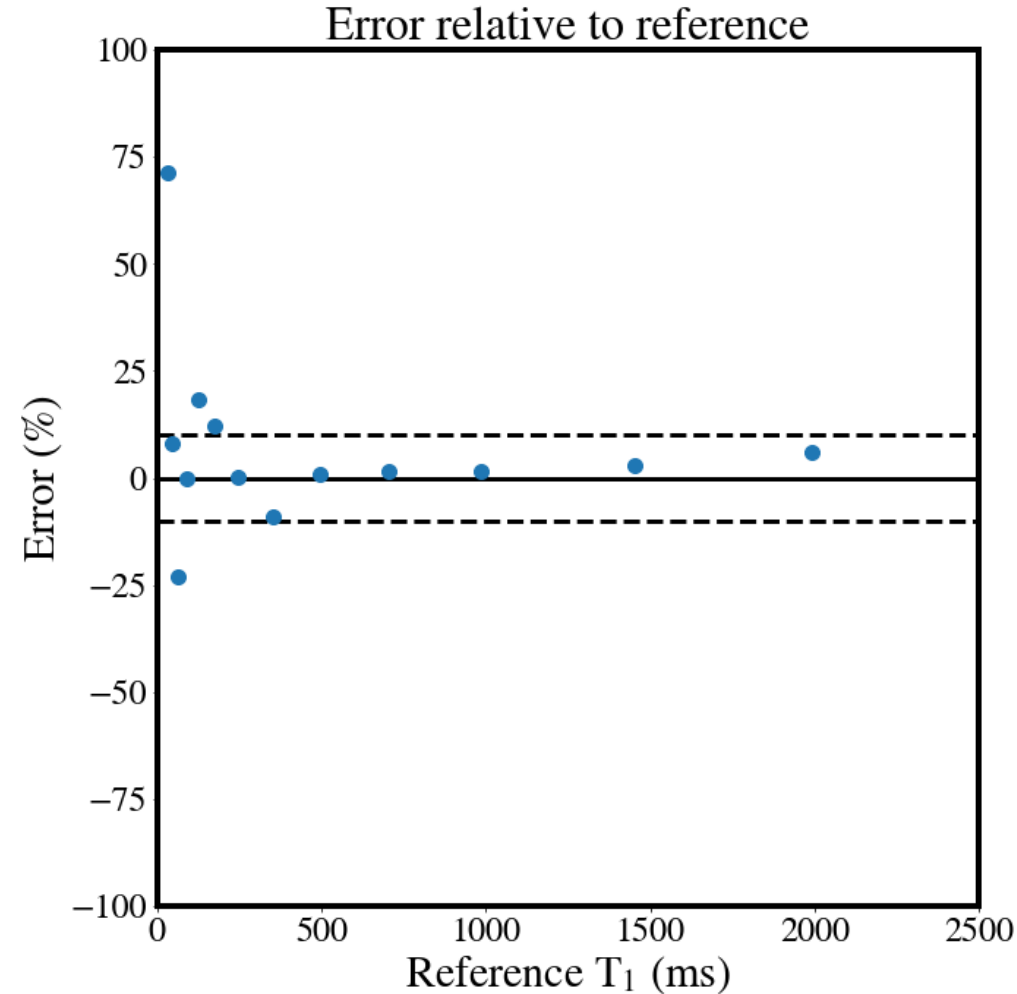
Phantom: Example Dataset

Site ID: 6.001

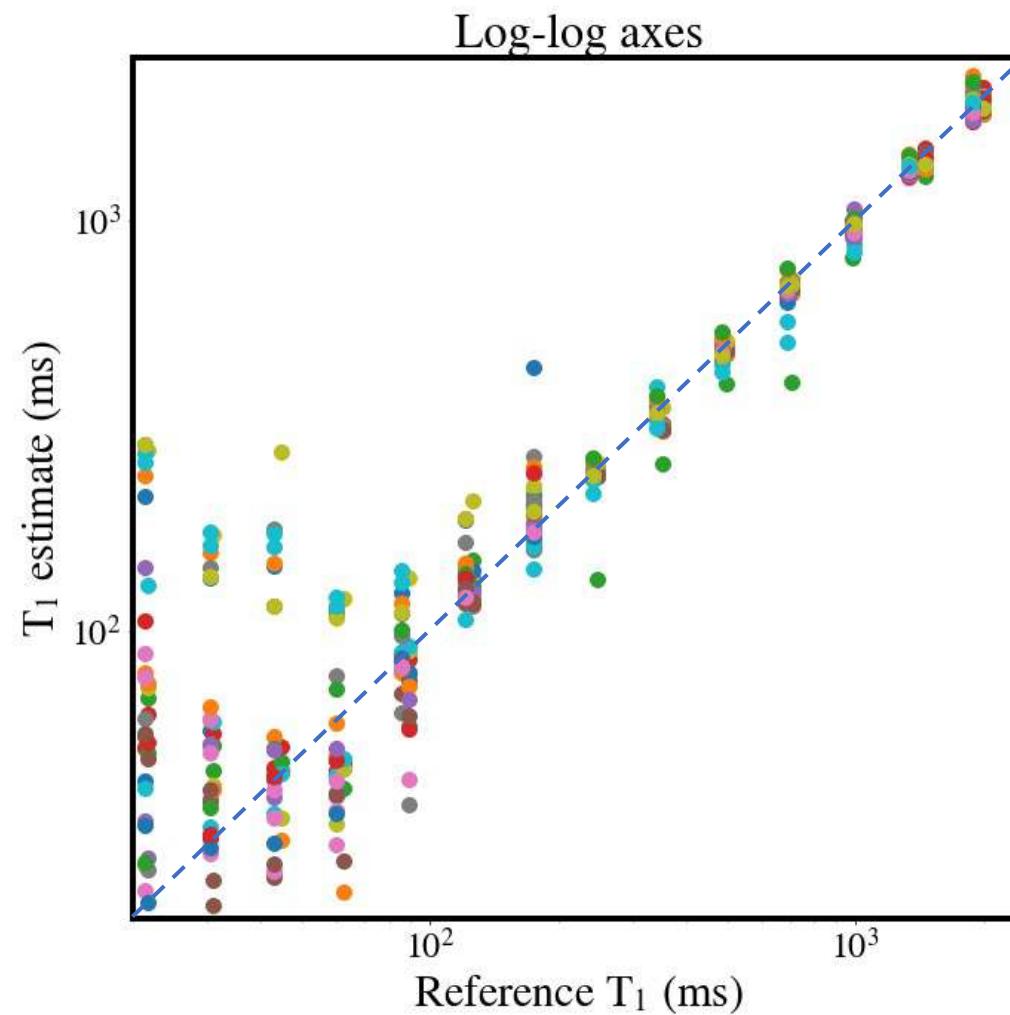
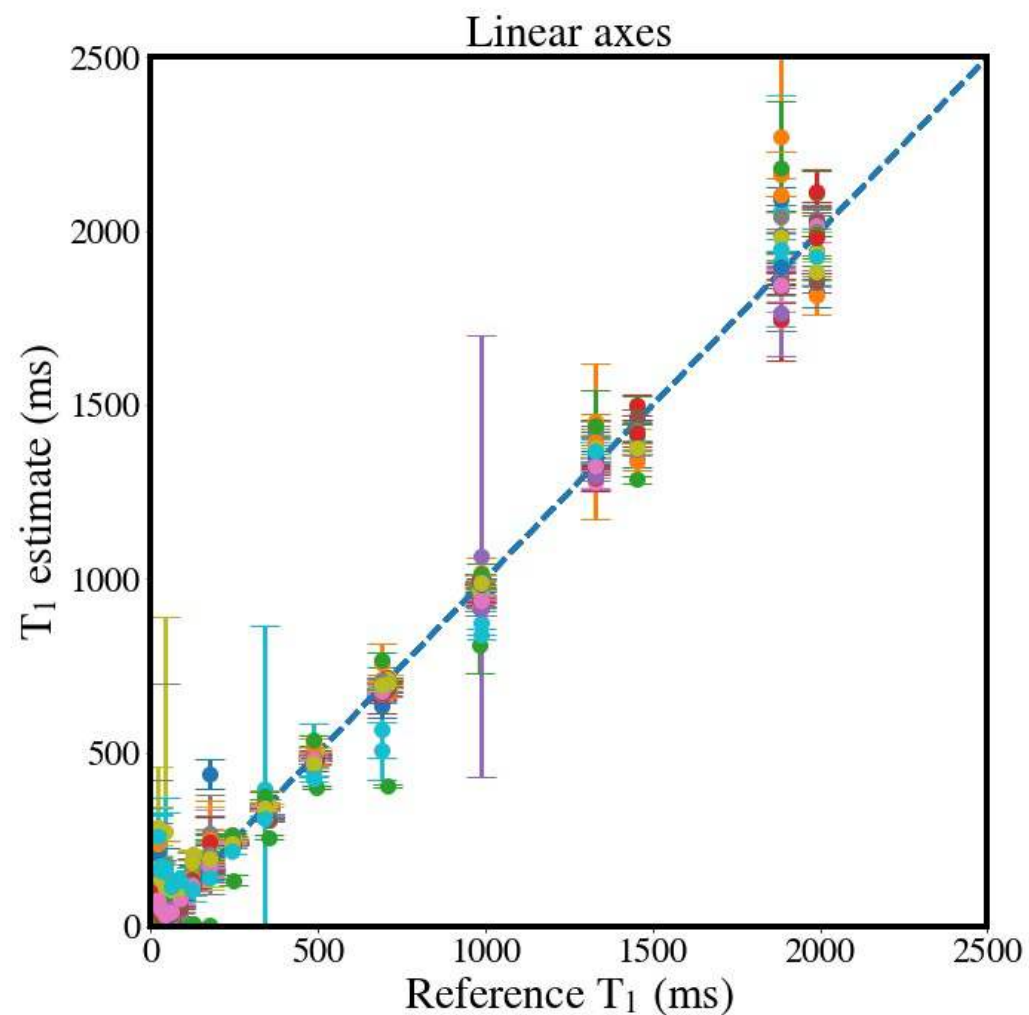


Phantom: Example Dataset

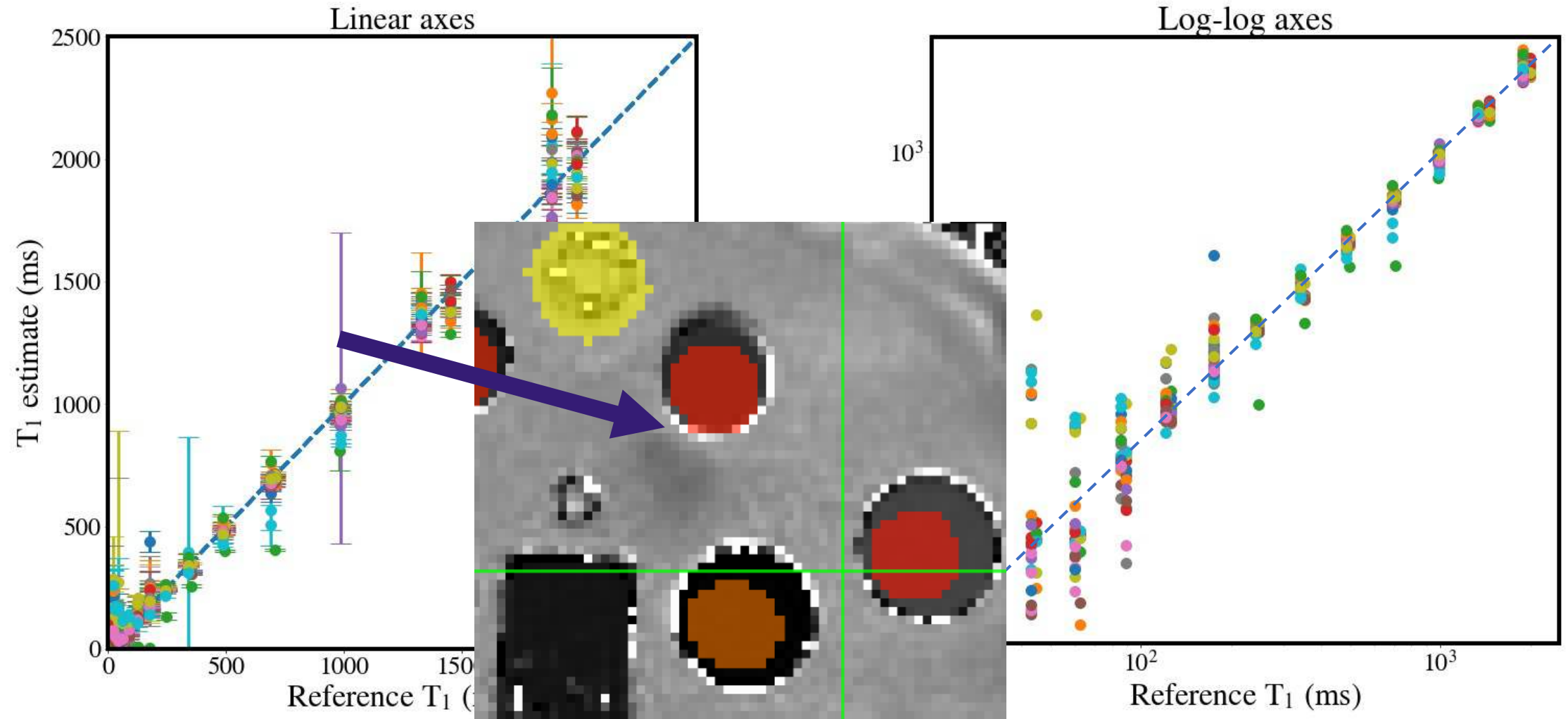
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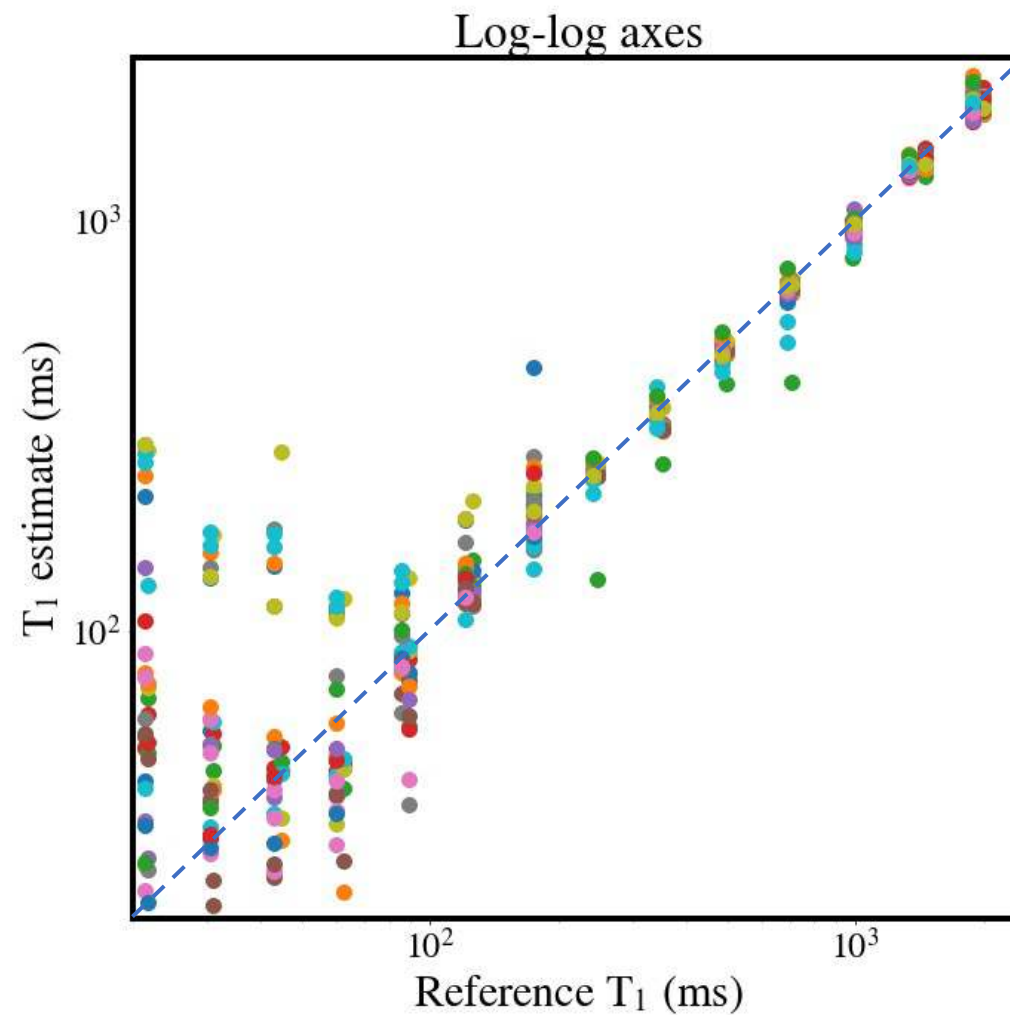
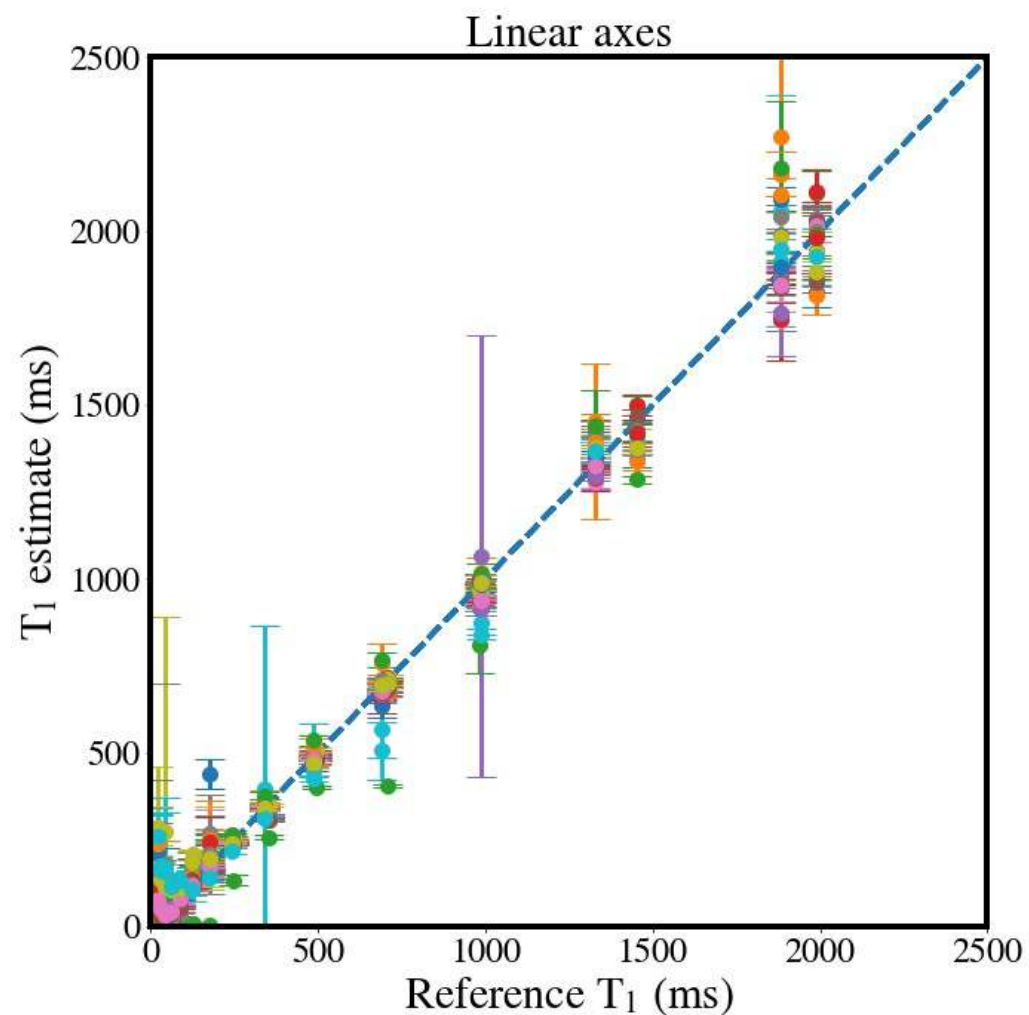
Phantom: All Datasets



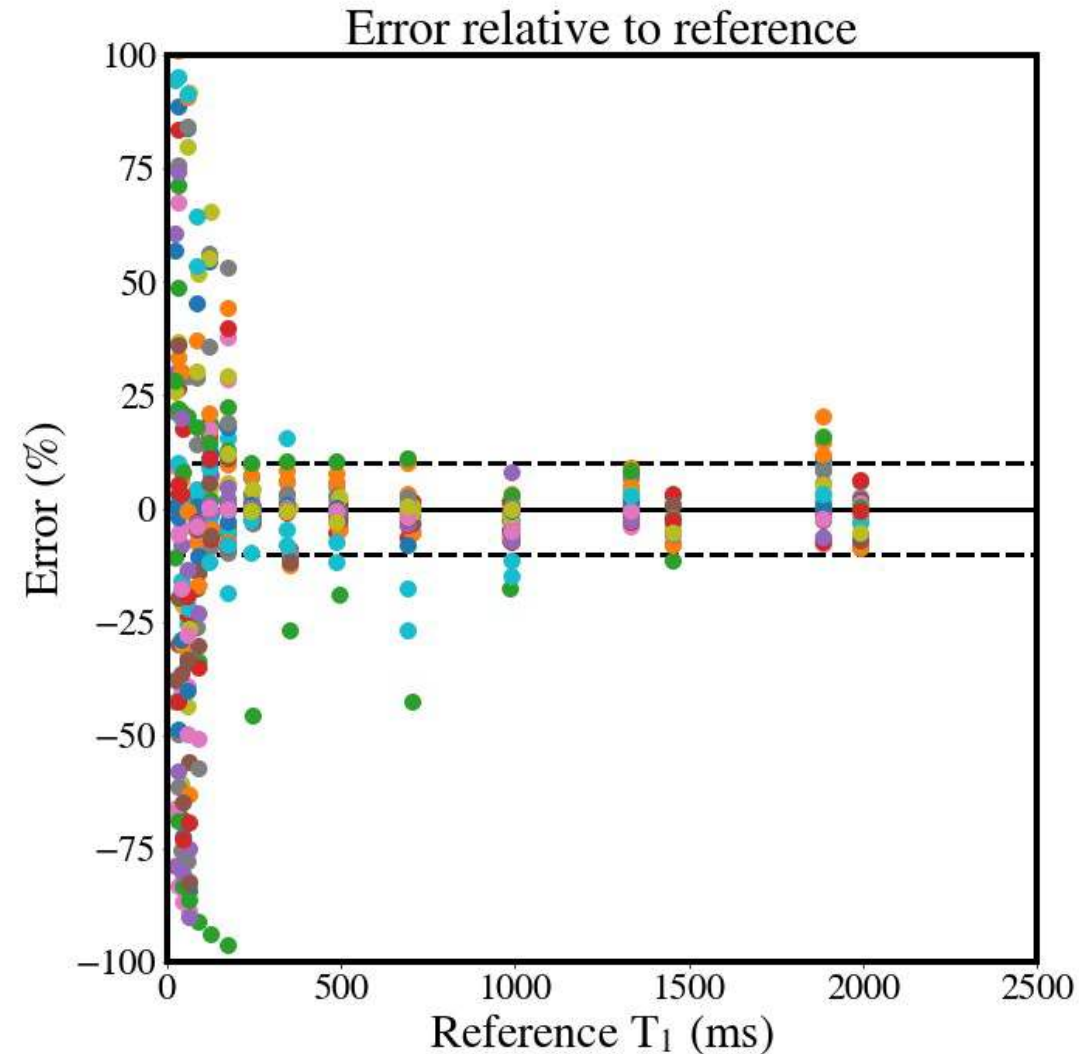
Phantom: All Datasets



Phantom: All Datasets

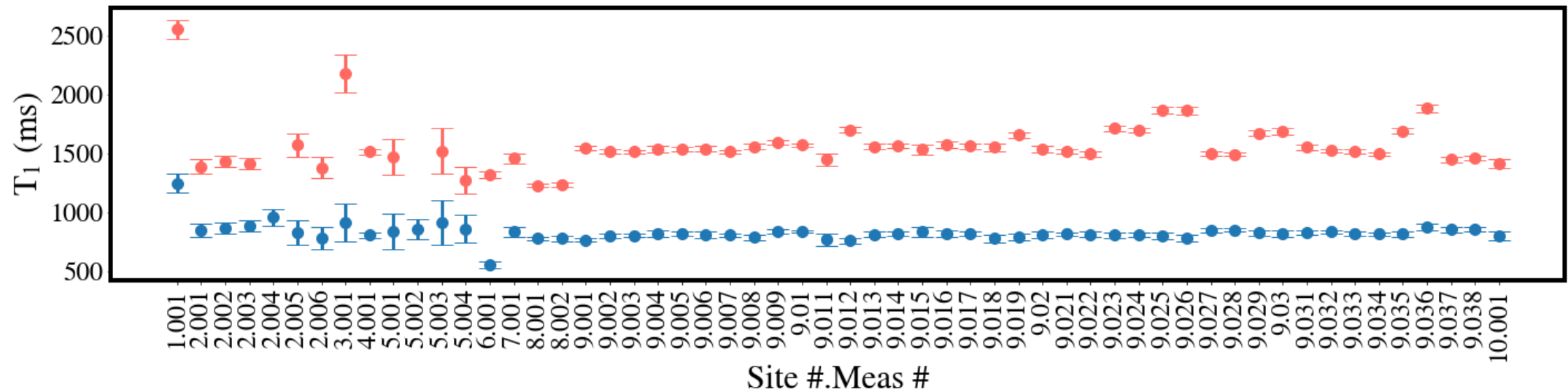
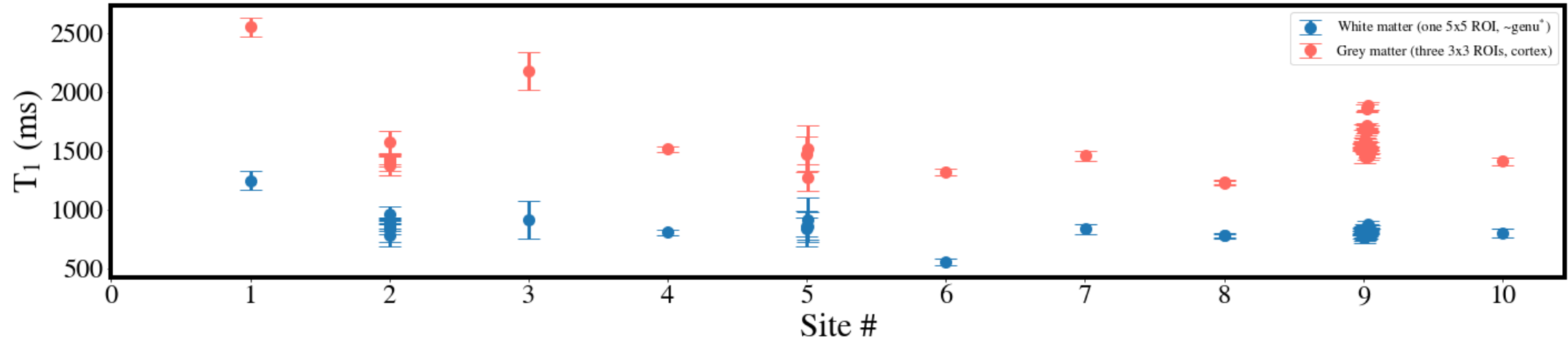


Phantom: All Datasets



Human Volunteers

Brains: Manually Segmented ROIs



*Genu was selected as WM ROI when slice position made it possible. Otherwise, right or left frontal white matter ROIs were selected.

Main Takeaway

< 5% CoV across vendors within human range values for NIST measurements.

Open Questions

Is the Barral fitting model the best & most practical one available?

Can we measure accurate T_1 using inversion recovery with a short TR?

What range of T_1 values can we accurately measure with this protocol?

Moving Forward

Dataset quality assurance.

Temperature calibration of phantom T_1 data.

Further explore several of the interesting subdatasets submitted.

Statistical analyses.

Publication(s)?

- Everything is setup to accompanying reproducible figures/pipelines.
- Could leverage services like MyBinder, NeuroLibre, or CodeOcean.

Contributions welcome!

Acknowledgements

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Sites & Affiliations

Case Western Reserve University
Center for Mind/Brain Sciences,
University of Trento
Centro de Investigación en
Matemáticas
Deutsches Herzzentrum Berlin
Douglas Brain Imaging Centre
Douglas Mental Health University
Institute
Henry Ford Health System
Henry Ford Medical Center - Cottage
Imperial College London
Ingham Institute of Applied Medical
Research
Keck Medical Center of University of
Southern California
Liverpool Hospital Australia

McGill University
McGill University Health Centre - Glen
Site - Cedars
McGill University Health Centre -
Montreal General Hospital
McGovern Medical School
MD Anderson
Montreal Neurological Institute
National Autonomous University of
Mexico
Philips Canada
Philips Clinical Science, Germany
Philips Research, Germany
Philips Research Hamburg
NeuroPoly, Polytechnique Montréal
Sahlgrenska University Hospital
Stanford University

University Hospital RWTH Aachen
Unité de Neuroimagerie Fonctionnelle
Universidad de Guanajuato
Universidad Nacional Autónoma de
México
Universitaetsklinikum Koeln
University Hospital Bonn Radiology
University of California, Los Angeles
University of Gothenburg
University of Padova
University of Southern California
University of Texas Health Science
Center at Houston
University of Trento
University of Verona
University of Wollongong

Collaborators and Contributors

RRSG Study Group

Organizing Committee

Martin Uecker

Florian Knoll

Nikola Stikov

Maria Eugenia Caligiuri

Daniel Gallichan

Quantitative MR Study Group

Organizing Committee

Kathryn Keenan

Diego Hernando

Xavier Golay

Annie Yuxin Zhang

Jeff Gunter

Registration Pipeline

Julien Cohen-Adad

Phantom ROI Templates

Zydrunas Gimbutas

Andrew Dienstfrey

Dashboard

Agah Karakuzu

General Discussions

Joëlle Barral

Paul Tofts

Ilana Leppert

Tommy Boshkovski

Kiril Zelenkovski

Filip Velkov

