Per quanto concerne i moderatori, relatori, formatori, tutor, docenti è richiesta dall'Accordo Stato-Regioni vigente apposita dichiarazione esplicita dell'interessato, di trasparenza delle fonti di finanziamento e dei rapporti con soggetti portatori di interessi commerciali relativi agli ultimi due anni dalla data dell'evento. La documentazione deve essere disponibile presso il Provider e conservata per almeno 5 anni.

Dichiarazione sul Conflitto di Interessi

Il sottoscritto_____Laganà Maria Marcella_____ in qualità di:

□ responsabile scientifico □ moderatore □ docente X relatore □ tutor

dell'evento "X CONGRESSO AIRMM - RISONANZA MAGNETICA IN MEDICINA 2019: DALLA RICERCA TECNOLOGICA AVANZATA ALLA PRATICA CLINICA"
Milano, 28-29 marzo 2019

da tenersi per conto di **Biomedia srl Provider n. 148,**

ai sensi dell'Accordo Stato-Regione in materia di formazione continua nel settore "Salute" (Formazione ECM) vigente,

Dichiara

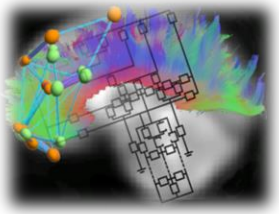
X che negli ultimi due anni NON ha avuto rapporti anche di finanziamento con soggetti portatori di interessi commerciali in campo sanitario

□ che negli ultimi due anni ha avuto rapporti anche di finanziamento con soggetti portatori di interessi commerciali in campo sanitario (indicare quali):

_____ _____
_____ _____
_____ _____
_____ _____

STrategically Acquired Gradient Echo (STAGE): protocol applications

Maria Marcella Laganà
and Alice Pirastru
IRCSS Fondazione Don Carlo Gnocchi, Milano
MR Lab



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MRI lab

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F. Baglio

P.Cecconi

L. Pelizzari

A. Pirastru

WAYNE STATE UNIVERSITY

E. M. Haacke

Y. Chen

SIEMENS Healthineers

M. Milite

N. Pineda

D. Zacà

Outline

1) Introduction
2) STAGE at 1.5T: parameter selection
   - Simulations
   - NIST phantom
   - In vivo acquisition
3) *In vivo* tissue mapping using the selected sequence:
   - T1 mapping in healthy subjects
   - Comparison with literature
   - Repeatability
   - Physiologic variability vs repeatability
4) Future developments

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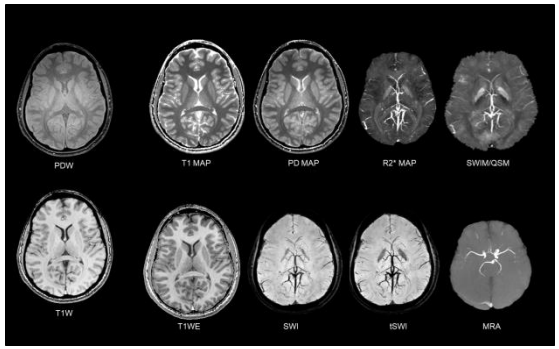
Introduction

Background

- MRI offers an incredible variety of **qualitative** contrasts and **quantitative** information, but collecting this can be very time consuming.
- STAGE provides qualitative and quantitative images within about 5 minutes scanning time
- **STAGE at 3T**: STAGE requires the acquisition of two dual echo **gradient echo (GRE)** scans with two flip angles.



Prot.	TR (ms)	TE (ms)	FA (deg)	BW (Hz/px)	Resolution (mm^3)	Slices	TA (min:sec)
T1W	25	7.5/17.5	24	220	0.67x1.33x2.0	64	2:30
PDW	25	7.5/17.5	6	220	0.67x1.33x2.0	64	2:30

References

Chen, et al., STAGE Imaging Parts I, MRI, 2017.
Wang, et al., STAGE Imaging Parts II, MRI, 2017.
Chen, et al., STAGE part B, MRAV, MRI, 2017.
Hsu, et al., SWI in acute cerebral ischemia, Neuroradiology, 2017.
Haacke et al, SWI and QSM, In the book, Quantitative MRI of the Brain, 2018.

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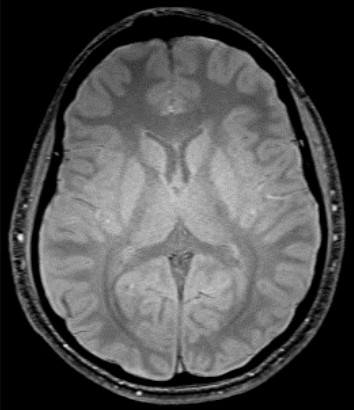
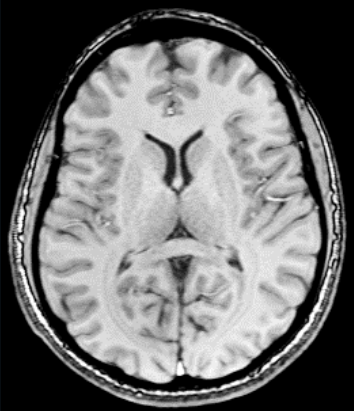
Introduction

Raw images

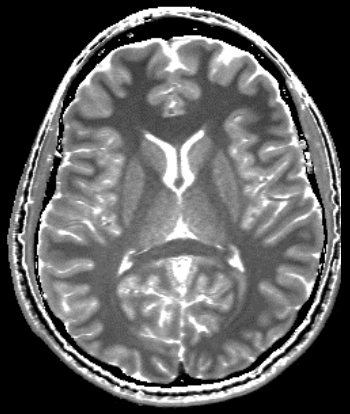


PDW

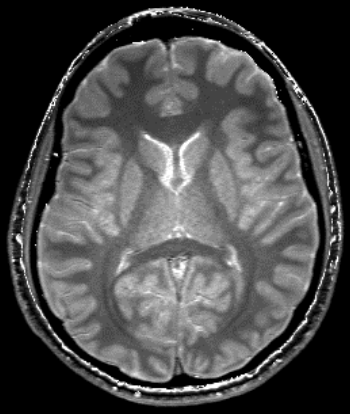


T1W

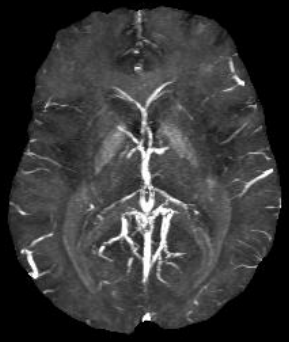
Reconstructed maps



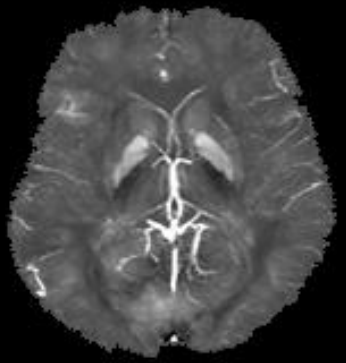
T1 MAP



PD MAP

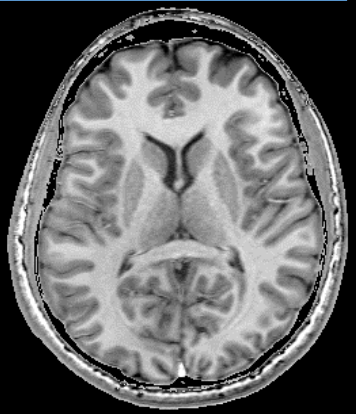


R2* MAP

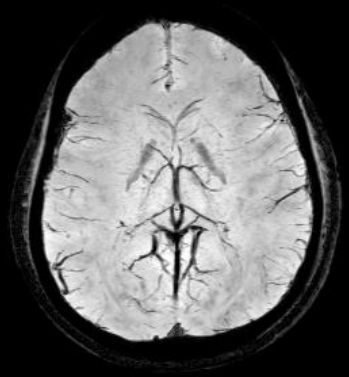


SWIM/QSM

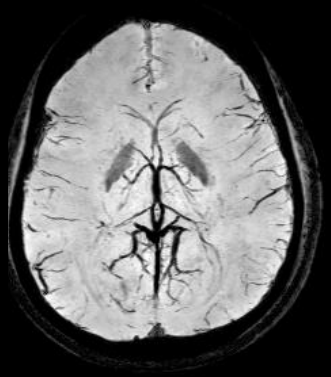
Reconstructed images



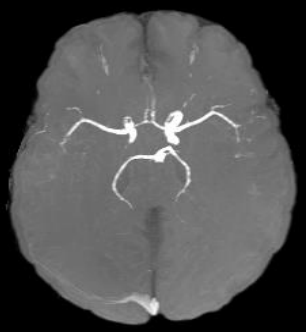
T1WE



SWI



tSWI



MRA

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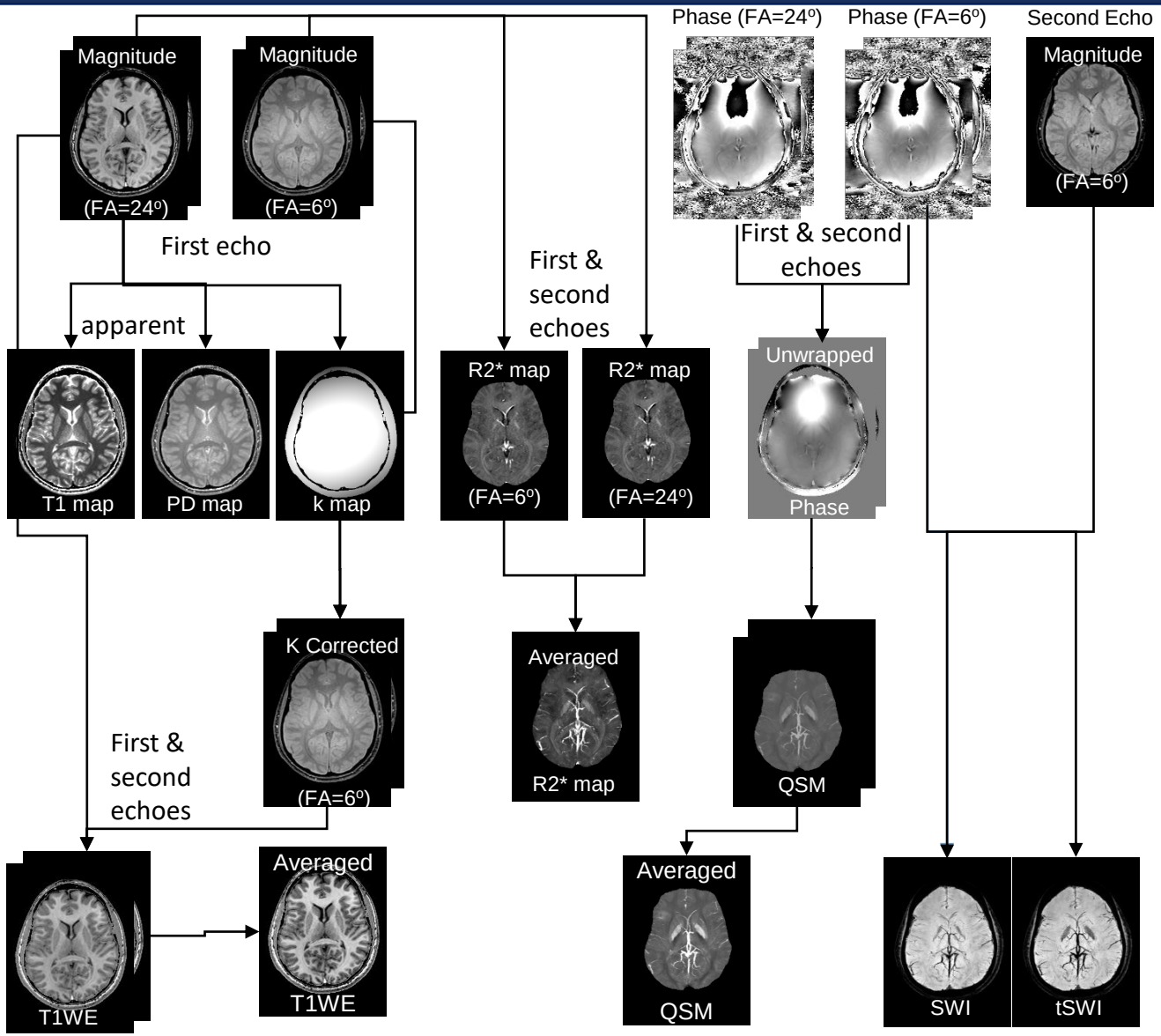
Introduction

Workflow:

- Raw STAGE images
- Processing
- Output maps



References

- Chen, et al.,
STAGE Imaging Parts I, MRI, 2017.
- Wang, et al.,
STAGE Imaging Parts II, MRI, 2017.

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Introduction

Collaborators (0.35-7T; various vendors)

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STAGE at 1.5T

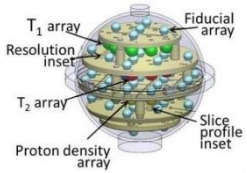
- In Italy, the most of the radiological MRI scanners used for diagnosis are still 1.5T
- How to adapt the parameters published at 3T?
  - Double-echo GRE: TR= 45ms; TE1=10ms; TE2=37ms.
  - Selection of two GRE with two different FA, for the best: 1) signal, 2) GM/WM contrast, 3) T1 precision
  - Eleven acquisitions with different flip angles (FA): range 5-55°.

MATLAB

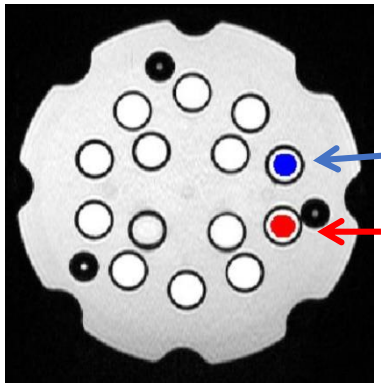
Simulations

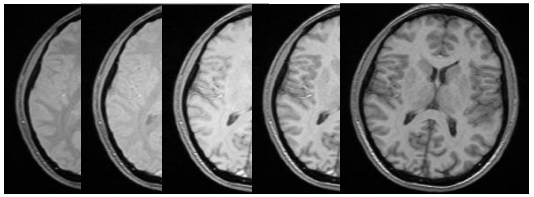
Input from literature:

- PD GM=0.84; PD WM=0.68.
- T1 GM=1100 ms; T1 WM=650 ms. Wright 2008 @ 1.5T
- T2* GM=50 ms; T2* WM=45 ms. Aquino, Radiology 2009

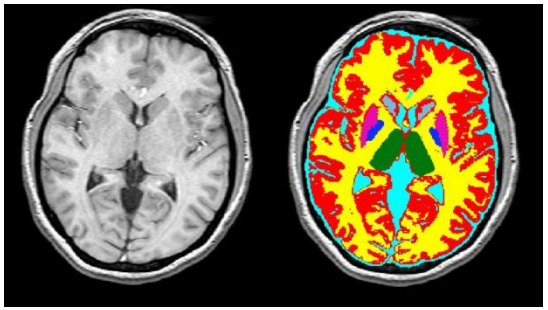


ISMRM/NIST phantom





In vivo



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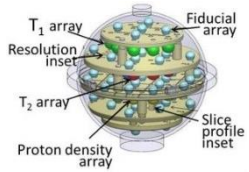
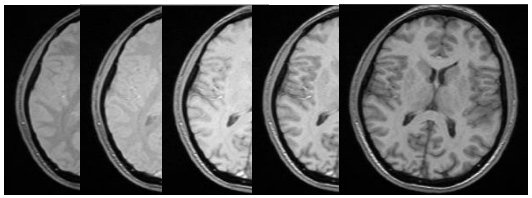
Parameter selection: 1) Signal

MATLAB





Methods

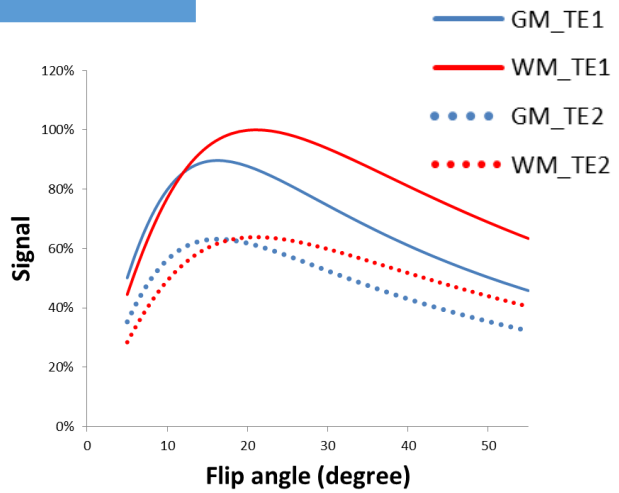
$$S(\theta) = \rho_0 \cdot \sin\theta \cdot \frac{1 - E_1}{1 - \cos\theta \cdot E_1} \cdot E_2$$

$E_1 = \exp(-T_R/T_1)$
$E_2 = \exp(-T_E/T_2^*)$
Teta=FA

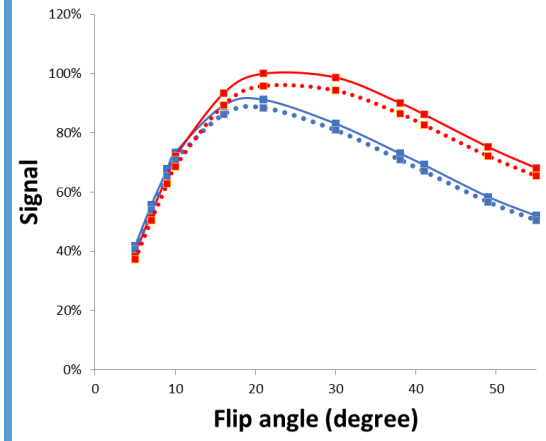
Signal in sphere 3 and 4

Signal in GM and WM

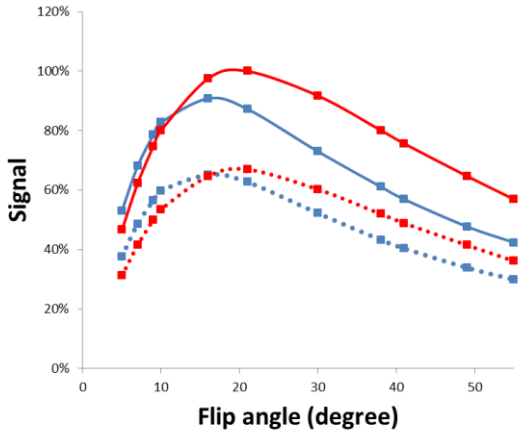
Results



Max GM=16°
Max WM= 21°



Max GM= 21°
Max WM=21°



Max GM=16°
Max WM= 21°

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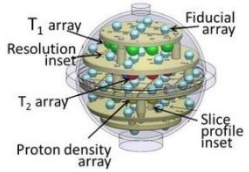
Parameter selection: 2) Contrast to noise ratio

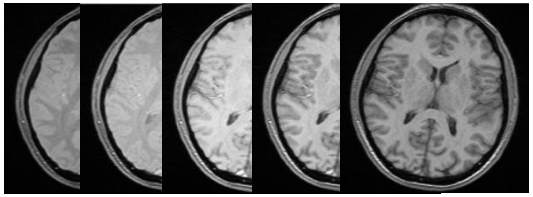
Methods

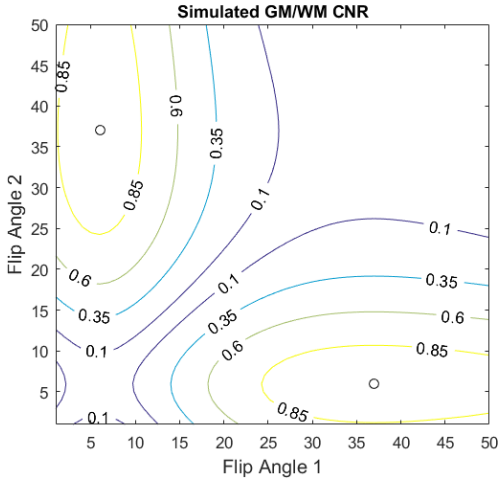
$$\mathrm{CNR}_{\mathrm{sub}} = \frac{\left|\left(S_{WM}(\theta_2) - S_{WM}(\theta_1)\right) - \left(S_{GM}(\theta_2) - S_{GM}(\theta_1)\right)\right|}{\sqrt{2}\,\sigma_0}$$

Results

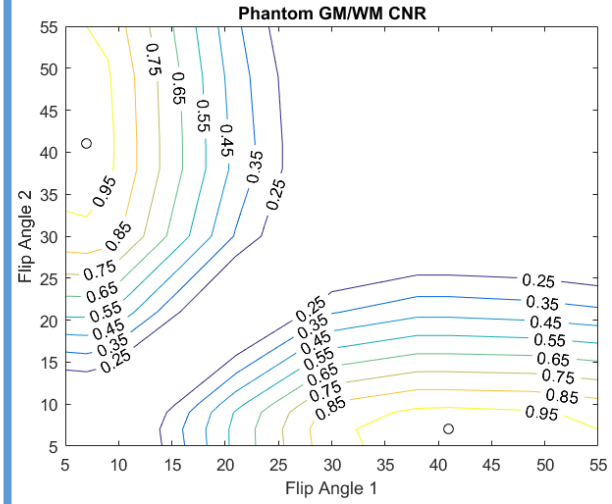
MATLAB



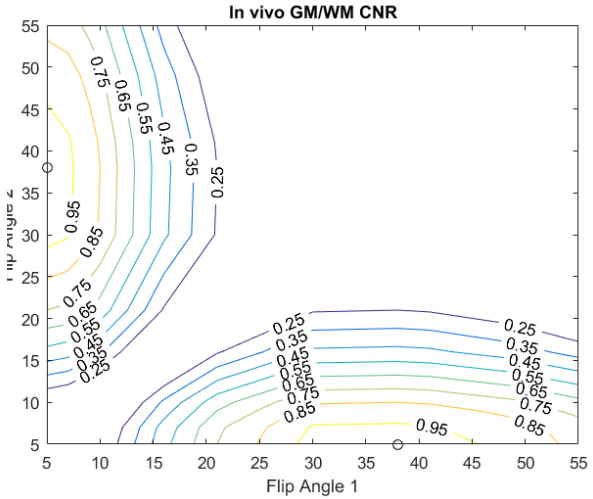




FA1=6°
FA2=37°



FA1=7°
FA2=41°



FA1=5°
FA2=38°

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Parameter selection: 3) T1 precision

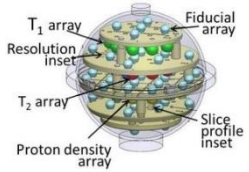
Methods

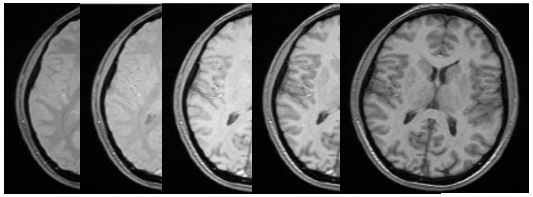
$$DR \times FS = \left[\frac{S(\theta_2)}{\rho_0 \sin\theta_2} - \frac{S(\theta_1)}{\rho_0 \sin\theta_1} \right] \times \left[\frac{S(\theta_1) + S(\theta_2)}{2S(\theta_E)} \right]$$

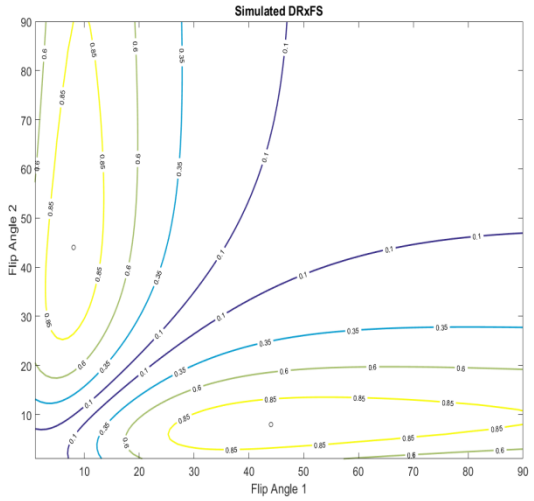
Dinamic range (DR) x fractional signal of the points (FS), Deoni et al., MRI 2003

Results

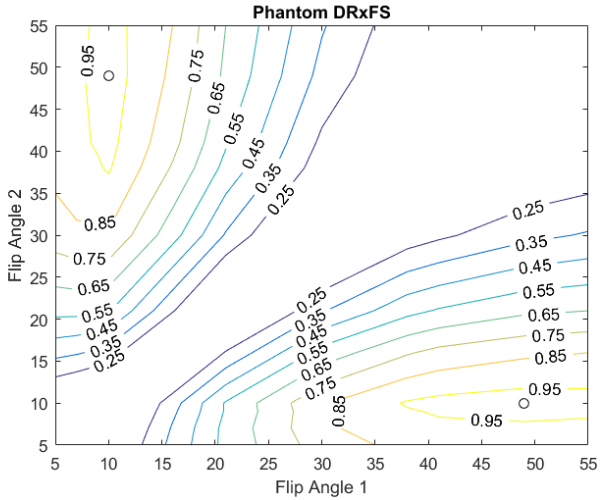
MATLAB



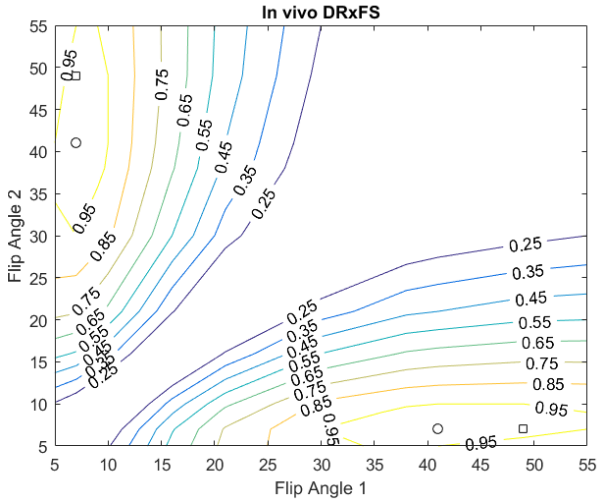




FA1= 8°
FA2= 44°



FA1=10°
FA2=49°



FA1=7°
FA2=41-49° ° (o - □)

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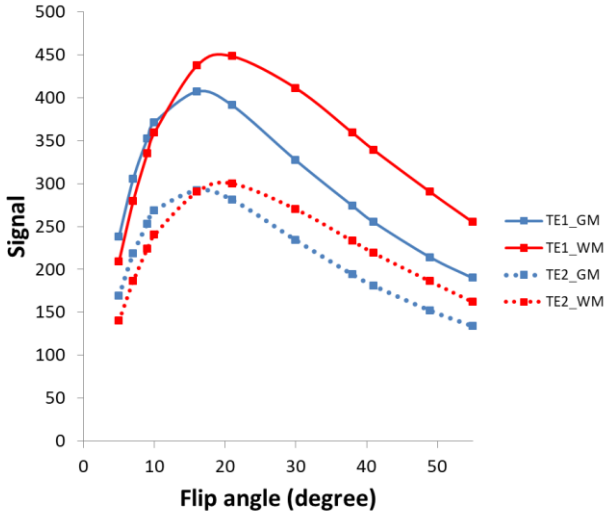
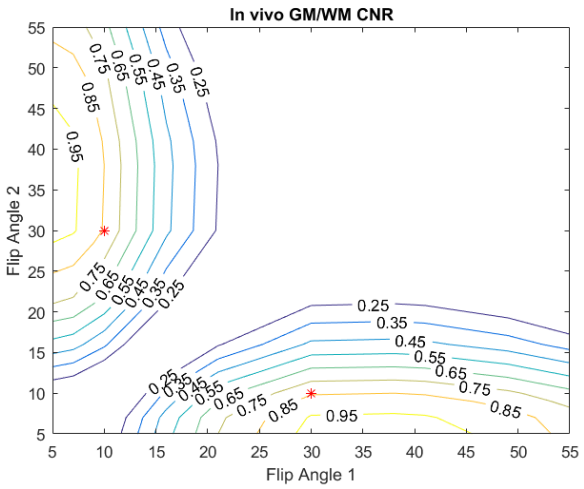
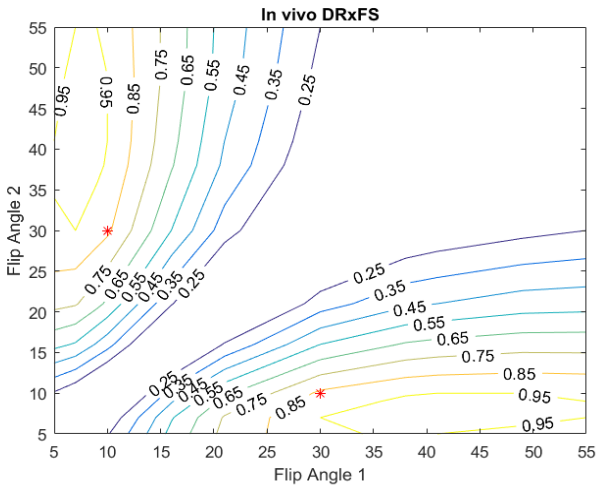
Parameter selection: results

- Max CNR + DRxFS for FA1=7° and FA2=38°
- For FA1=10° the SNR is higher
- For FA2=30° the SNR is higher and SAR is lower
- With the selected FA (10° and 30°, *),
  both CNR and T1 precision should be > 85% of the maximum







→ Evaluation of T1 accuracy using ISMRM/NIST phantom

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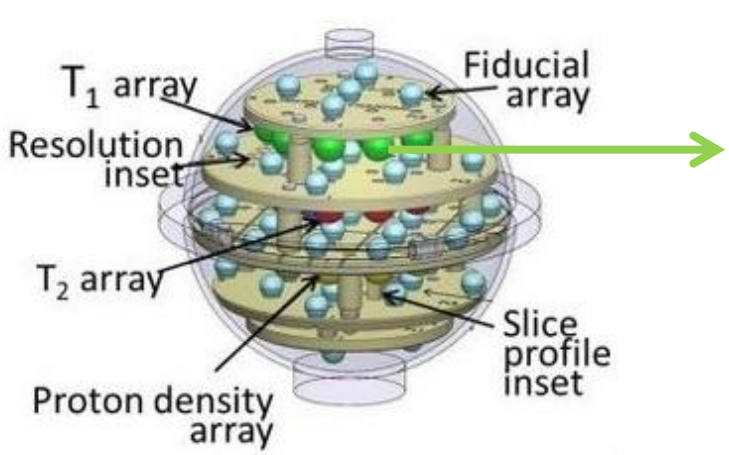
ISMRM/NIST phantom

Evaluation of T1 accuracy

- T1 estimated using the dual-echo GRE with FA=10° and FA=30°
- Comparison of the estimated T1 vs nominal



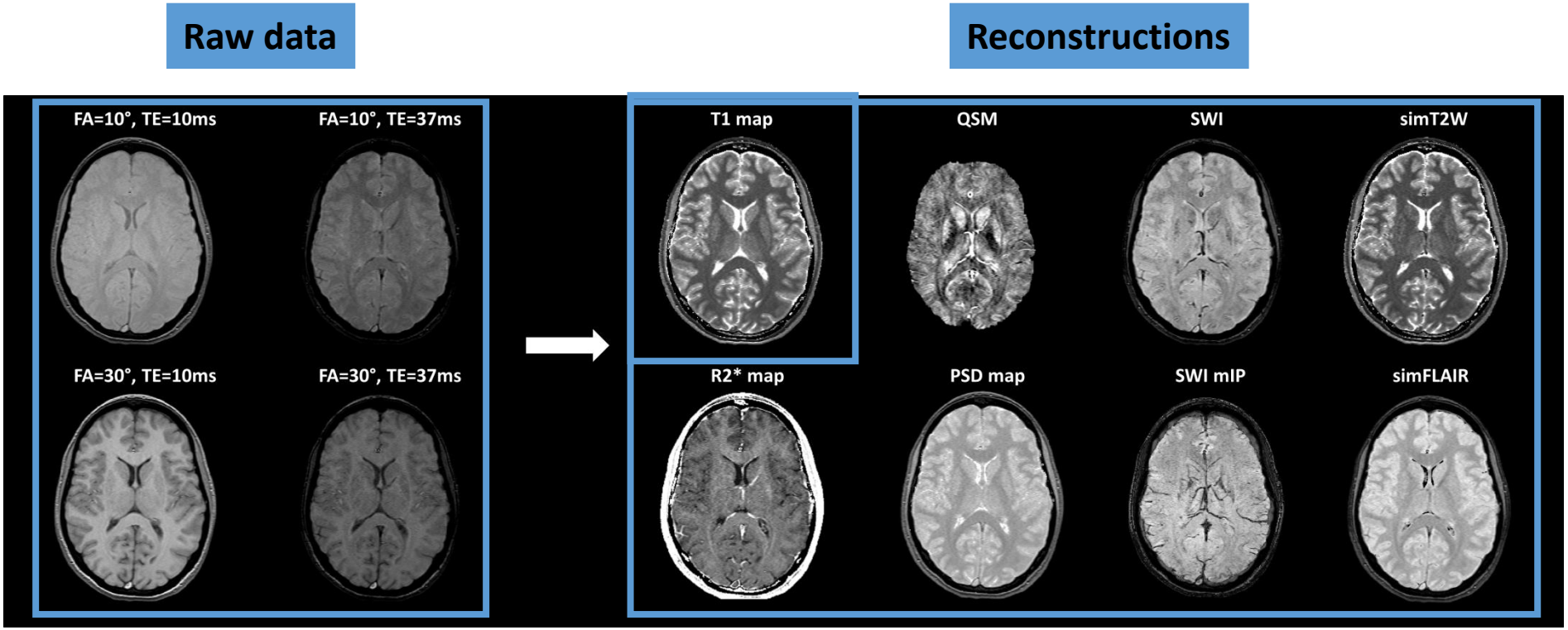
Sphere	Nominal T1 (ms)	STAGE apparent T1 (ms)	error (vs nominal)	STAGE corrected T1 (ms)	error (vs nominal)
sphere 03	1012	1034	2.1%	1003	0.9%
sphere 04	731	688	5.8%	715	2.1%

→ The RF transmit field correction improves the T1 estimate, decreasing the errors

Outline

1) Introduction
2) STAGE at 1.5T: parameter selection
   - Simulations
   - NIST phantom
   - In vivo acquisition
3) ***In vivo* tissue mapping using the selected sequence:**
   - **T1 mapping in healthy subjects**
   - **Comparison with literature**
   - **Repeatability**
   - **Physiologic variability vs repeatability**
4) Future developments

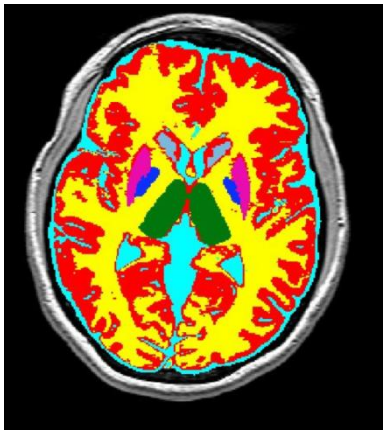
STAGE at 1.5T: in vivo results

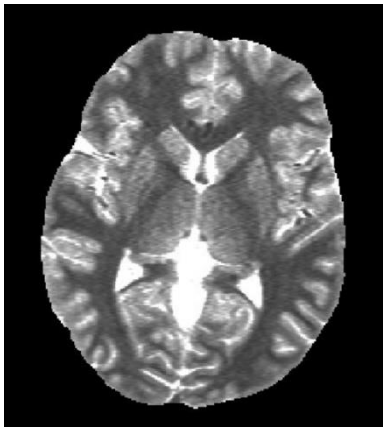


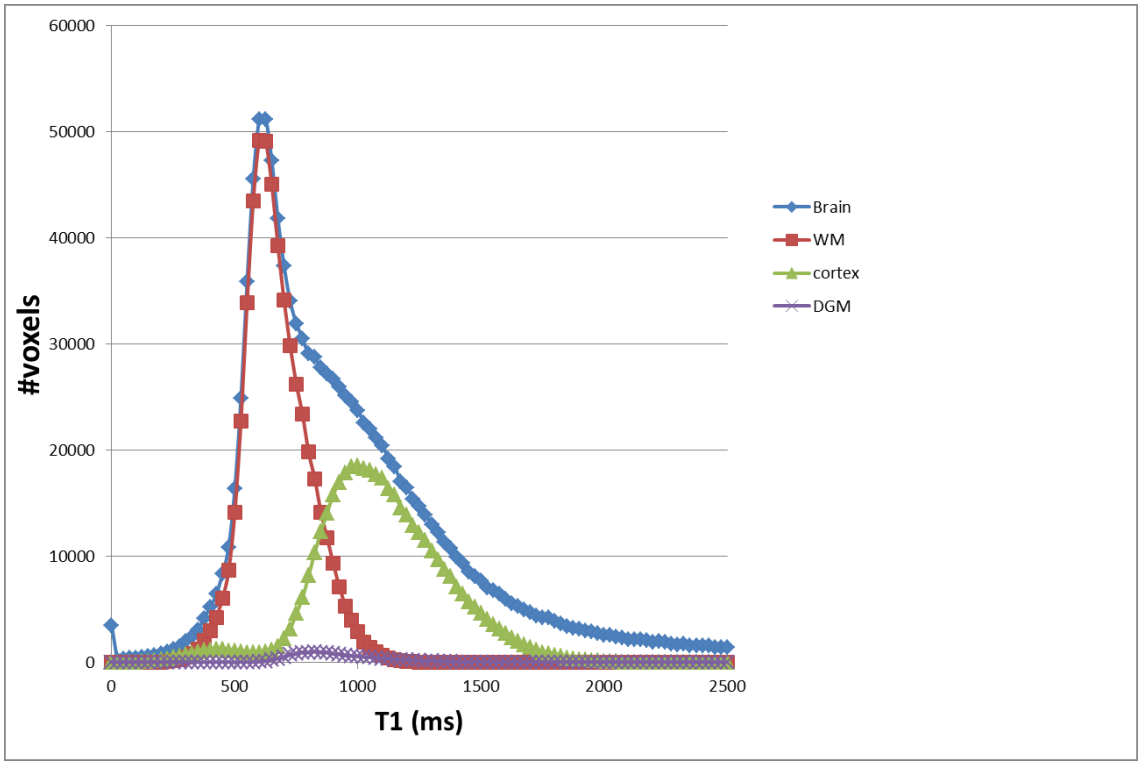
In vivo T1 tissue mapping

1) T1 distribution in the different tissues

Exemplificative subject







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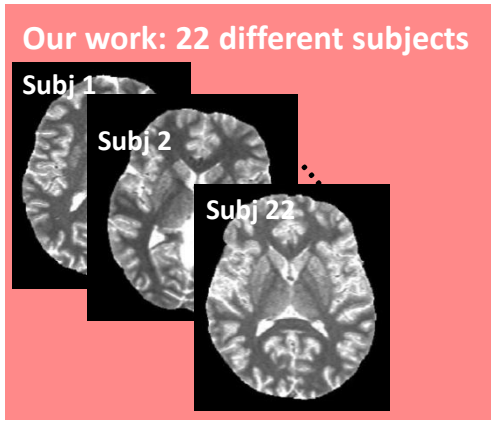
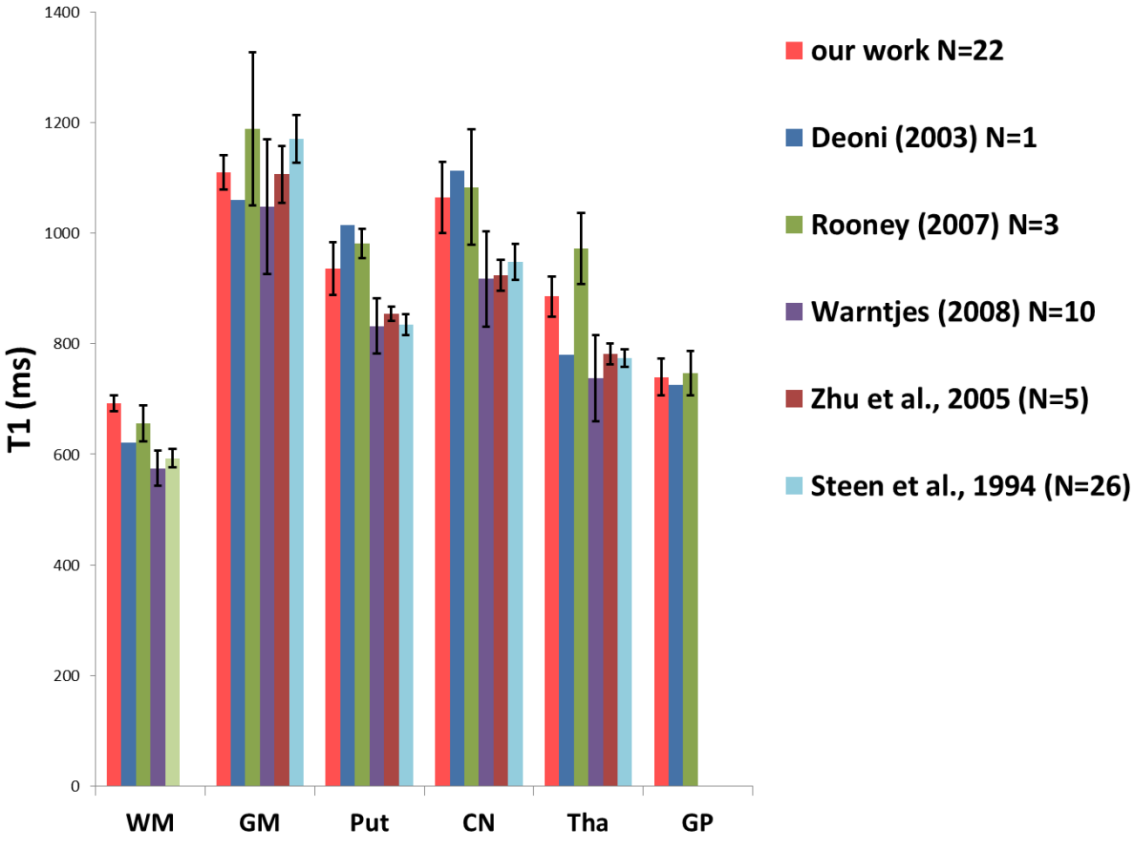
In vivo T1 tissue mapping

2) Comparison with literature

Average and SD from 22 healthy subjects

→ T1 values similar to those of literature





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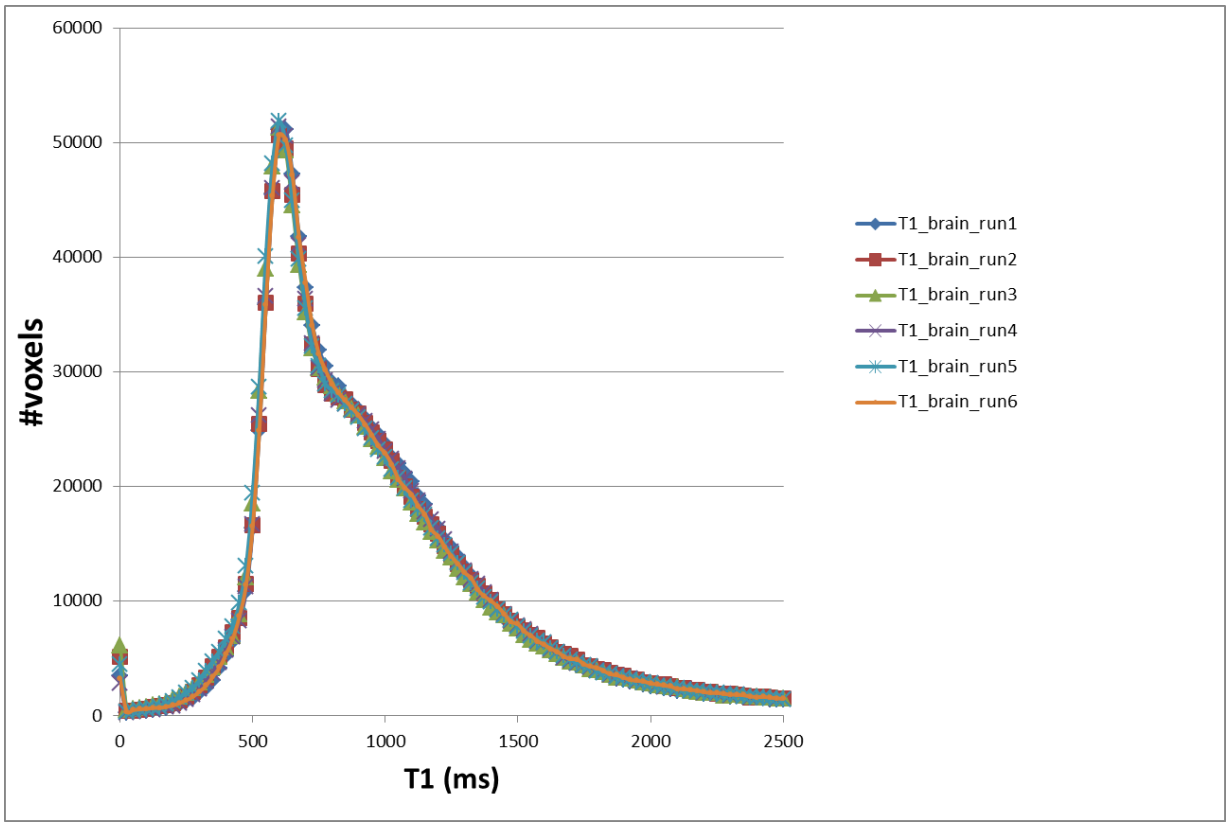
In vivo T1 tissue mapping

3) Repeatability

- One subject was acquired 10 times.
- The histograms are almost overlapped

  → Very good repeatability of T1 distribution across the brain

Our work: same subject, 10 runs



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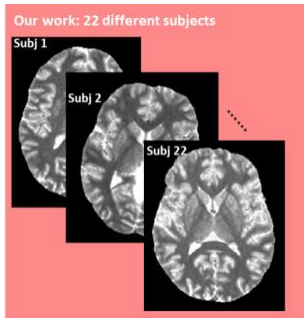
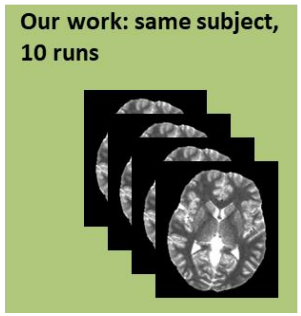
In vivo T1 tissue mapping

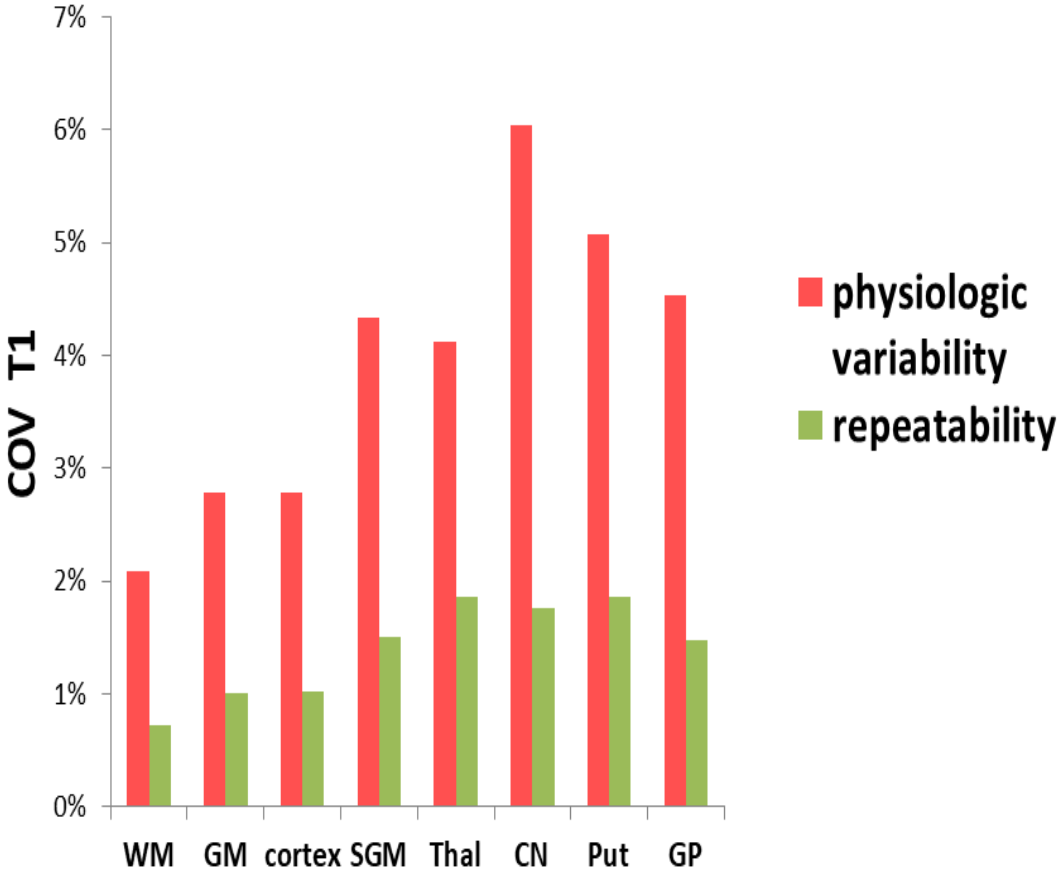
4) Physiologic variability vs Measure repeatability

- Coefficient of variation (COV)=SD/avg

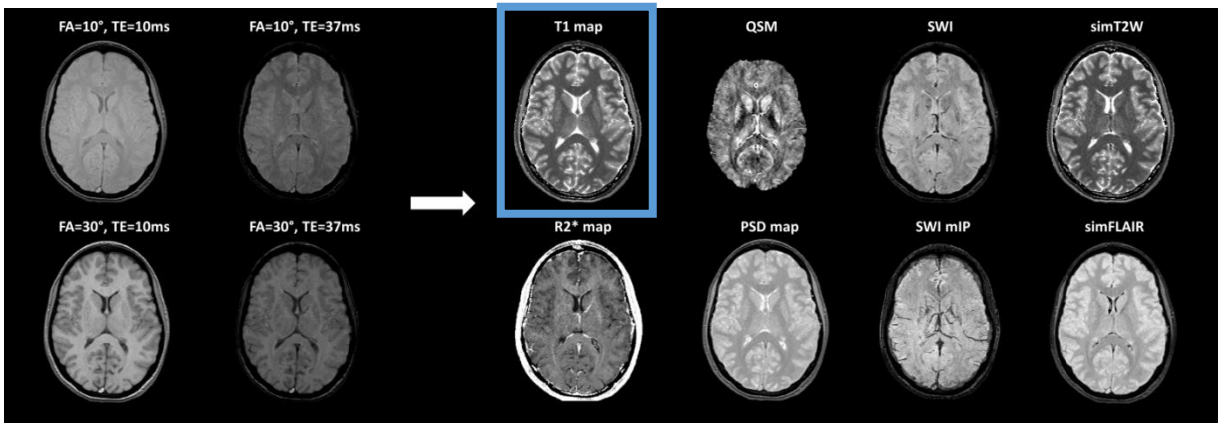
→ Good repeatability, lower than the physiologic repeatability







Conclusions and future developments



- STAGE provides qualitative and quantitative images in 5 minutes
- FA selection for accurate and repeatable T1 mapping
- In vivo PD, R2* and QSM mapping: comparison with literature; repeatability
- Influence of # flip angles on the mapping accuracy
- Clinical studies using STAGE protocol
- Differences compared to maps obtained using other ad-hoc sequences
  → are you interested? Contact me: mlagana@dongnocchi.it
  → network for comparing results from different scanner, different sequences..
  → **Workshop at Ferrara: May 30. Ge Y., Laganà M., Haacke M.**

Thank you

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