T_1 measurement of the myelin water fraction

Peter van Gelderen, Xu Jiang, Jacco A. de Zwart, Jeff H. Duyn
AMRI, LFMI, NINDS, National Institutes of Health
Bethesda MD, USA

Conflict of interest:
none

Introduction

- Myelin related contrast of interest for MS and other neurological disorders

- Myelin (water) identified by different contrast mechanisms:
  - T_2 [a]
  - MTC [b]
  - T_1 [c]

a) A. McKay et.al., MRM 31, 1994, 673
b) J.G. Sled & G.B. Pike, MRM 46, 2001, 923
c) Labadie et.al., MRM 71, 2014, 375

Motivation

- WM T_1 short due to relaxation effect of bound protons in myelin

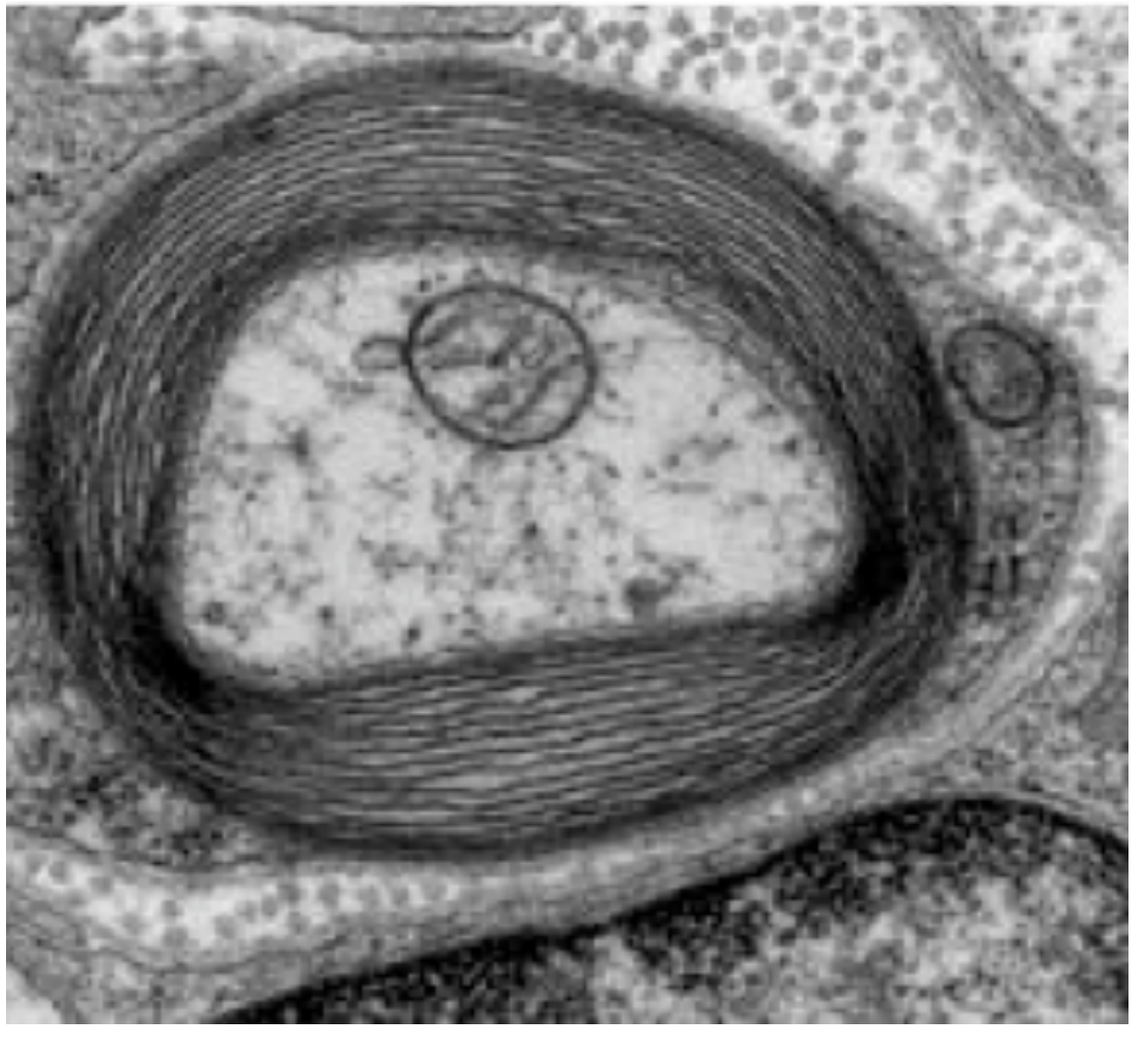
- MT data suggest exchange fast compared to T_1 [a,b)]

- Proposed T_1 based selection methods[c,d)] assume limited exchange effects

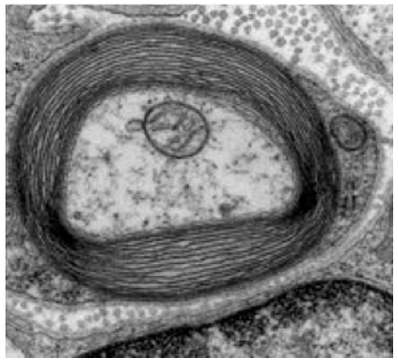
- What is the T_1 of myelin water identified by multi component T_2^* decay[b,e)]?

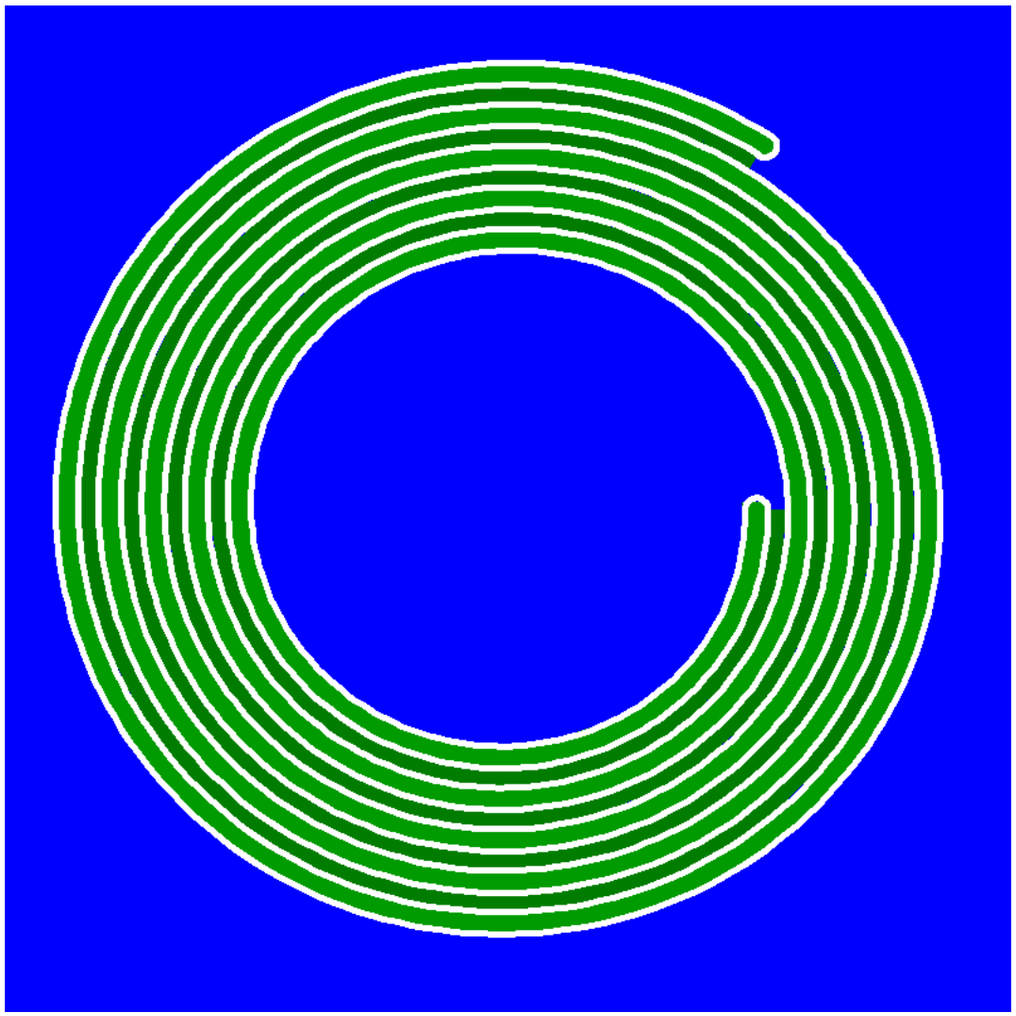
a) I.M. Vavasour et.al. MRM 44, 2000, 860
b) P. Sati et.al, Neuroimage, 77, 2013, 368
c) Labadie et.al., MRM 71, 2014, 375
d) S-H. Oh et.al., Neuroimage 83, 2013, 483
e) Y. Du et.al., MRM 58, 2007, 865

Myelin water

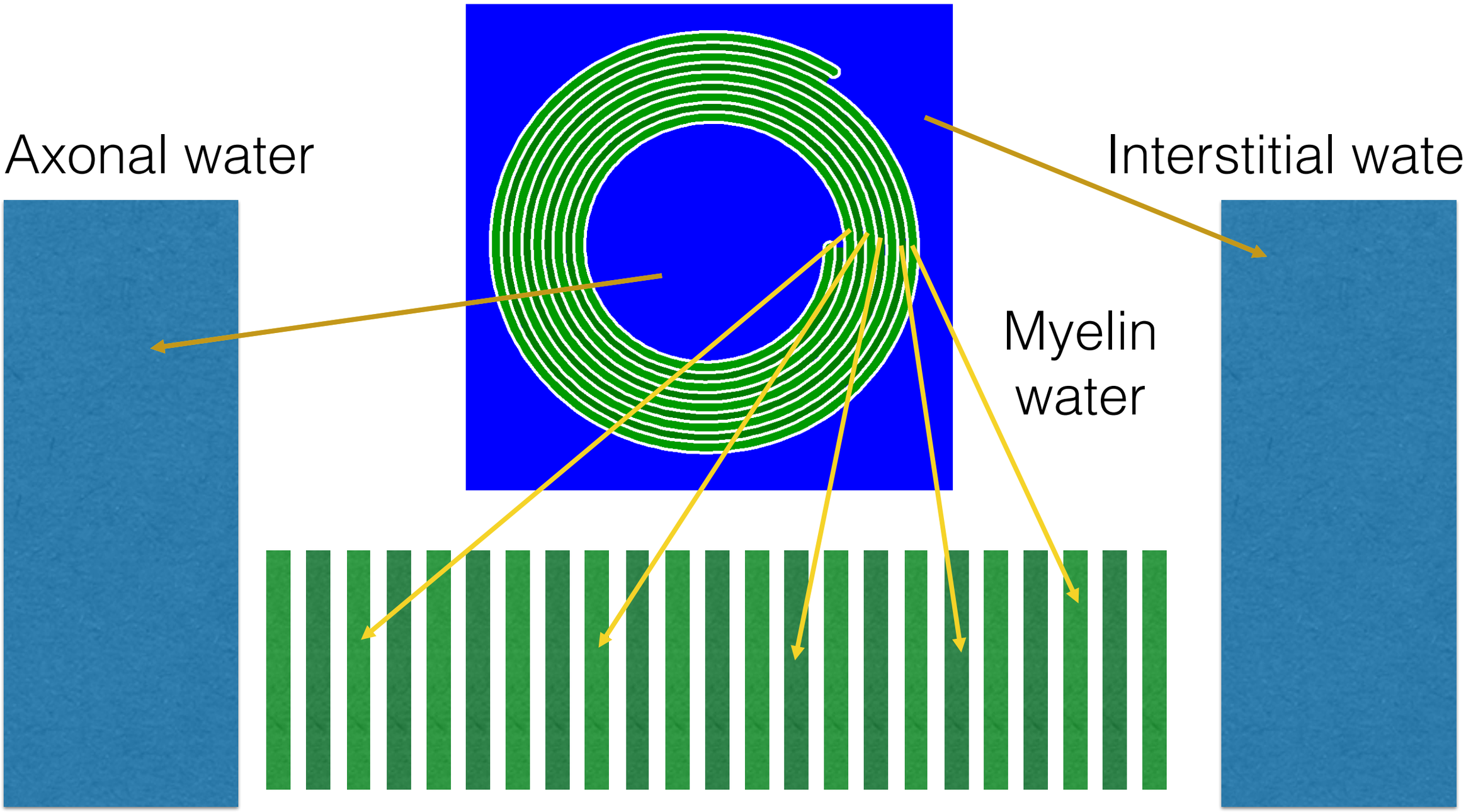


Modeling

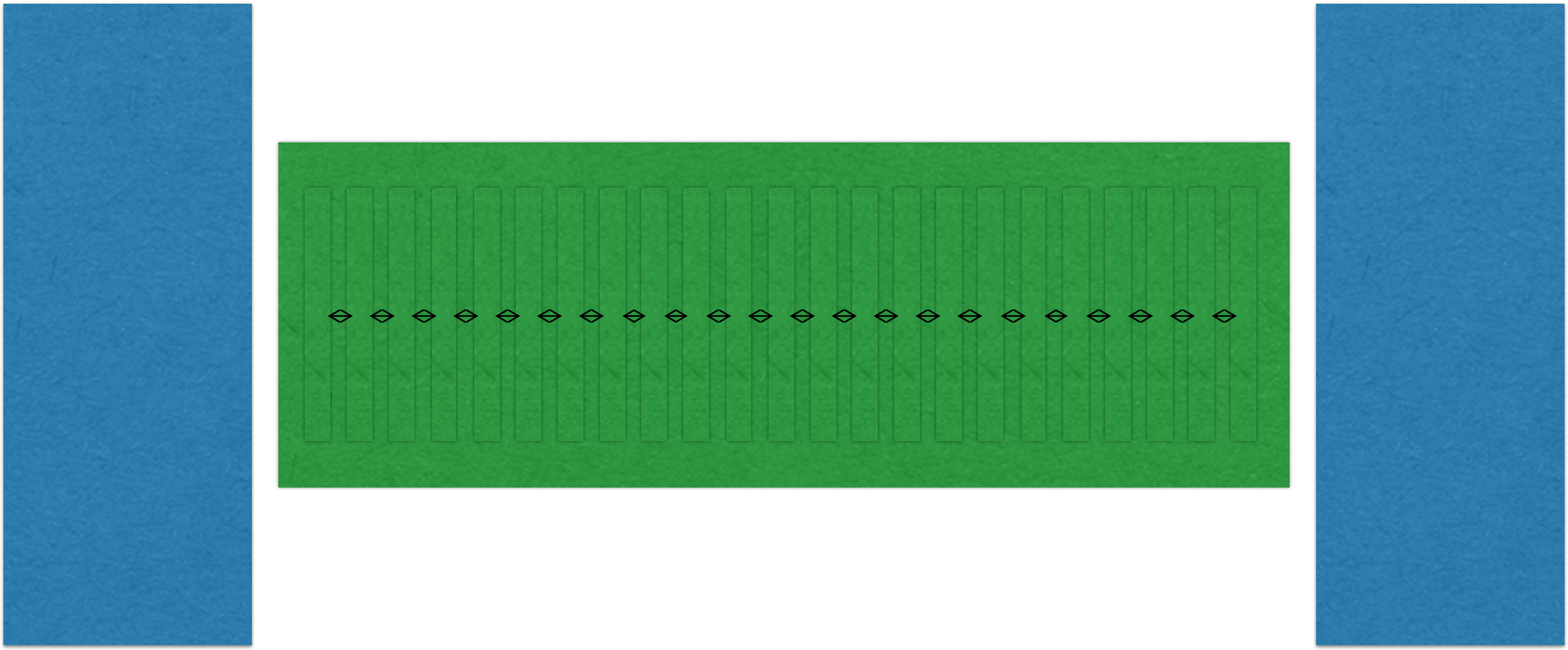




Many compartments



Simplification



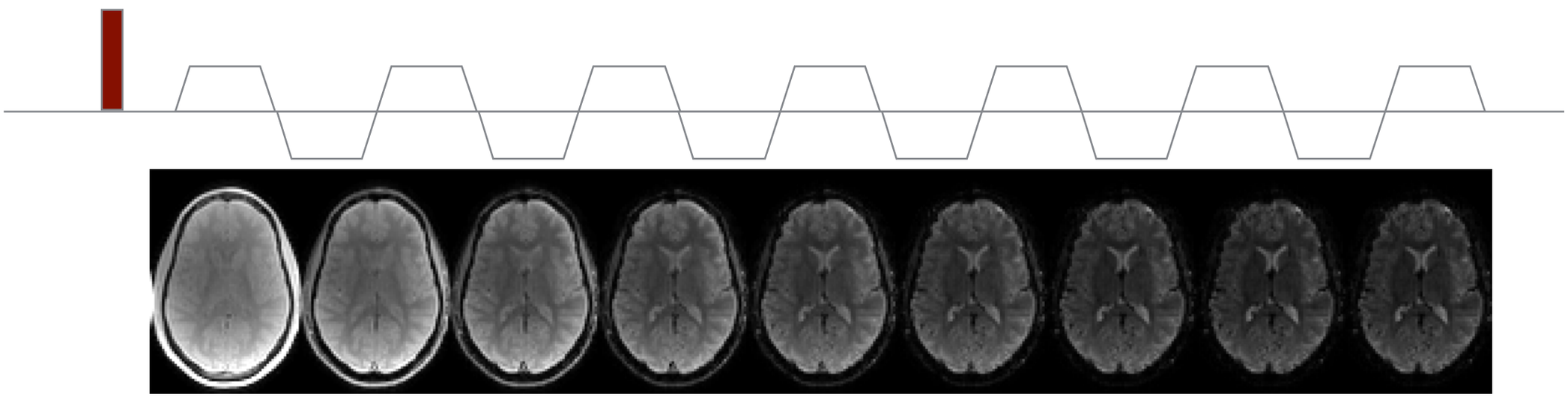
Three compartment model

Axonal water

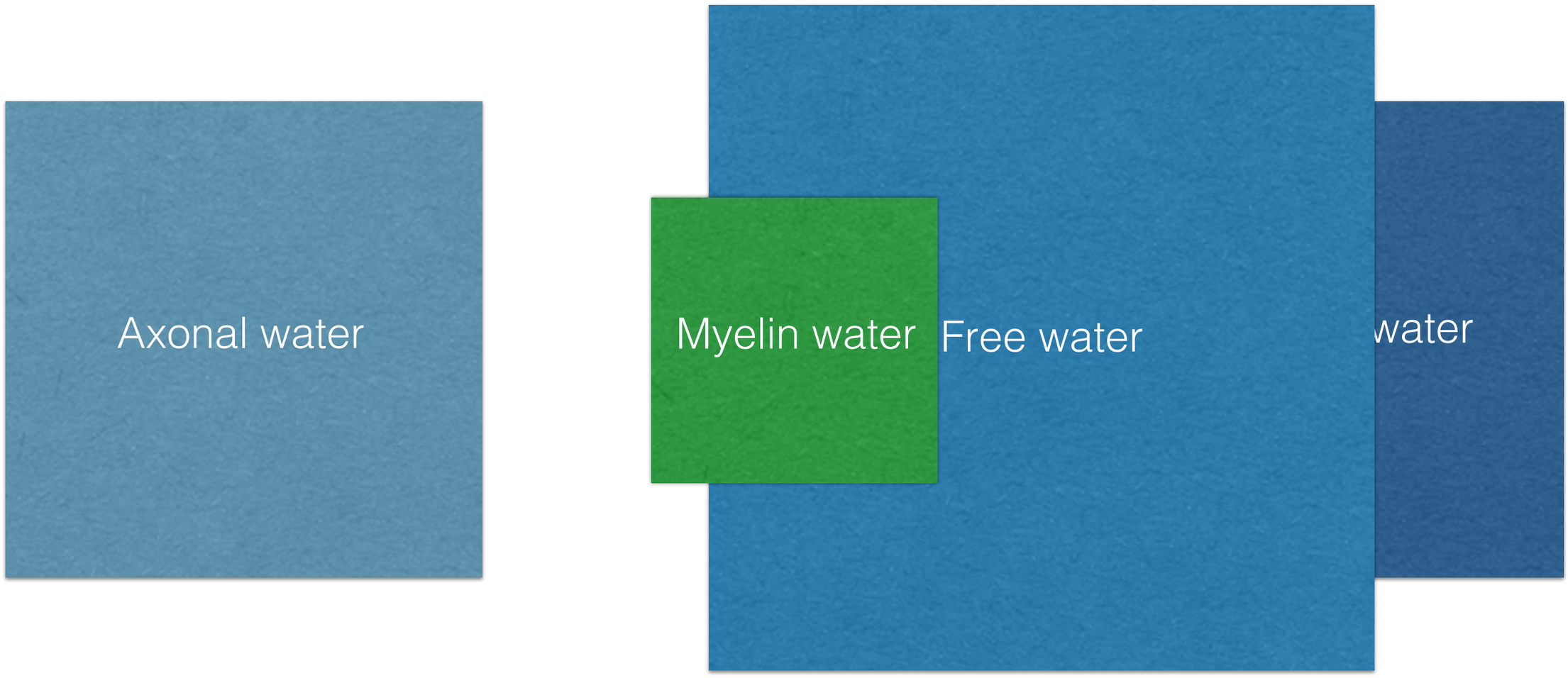
Myelin water

Interstitial water

$$S = A_1 e^{-tR^*_{2,1} + i\omega_1 t} + A_2 e^{-tR^*_{2,2} + i\omega_2 t} + A_3 e^{-tR^*_{3,2} + i\omega_3 t}$$

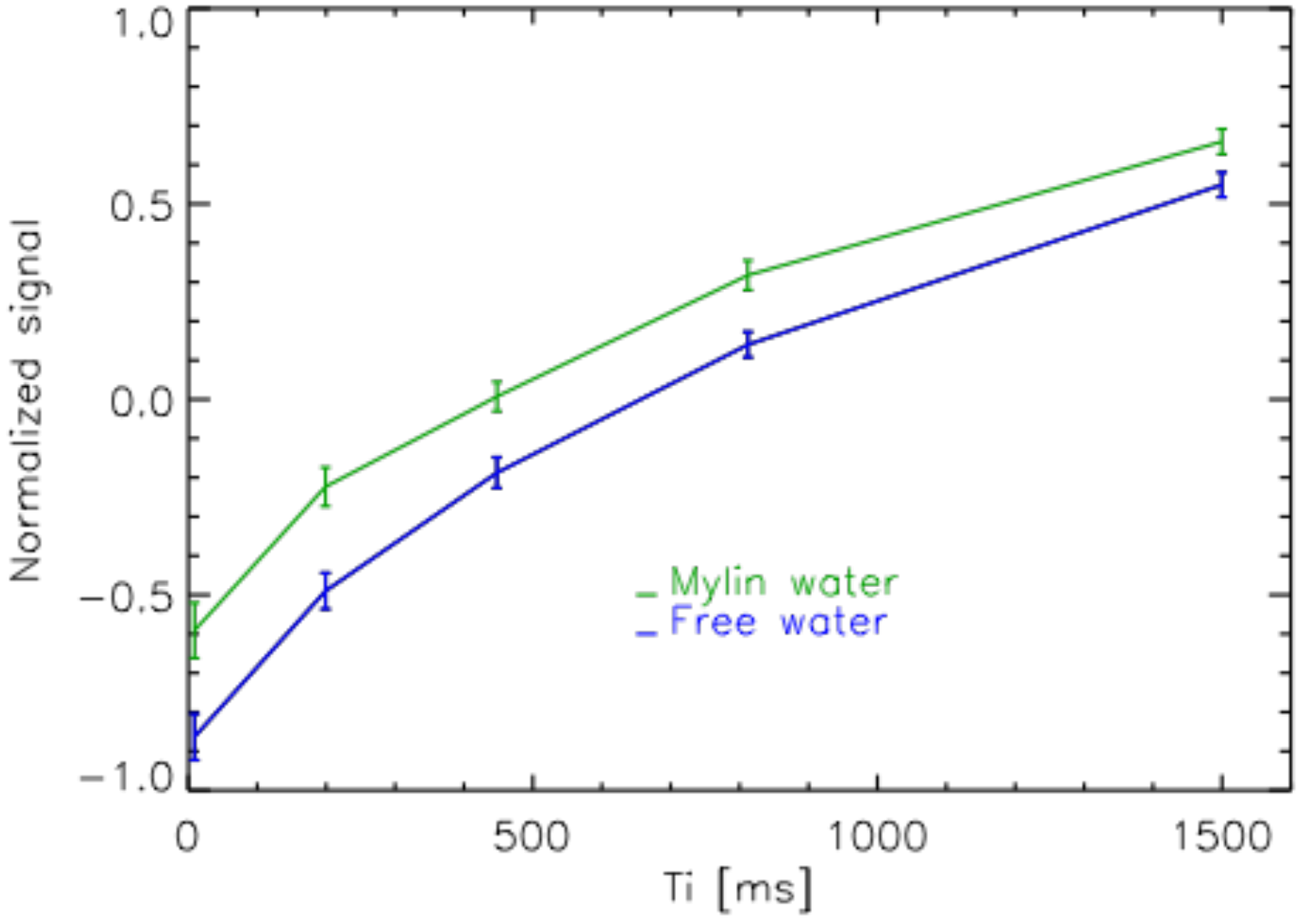


Simplification (II)



Experiment

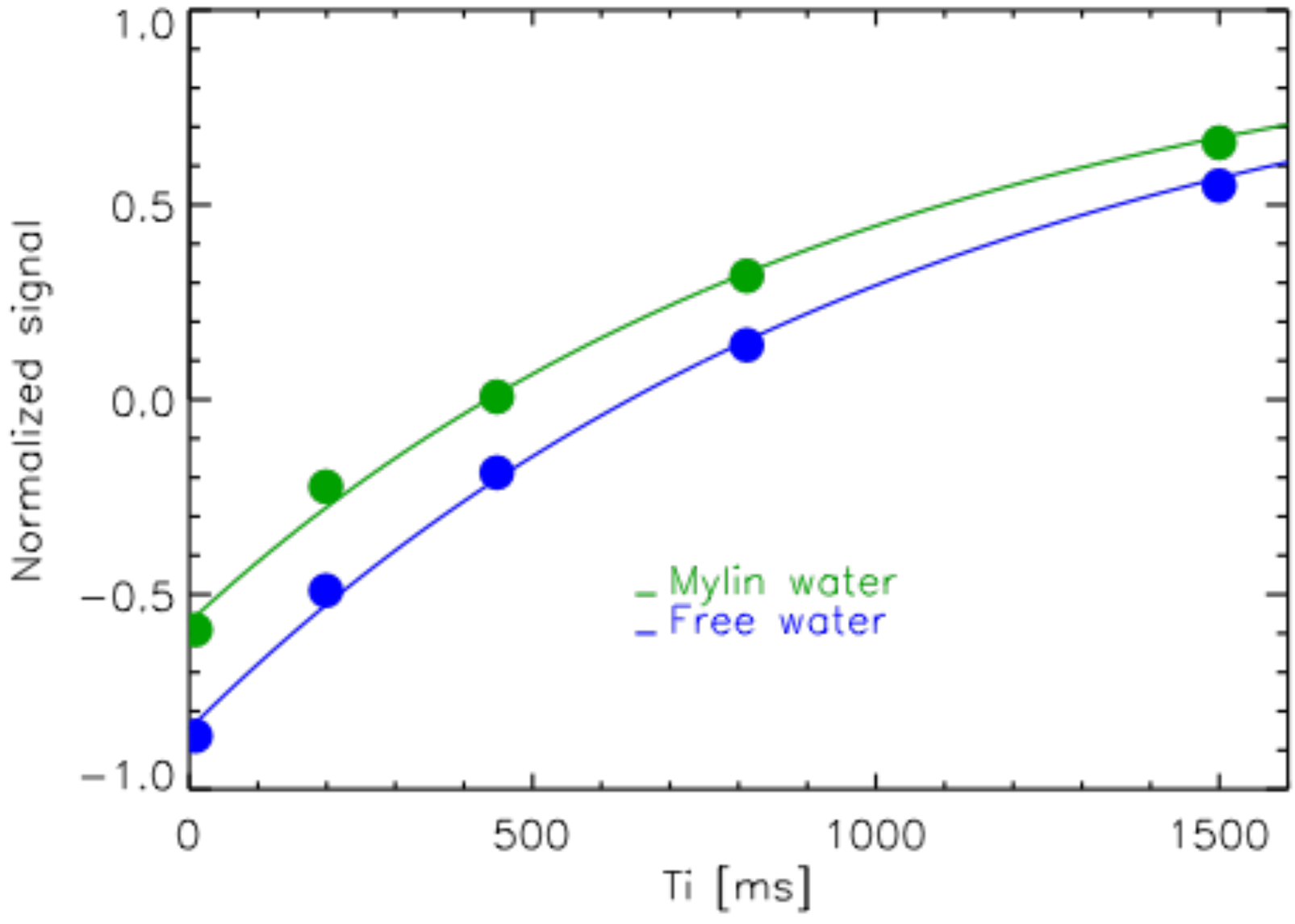
- 7T
- Adiabatic Inversion (10ms, 800Hz)
- Average over ROI in splenium of corpus callosum
- MGRE, 80 echoes, 51 positive,
- Navigation
- Full model fit on reference w/o inversion
- Linear fit on inversion data
- Average and SD over 22 subjects



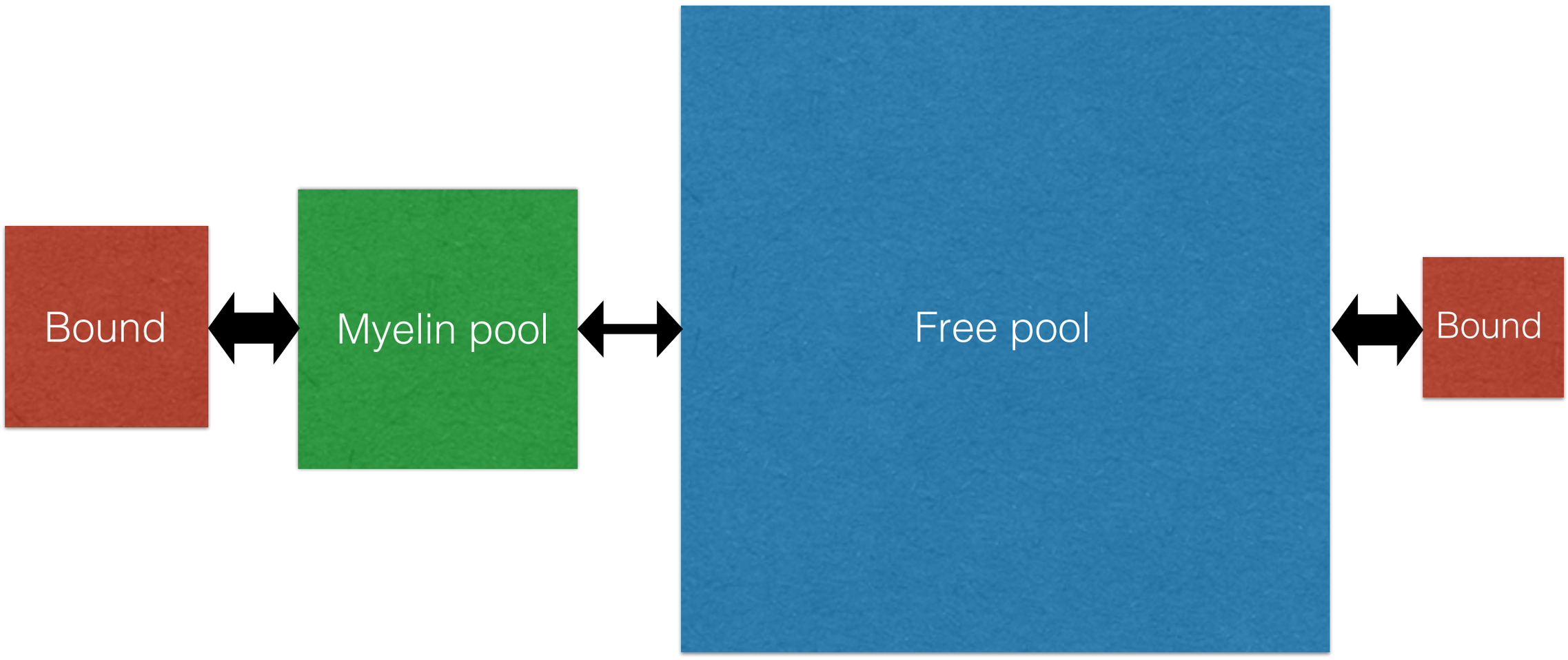
Results: T_1 model

- T_1:
  - 950ms myelin water
  -1050ms free water

- Inversion efficiency:
  - 61% myelin water
  - 92% free water

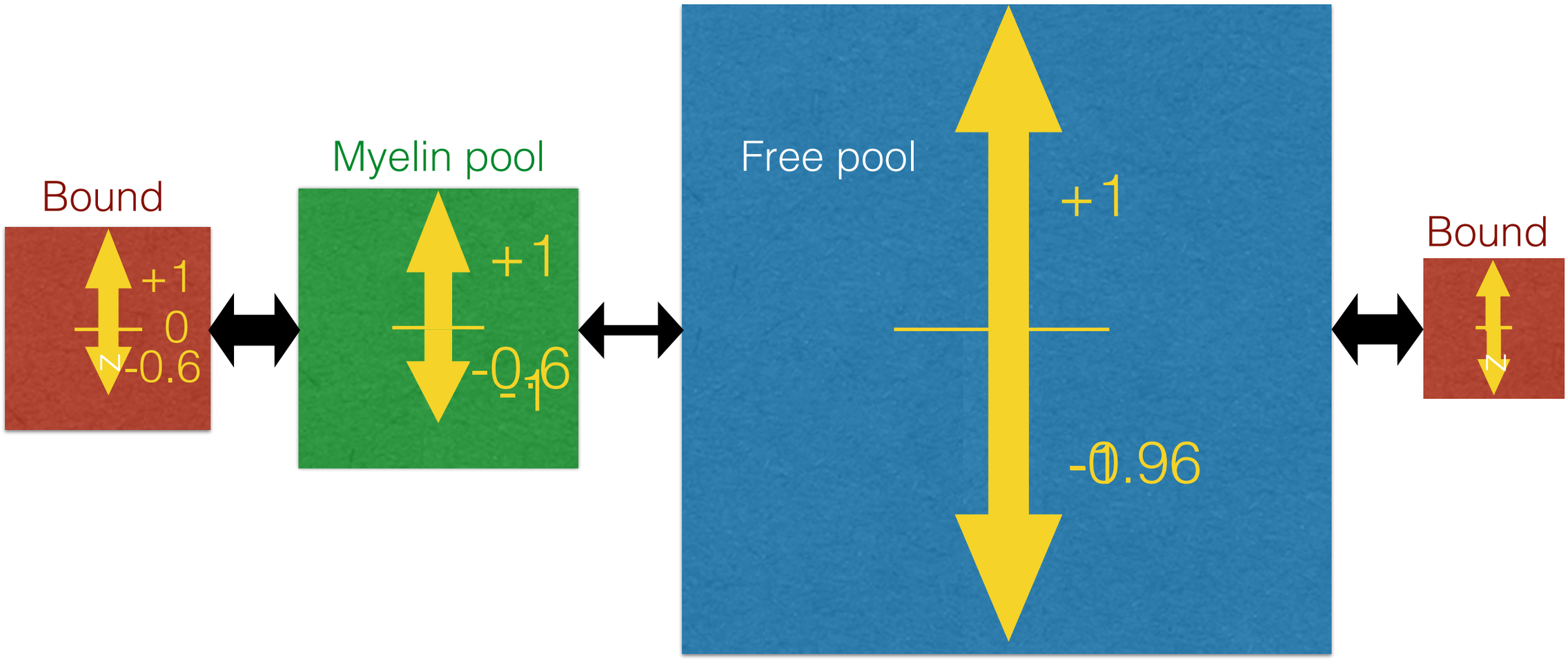


Four compartment model[e-g)]

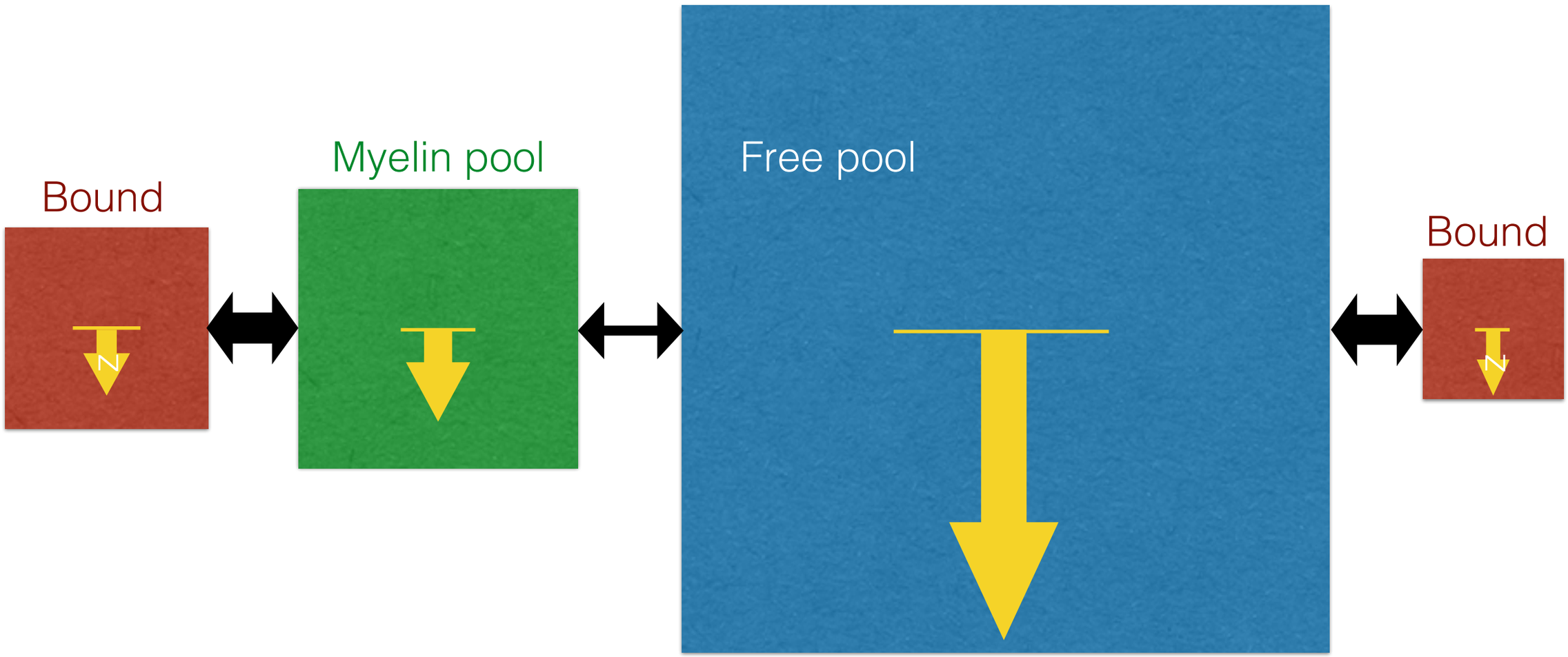


e) Stanisz et.al., MRM, 42, 1999, 1128
f) I.R. Levesque & G.B. Pike, MRM 62, 2009, 1487
g) Kalantari et.al. MRM 66, 2011, 1142

Exchange effects: inversion

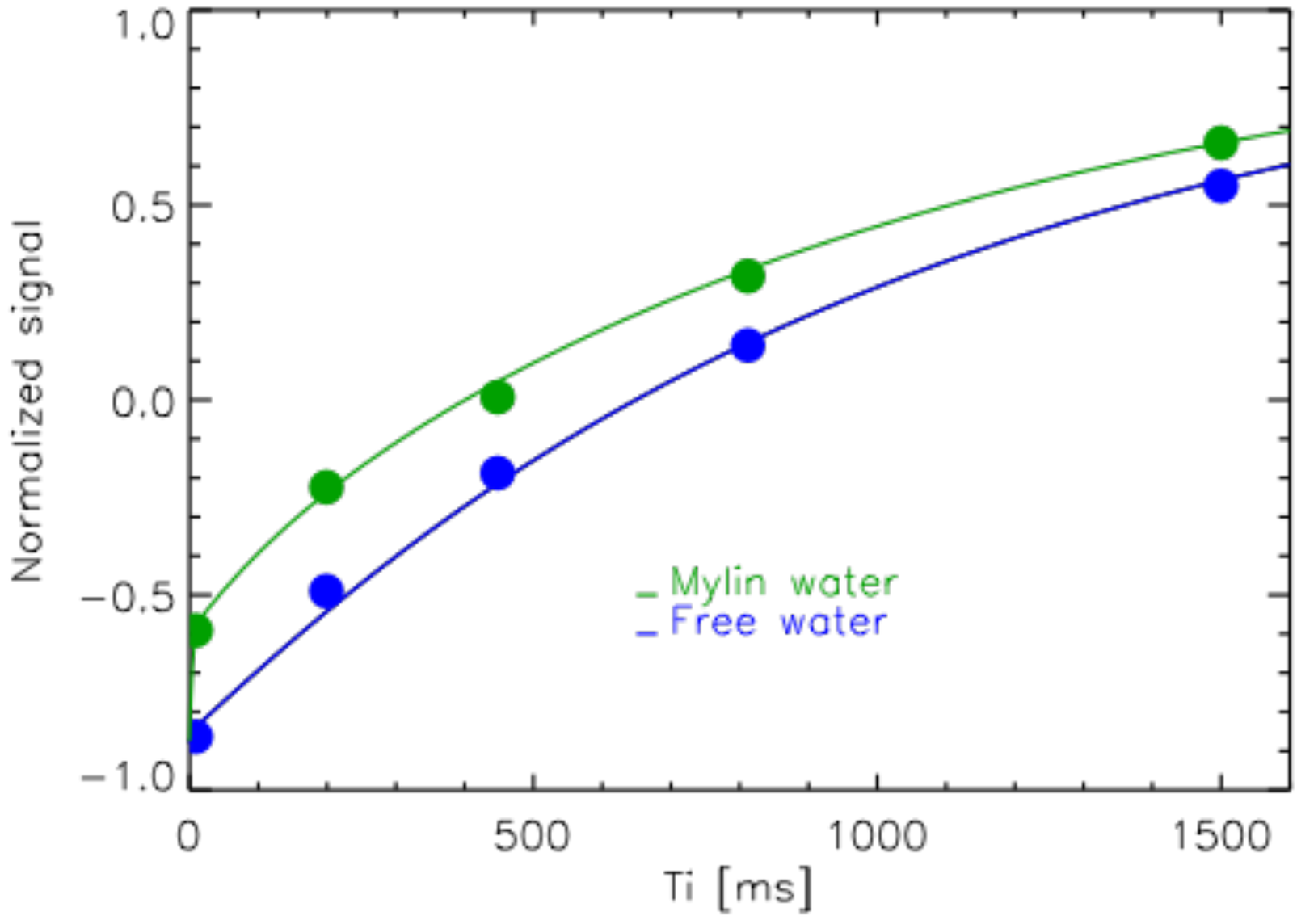


Exchange effects: recovery

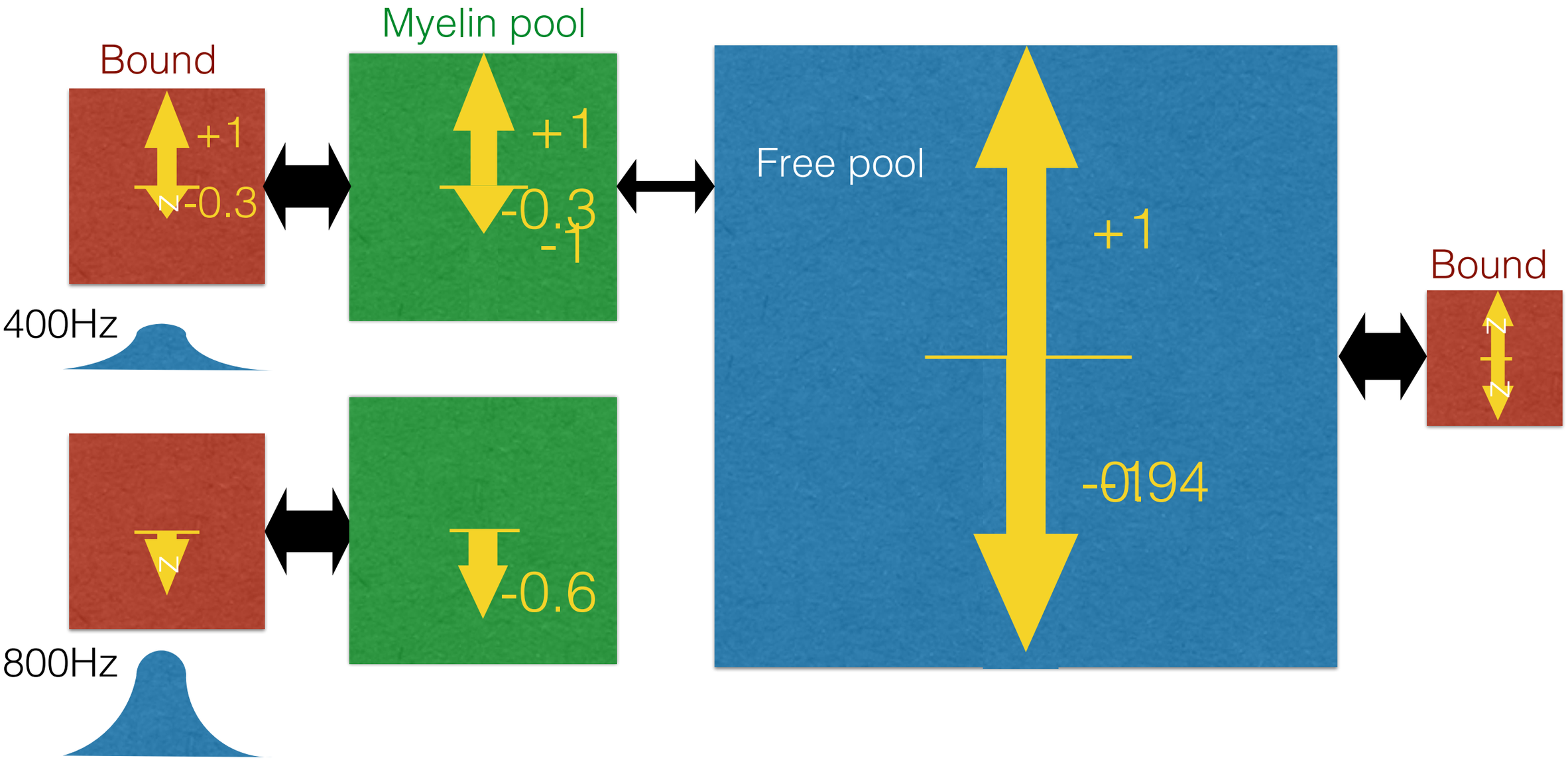


Results: exchange model

- Bound pool (1):
  - volume 7%
  - T_1 180ms
  - τ (b↔m) < 5ms, **fast**
- Myelin pool:
  - **volume 14%**
  - T_1 1.8s
  - τ (m↔f) ≃ 120ms, **slow for RF, fast for T_1**
- Free water
  - **volume 76%**
  - T_1 1.8s
- Bound pool (2):
  - volume 3%
  - T_1 180ms
  - τ (b↔f) < 5ms, fast

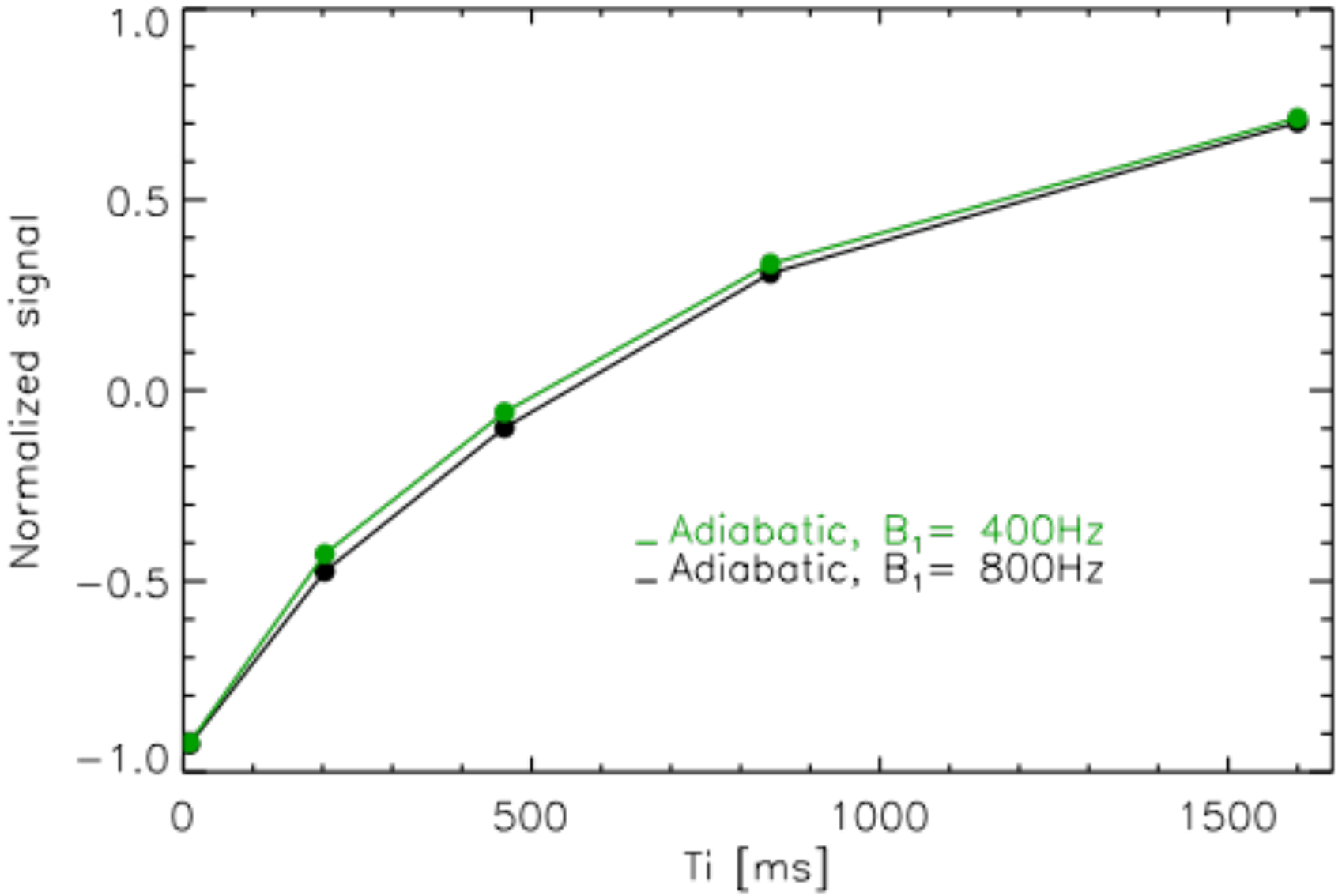


Prediction: B_1 matters



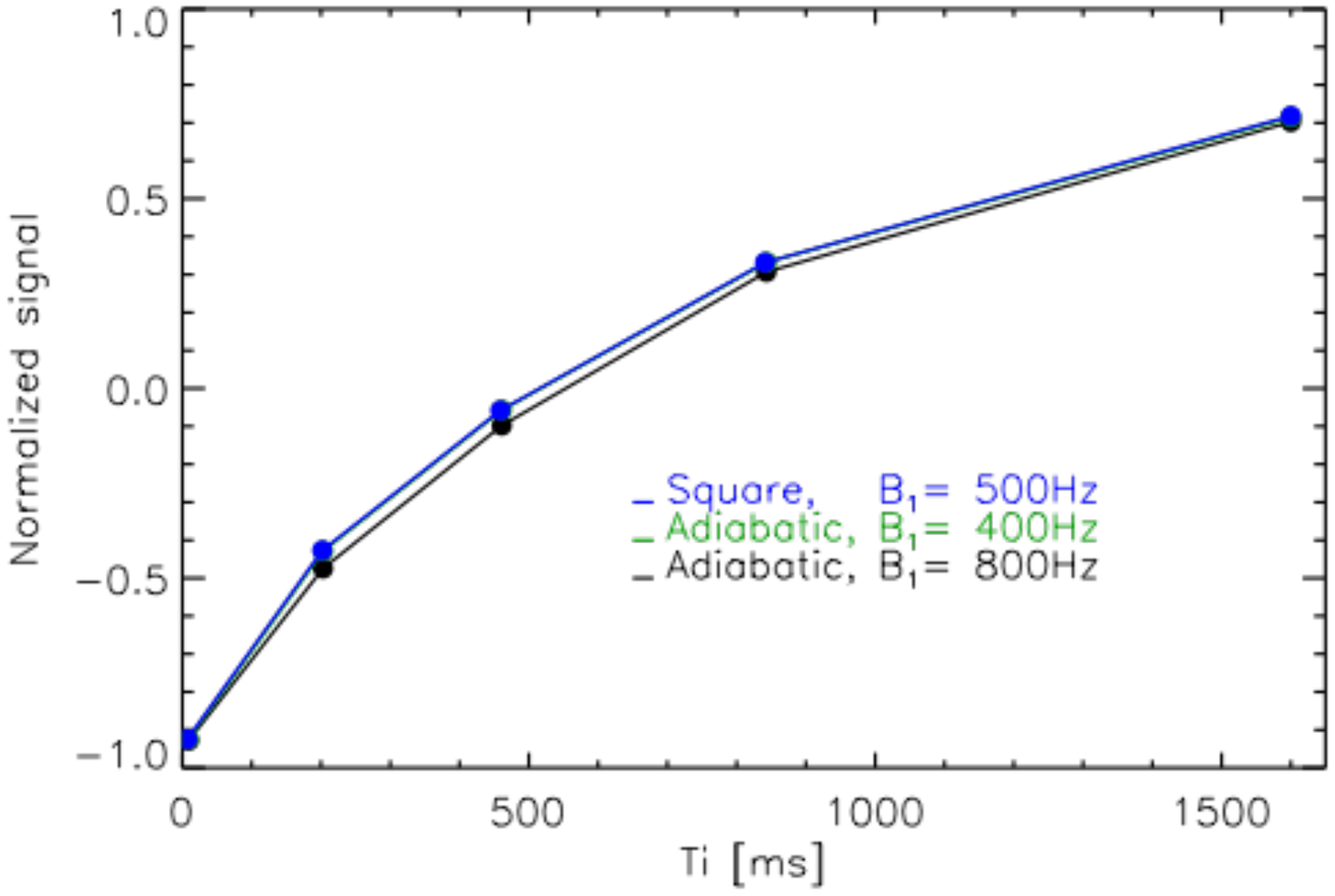
Bonus result

- 3T
- Adiabatic Inversion (5ms)
- Average over ROI in splenium of corpus callosum
- EPI, TE 25ms (=free water only)
- Normalized to reference w/o inversion
- One subject



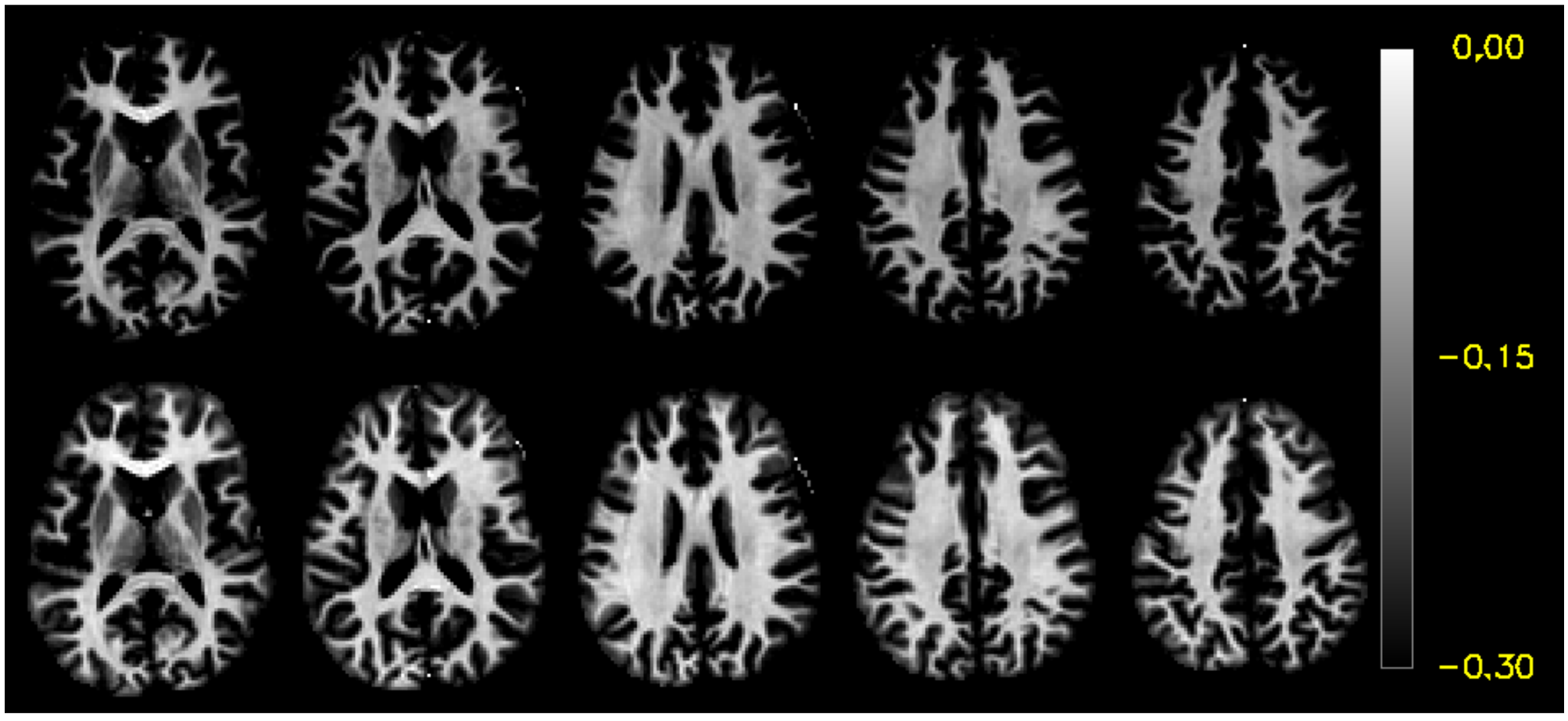
Bonus result

- 3T
- Adiabatic Inversion (5ms)/ Square 180°
- Average over ROI in splenium of corpus callosum
- EPI, TE 25ms (=free water only)
- Normalized to reference w/o inversion
- One subject



Bonus result

B_1= 800Hz



B_1= 400Hz

T_i= 476ms

Normalized amplitude

Discussion

- Myelin water exchange with free water fast compared to T_1, confirming previous findings

- Saturation effects of bound protons influence T_1 measurements, complicating T_1 based measurement of myelin water

- Effects of bound protons mediated by myelin water, limiting the exchange to the free water

- Bound proton relaxation likely dominant contribution to WM/GM contrast

for more results on saturation and myelin water imaging: see ISMRM 2014 #3166 and # 3332