UMC Utrecht

Accelerating the MRI exam: MR-STAT

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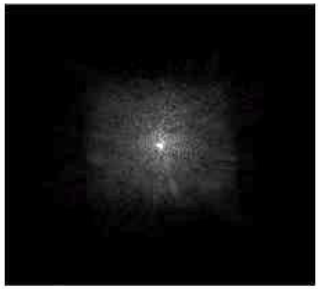
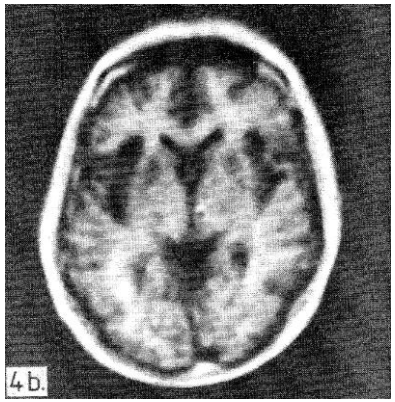
MRI's invention and adoptation: a success story

- 2003 Nobel prize for key idea that enabled birth of MRI in 1970s.
  - *Design MRI hardware and acquisition such that reconstruction can be performed by a simple fast Fourier transform.*

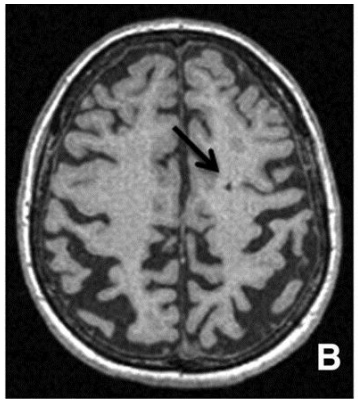
Acquired signals
In Fourier space



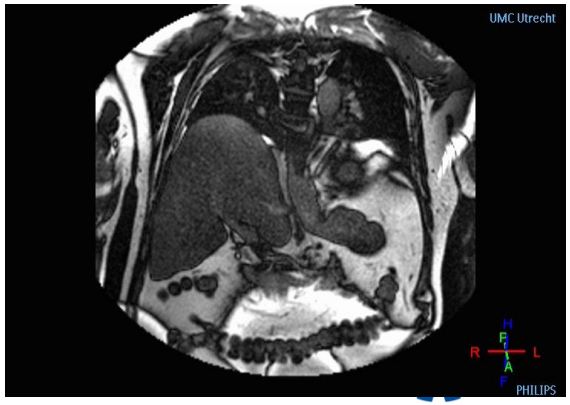
Reconstructed image
In image space



1981



2013->

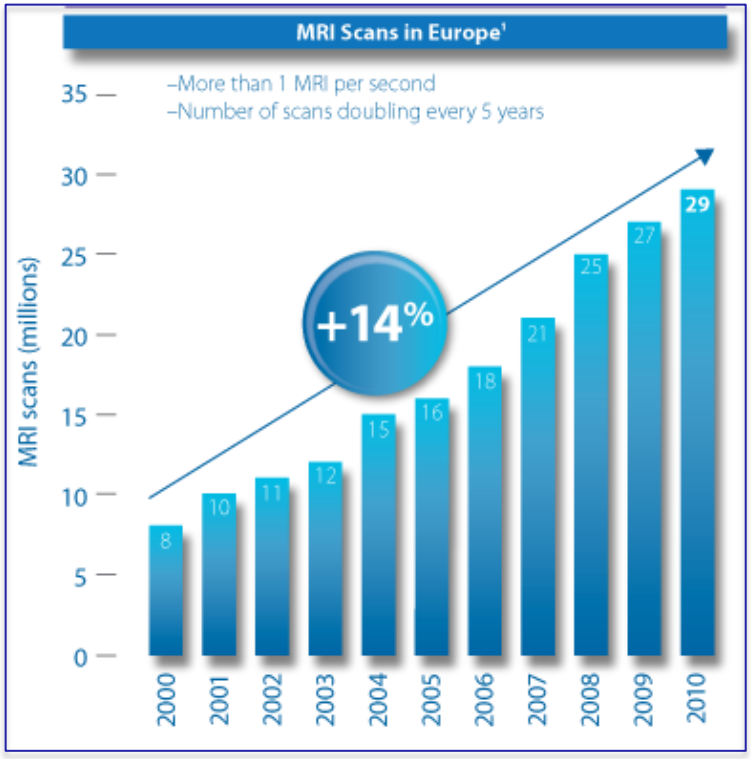


Two main drawbacks of current MRI practice

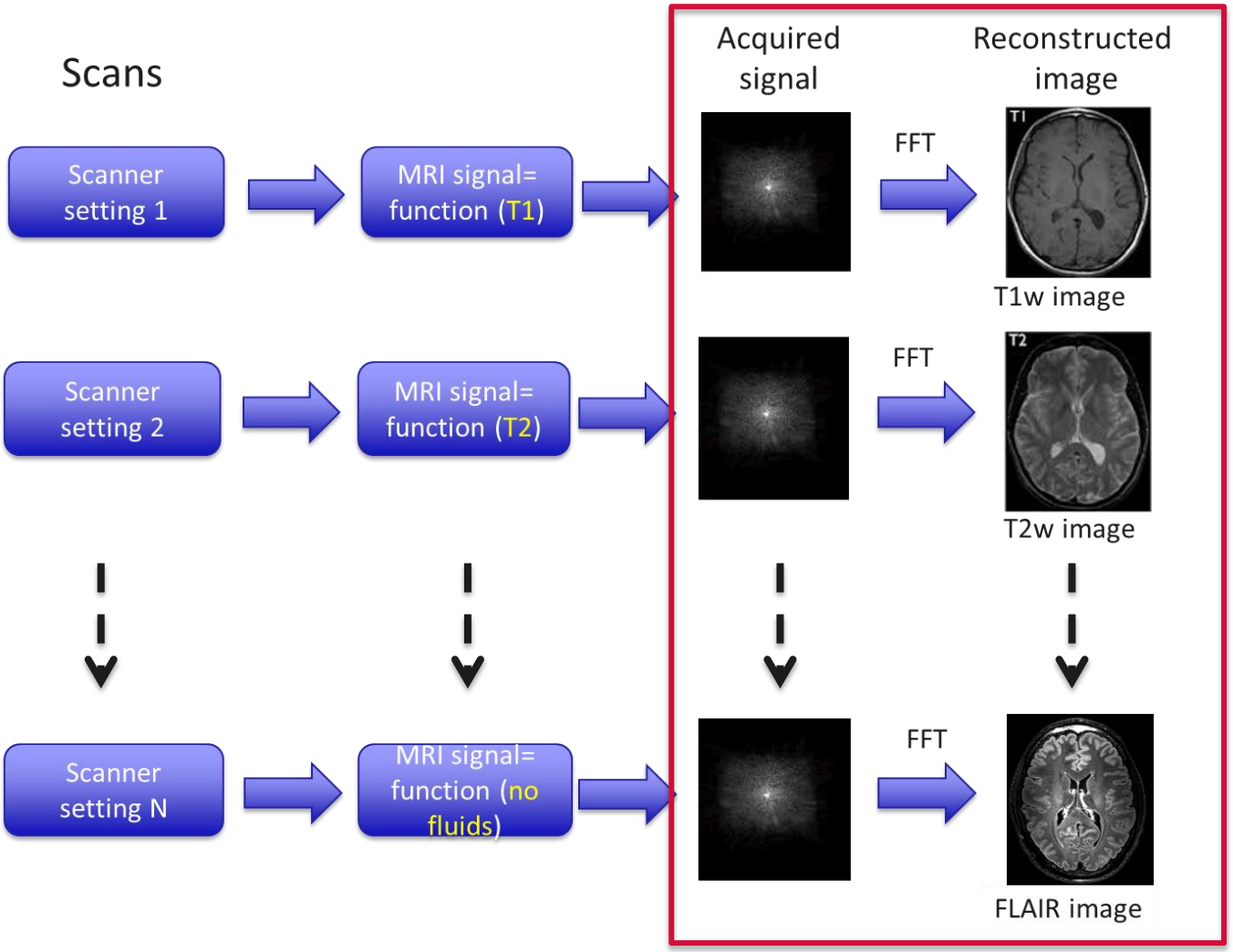
1. MRI is not **quantitative**

2. MRI exam **takes long**
   - A typical MR exam ***was*** and ***is*** 30-45 min.
   - Makes MRI **costly**.

- **Strong demand for MRI**
  - 30 Million MRI exams annually in Europe
  - number of exams doubles every 5 years
  - Thus double number of systems per 5 years?

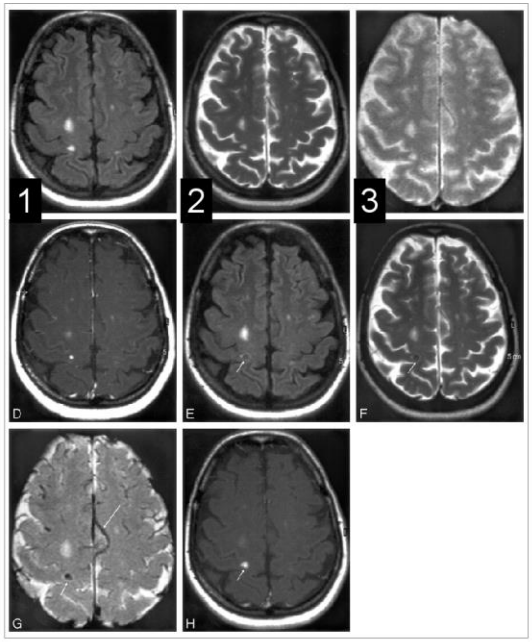


Why is MRI slow?



30-45 minutes

The Synthetic MRI approach

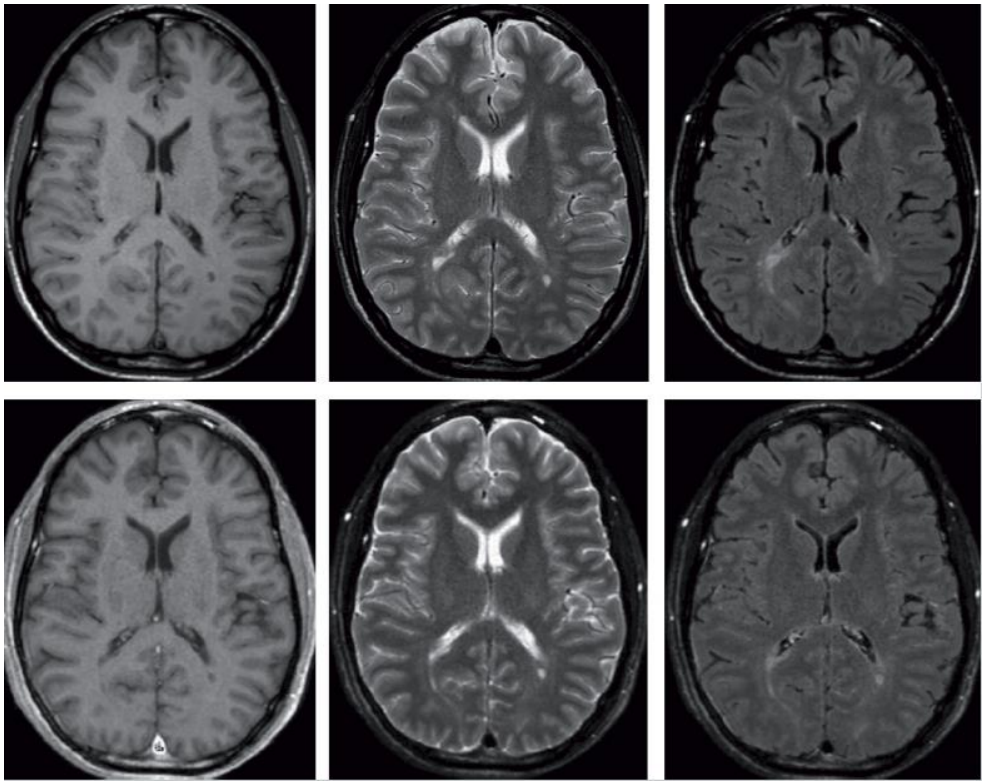


1. One scan

Example of Synthetic MRI

1.5 T conventional scans
15 min

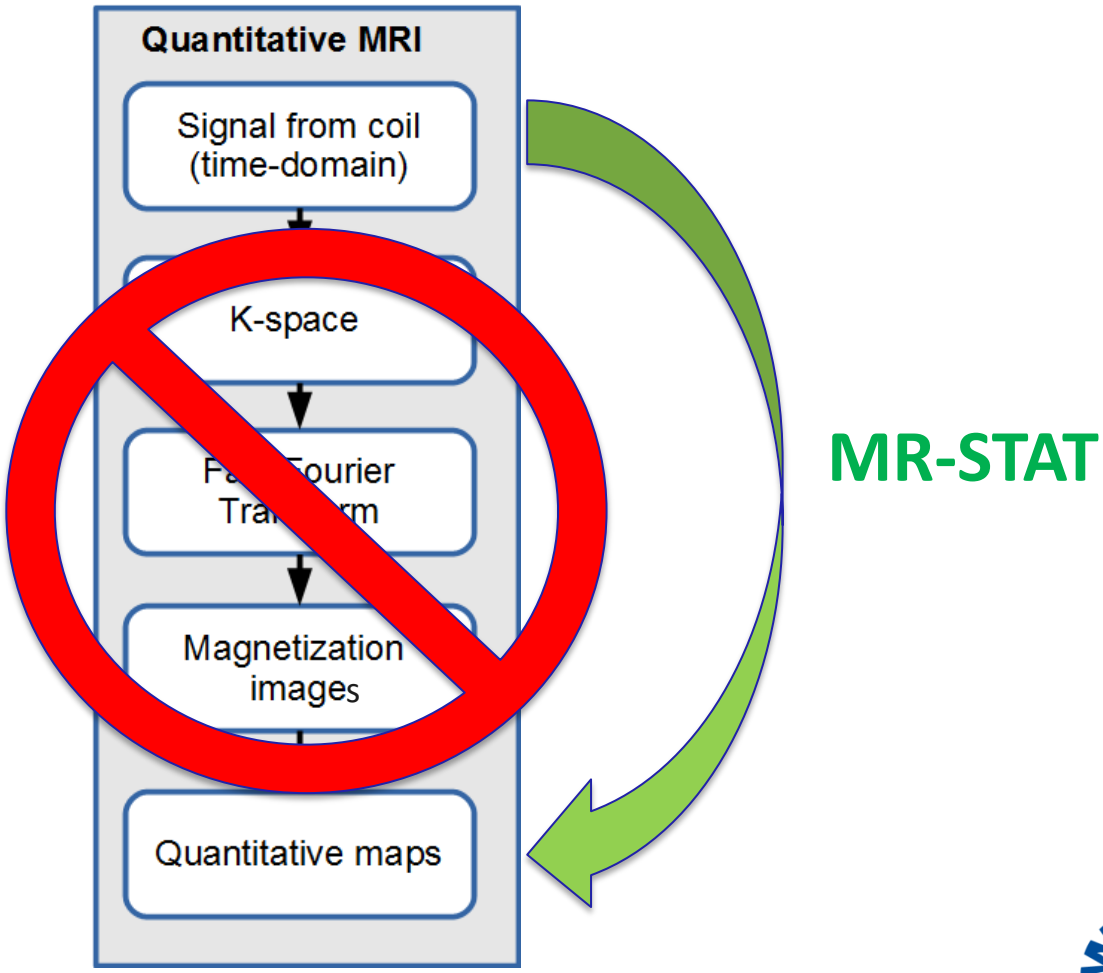
1.5 T "SyMRI" scan
6 min



T1W T2W T2 FLAIR

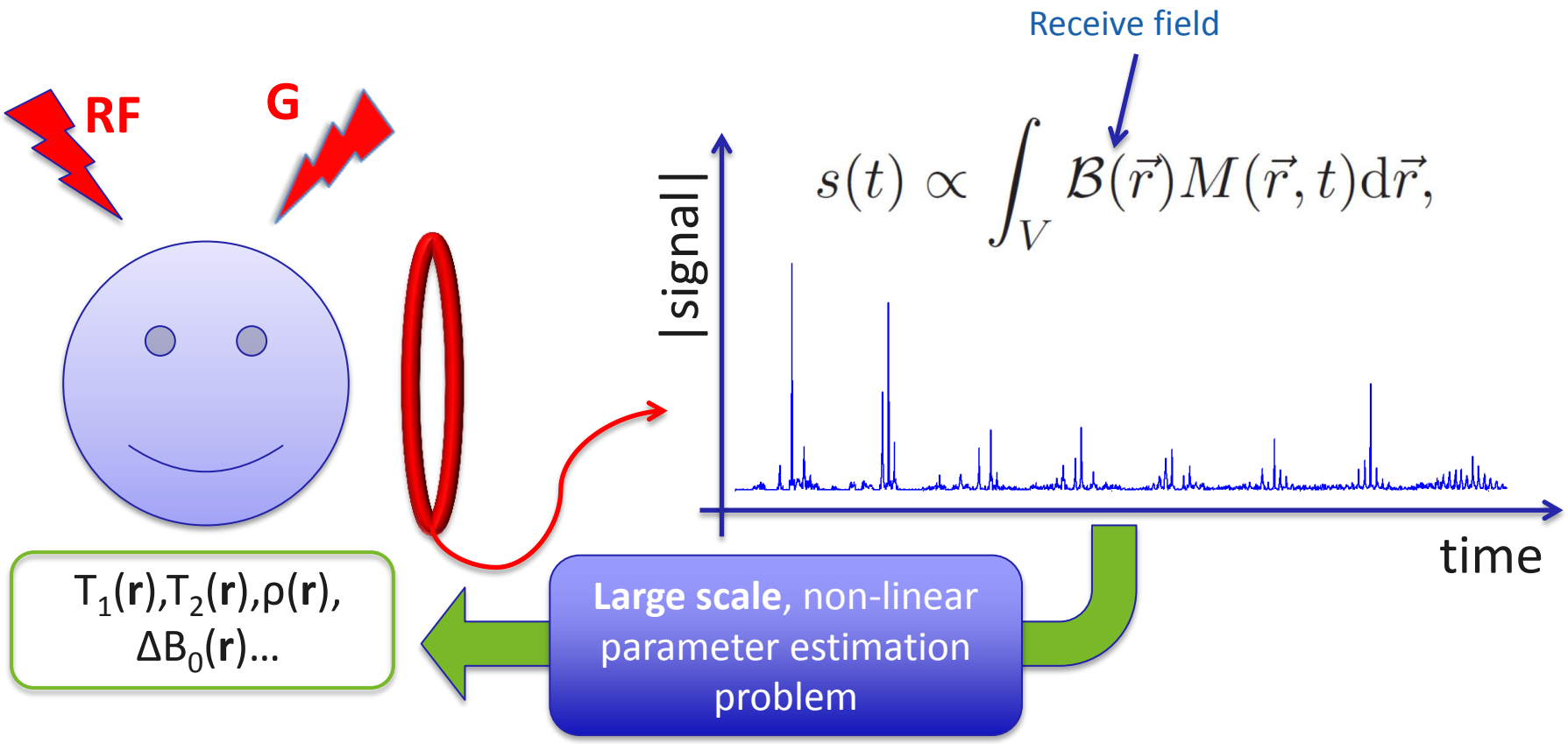
http://www.syntheticmr.com

MR-STAT*: quantitative MRI directly from time domain data



*Alessandro Sbrizzi *et al*, MRI 2018, *In press*

Time-domain approach*



MR signal(t) = non-linear ***function***(T1(r), T2(r), PD(r), *scanner settings*)

*Alessandro Sbrizzi *et al*, MRI 2018, *In press*

MR-STAT reconstruction

$$\alpha \equiv \mathcal{B}M_0 \quad \text{and} \quad \vec{\beta} \equiv (T_1, T_2, B_1^+, \Delta B_0)$$

Time-data signal model

$$\begin{aligned}
(\alpha^*, \vec{\beta}^*) &= \arg\min_{\alpha,\vec{\beta}} \int_{t\in\tau} \left| d(t) - s(\alpha, \vec{\beta}, t) \right|^2 \mathrm{d}t, && && \text{(Data consistency)} \\
\text{such that} \quad & s(\alpha, \vec{\beta}, t) = \textstyle\int_V \alpha\, m(\vec{\beta}, t)\mathrm{d}\vec{r}, && t \in \tau && \text{(Faraday's law)} \\
& \tfrac{\mathrm{d}}{\mathrm{d}t}\vec{m} = \Pi\vec{m} + \vec{c} && && \text{(Bloch equation)} \\
& \vec{m}(\vec{\beta}, 0) = \vec{e}_3 && && \text{(Initial condition)} \\
& \vec{\beta} \in \mathbb{B} && && \text{(Physical bounds)}
\end{aligned}$$

Large scale nonlinear inversion

Parallelization/implementation

- 200 CPUs (local HPC center)
- Iterative trust region algorithm
- Julia/C implementation
- Computation time ≈ 1 hour for a 2D slice

Conclusion

*MR-STAT stands for a **generalized tomography** approach to MRI.*

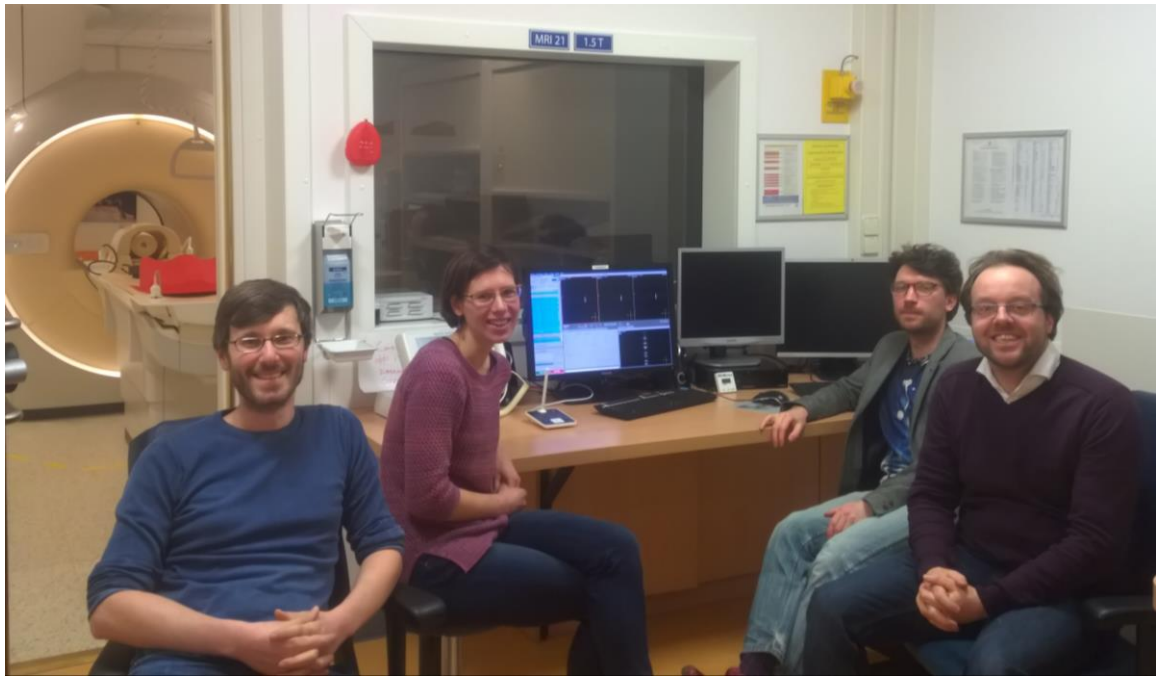
*Reconstructing the **quantitative** MR parameters from*
one acquisition

*The gain is **ultra short** exam times and **quantification:***
*whole MRI exam in **5 minutes***

*The prize is more **challenging reconstructions**.*
algorithms, modelling and computing hardware

Thank you for your interest in the

MR-Spin TomogrAphy in Time-domain project !



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