



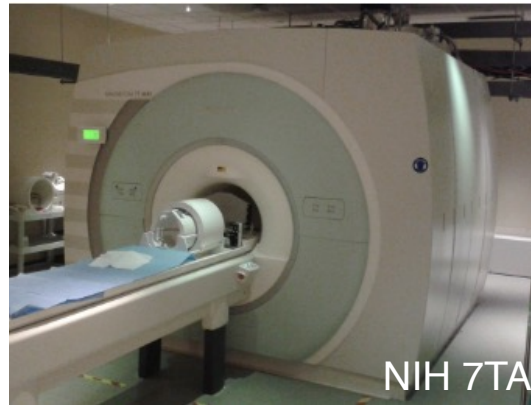
Functional MRI at 7 Tesla

fMRI Summer Course 2026
Thursday, August 13

Tyler Morgan
Functional MRI Core Facility

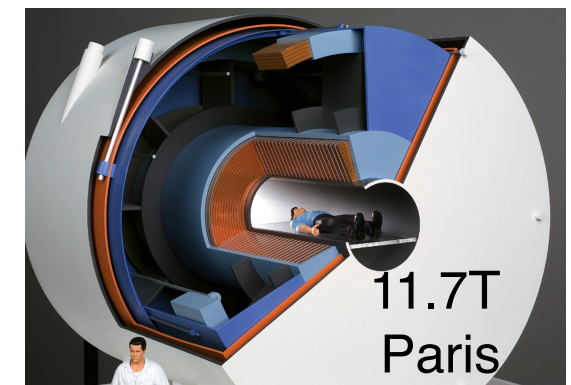
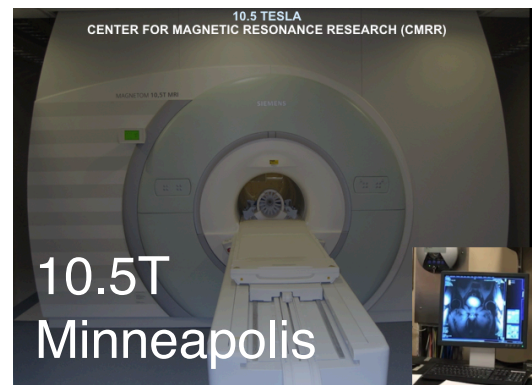
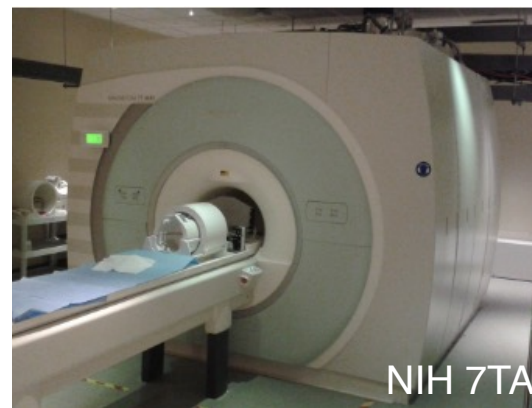


Functional MRI at 7T (or even higher fields!)



Functional MRI at 7T (or even higher fields!)

- We sometimes require higher resolutions or more signal than traditional fMRI can provide
- Typically, that means using an ultra high-field MRI machine
- These can include 7 Tesla, 9.4T, 10.5T, 11.7T, or even 14T!



Ultra high-field MRI around the World

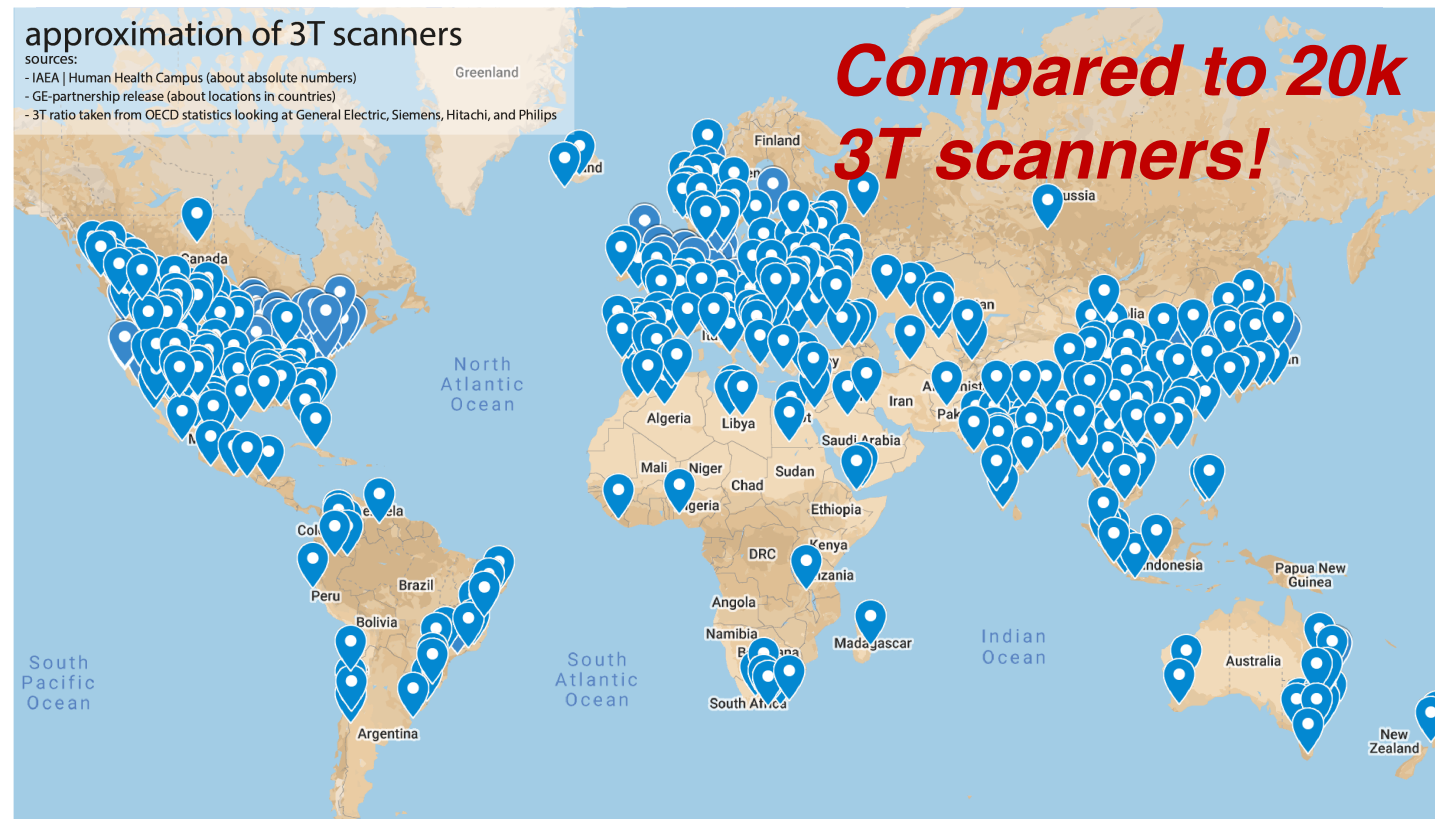
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- Today, there are about 140 of them!



[Layer fMRI Google Map](#)

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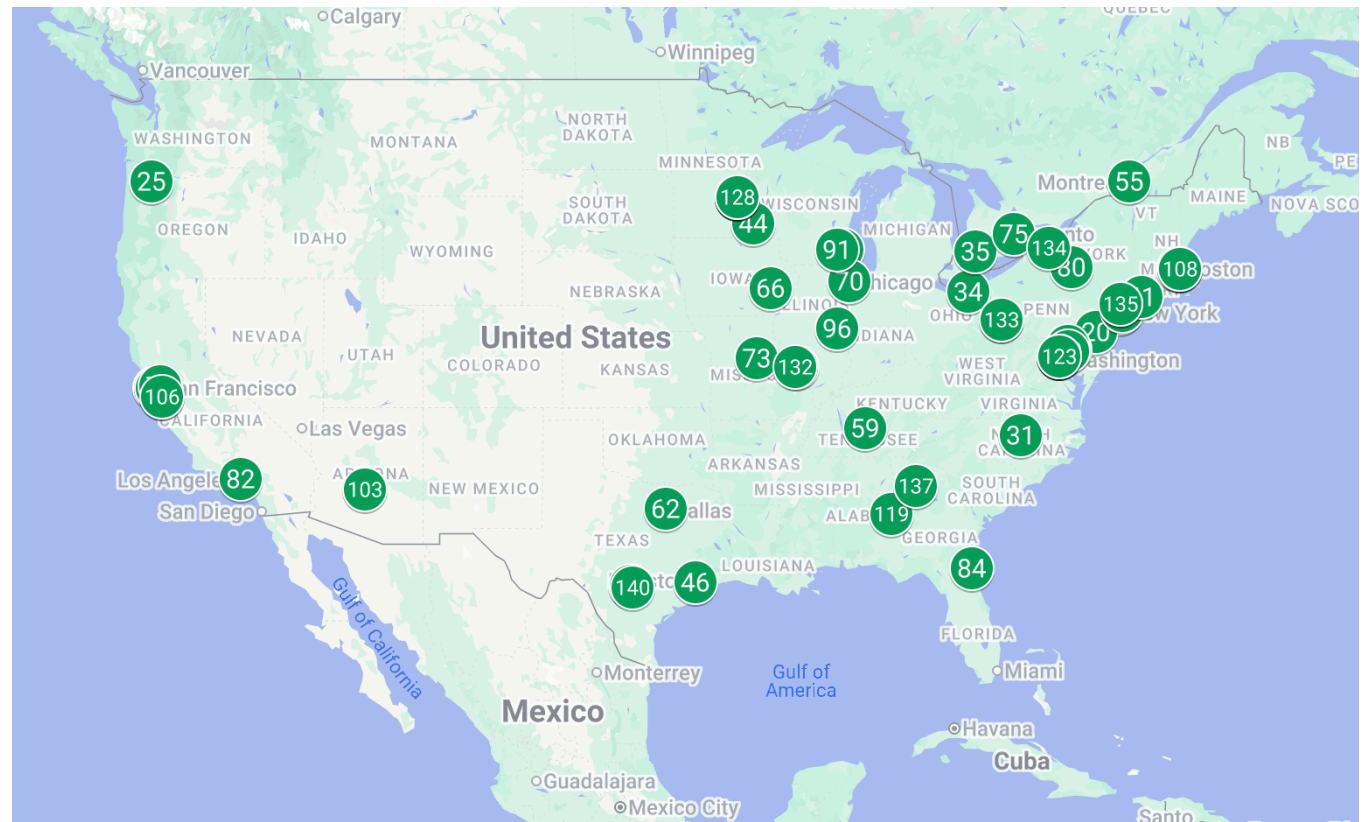
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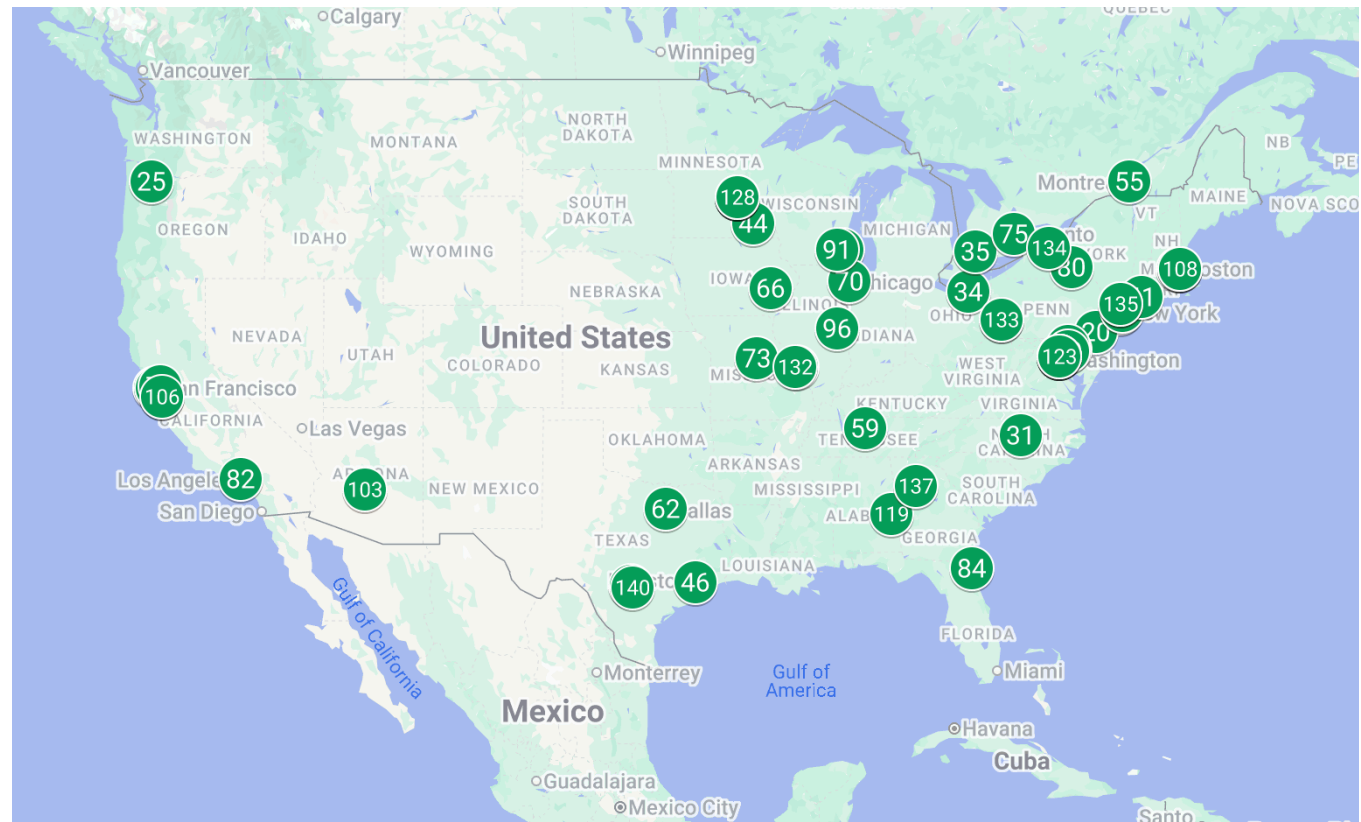
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- Nearly 45 of those are in North America



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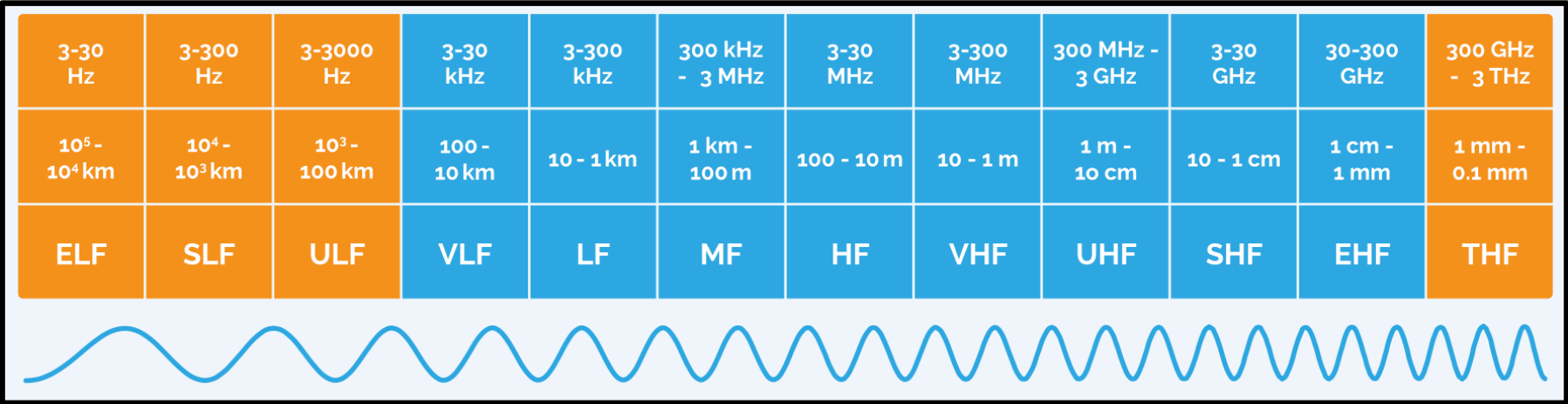
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- Today, there are about 140 of them!
- Nearly 45 of those are in North America
- ***And there are 3 downstairs!***



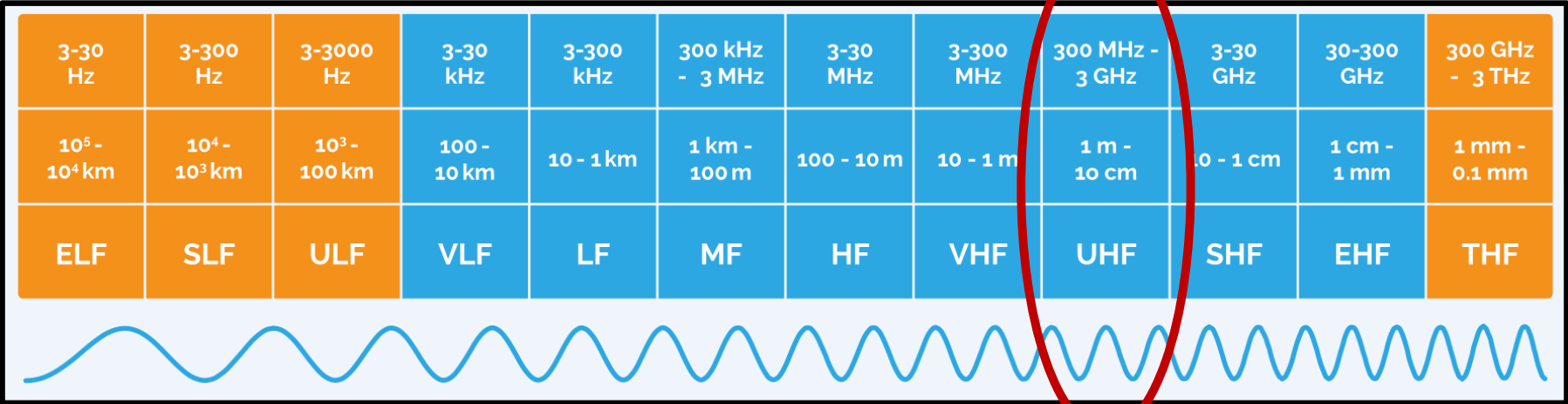
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But why is it called Ultra High-Field MRI?

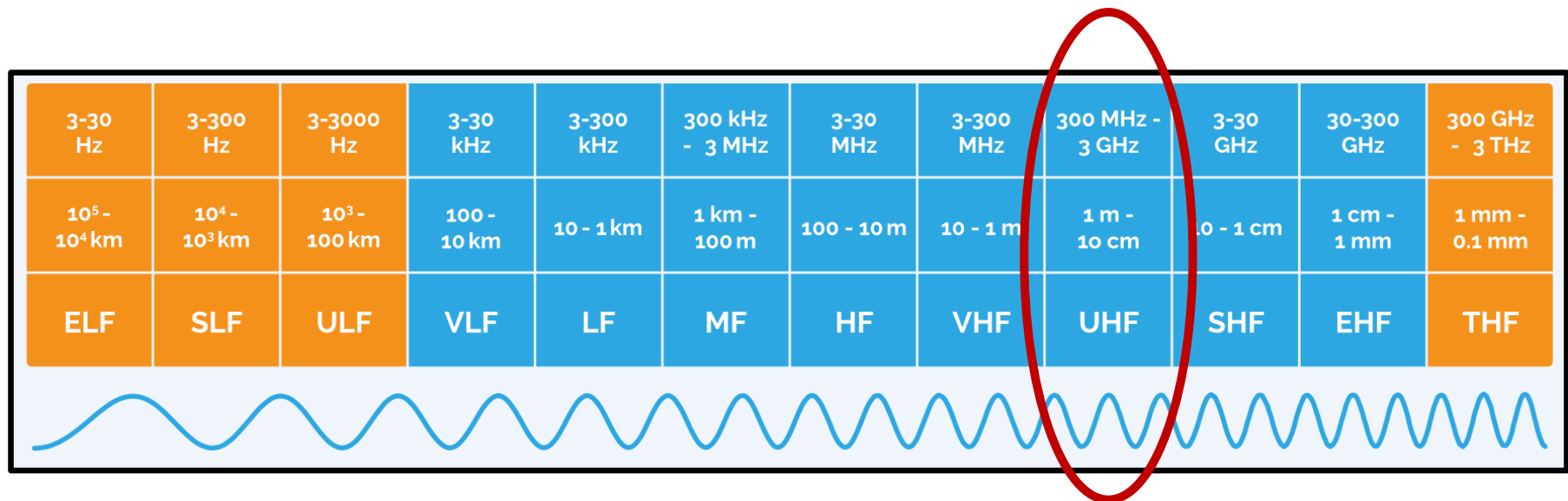
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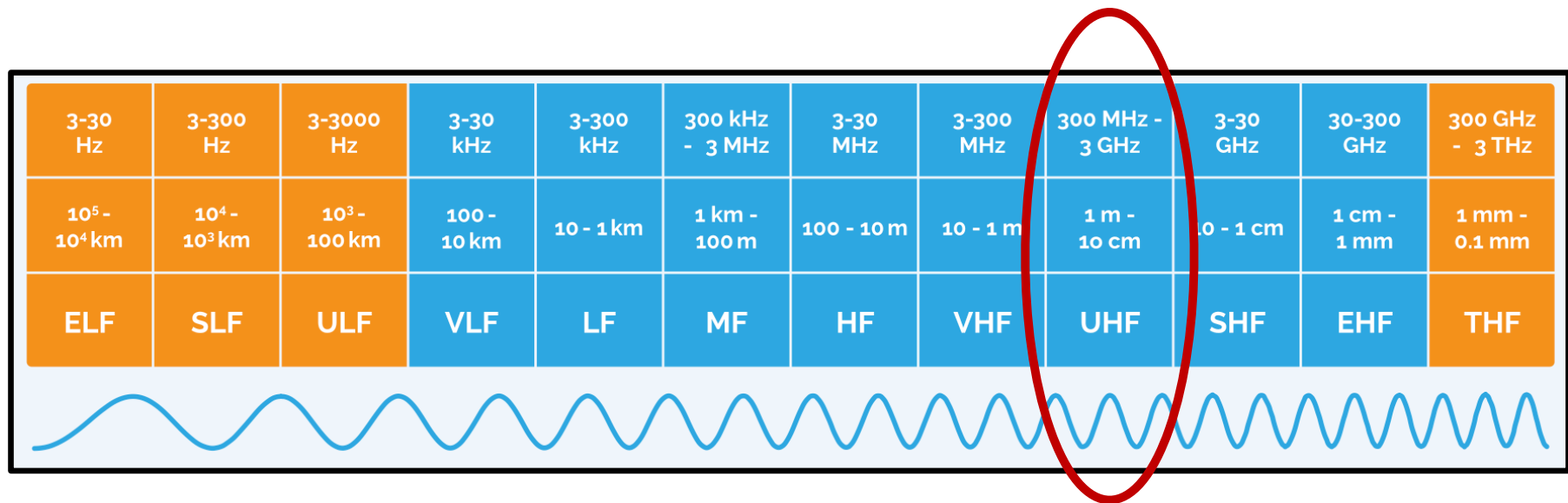


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$$\gamma \times B_0 = 42.57 \text{ MHz/T} \times 7 \text{ T} = 297.99 \text{ MHz}$$

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Close enough... 😊

Why Do People Use 7T?

Olaf Dietrich blog (https://dtrx.de/od/mmm/mmm_20180222.html)

Why Do People Use 7T?

- So we go to higher field strengths (B_0), but why?
- The simple explanation is:

***Signal increases with
field strength!***

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Signal Strength
(Frequency & Magnetization)

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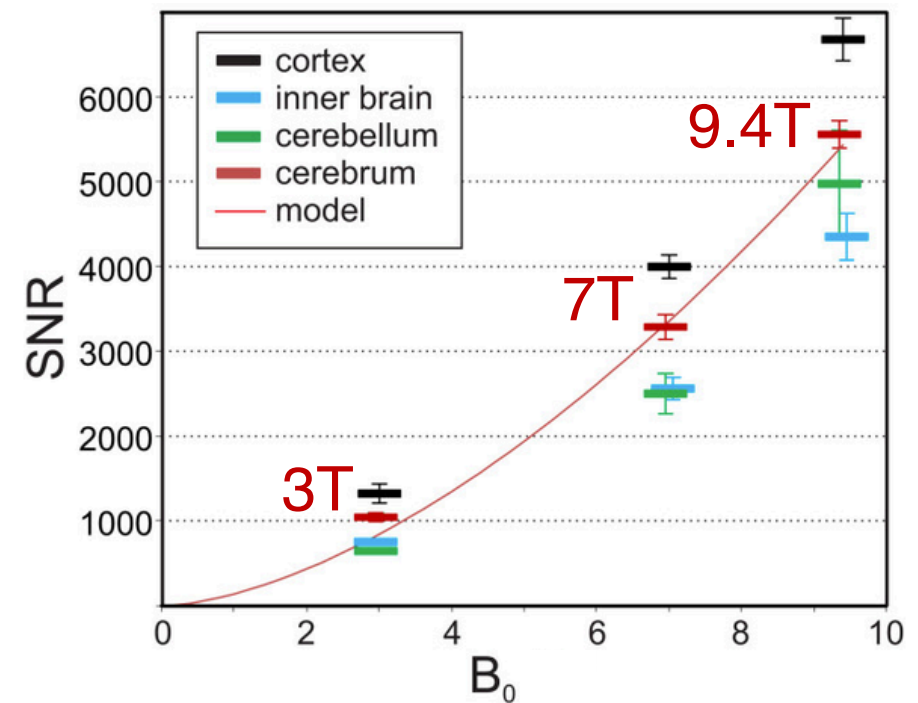
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Signal Strength
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Accounting for
thermal noise,
coil quality and
sample conductivity

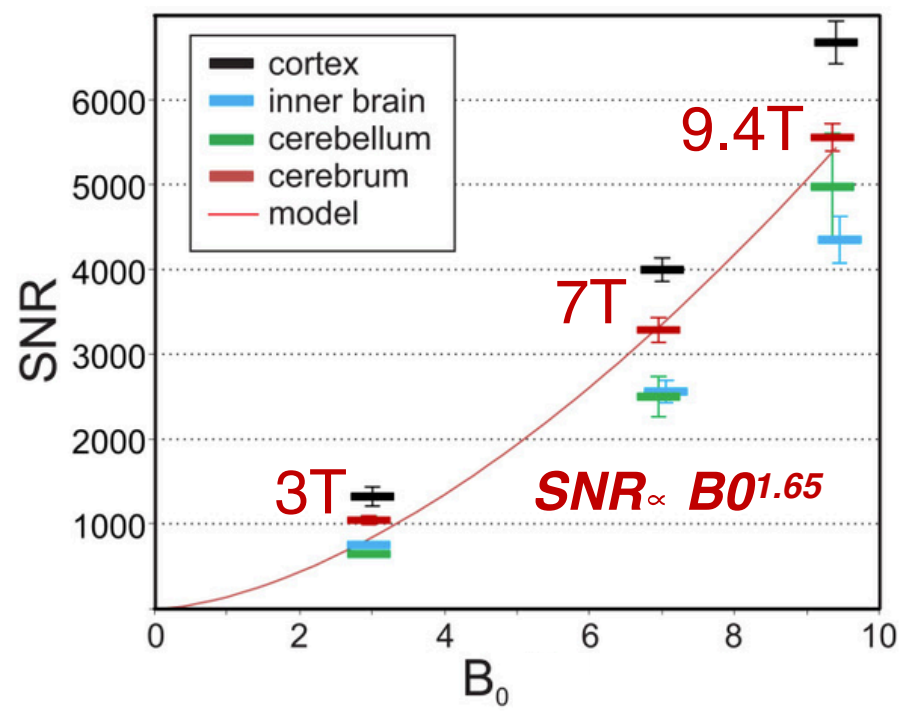
Signal Strength at 7T

- Empirical data seem to be something in the middle...



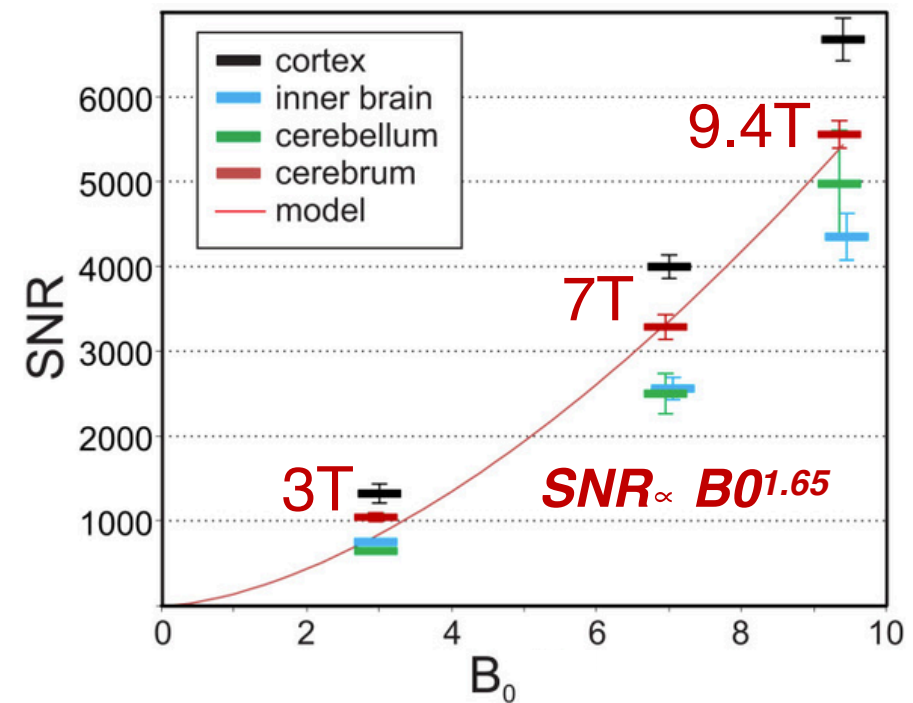
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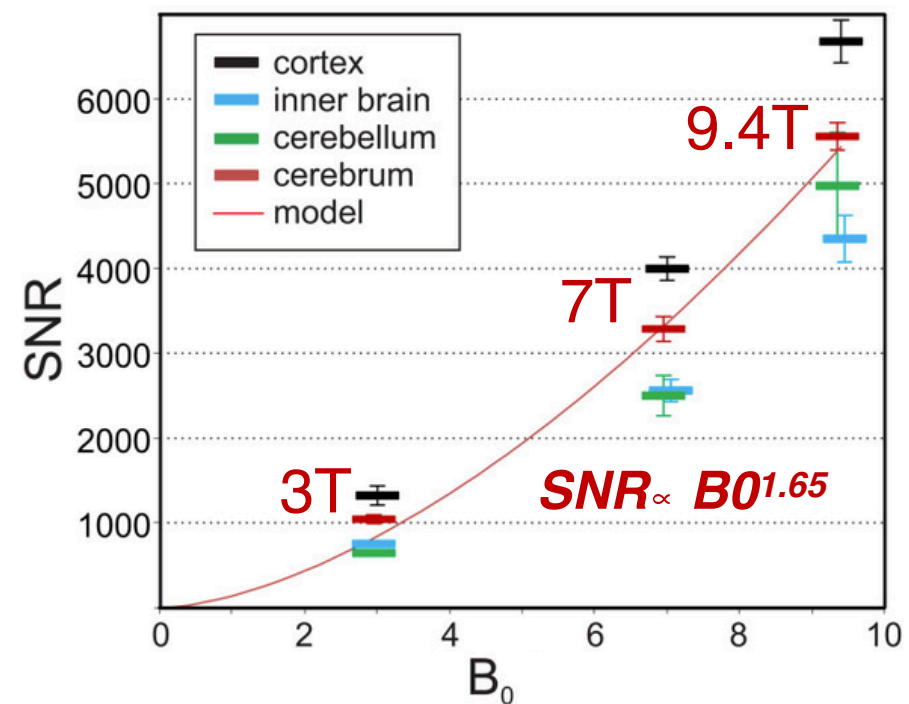
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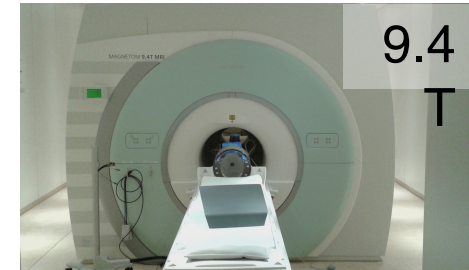


Signal Strength at 7T

- Empirical data seem to be something in the middle...
- This function makes 7T a good deal!
- We get a big increase in SNR compared to 3T, and we avoid the intense engineering challenges at higher magnetic fields

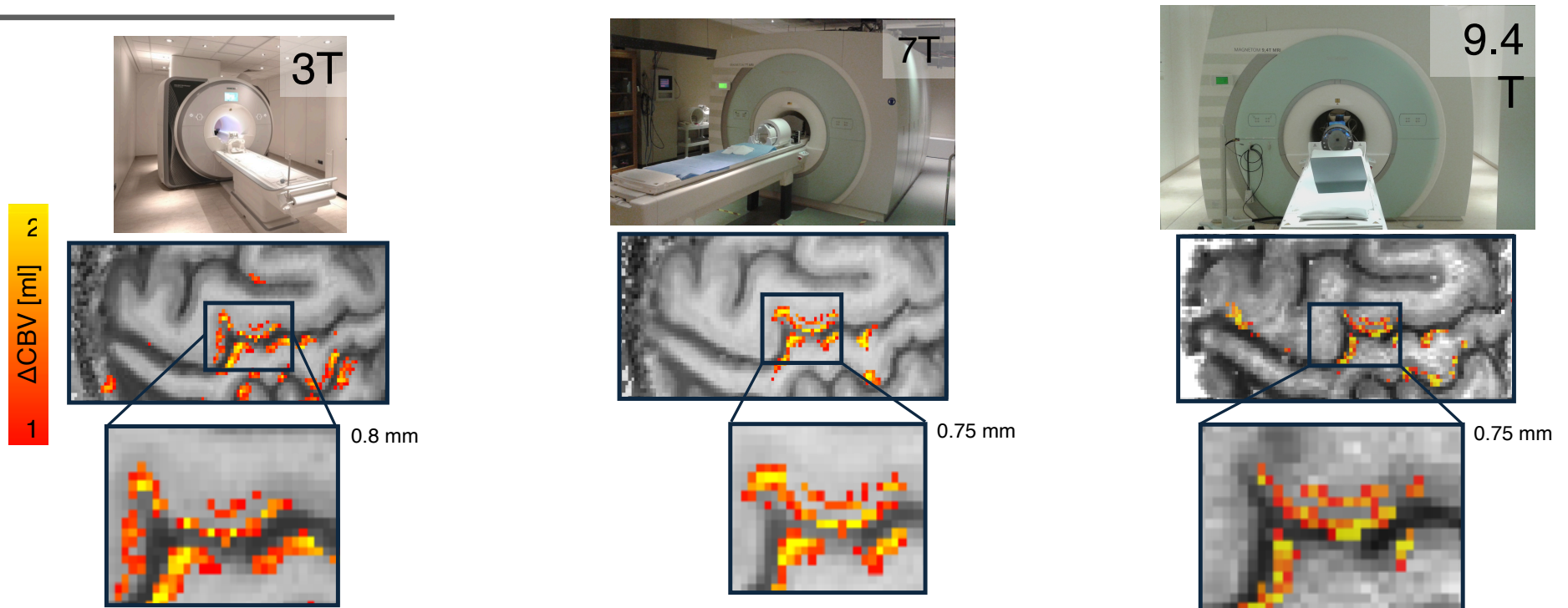


Field Strength of MRI



From
Renzo Huber

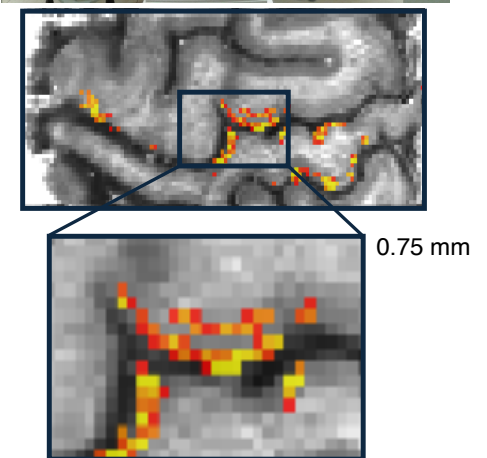
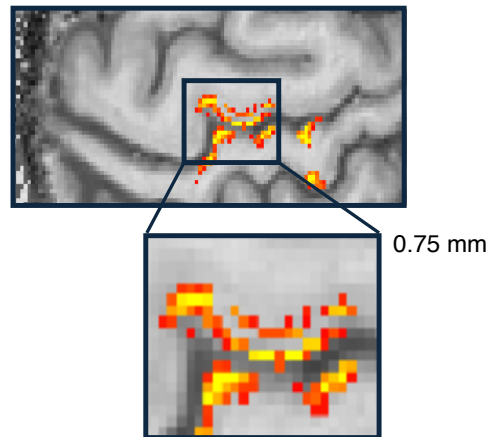
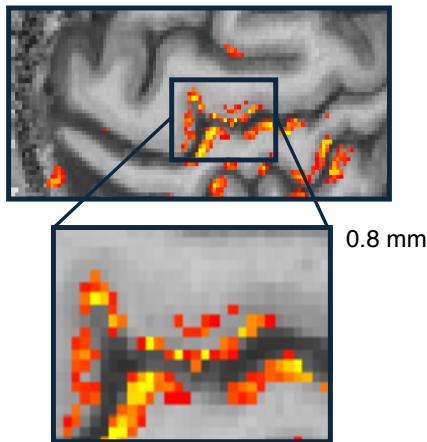
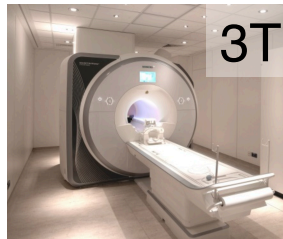
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Field Strength of MRI

2
1
 $\Delta\text{CBV [ml]}$



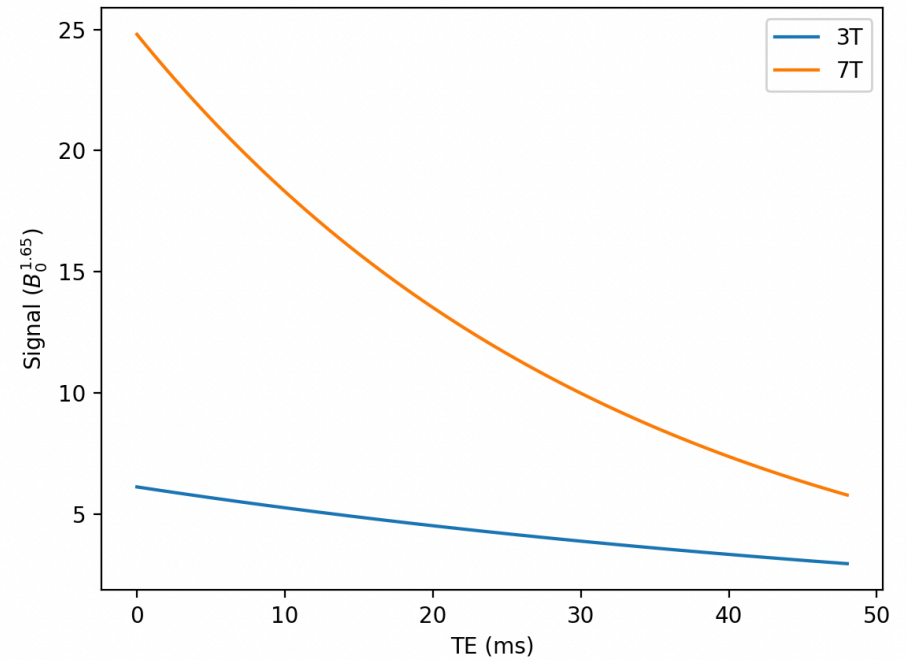
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But 7T is not magic...

- It comes at a cost!

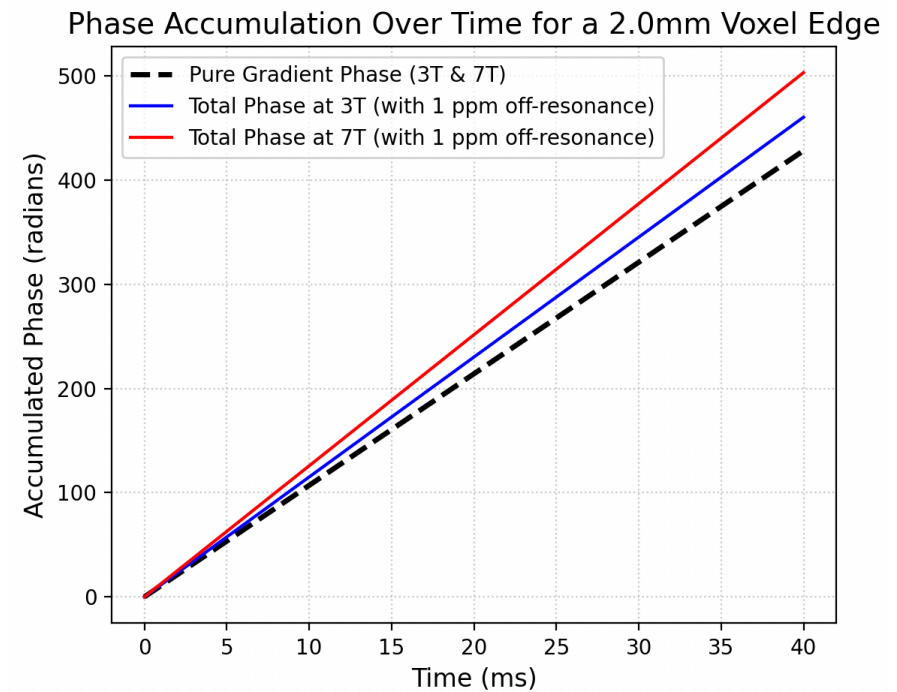
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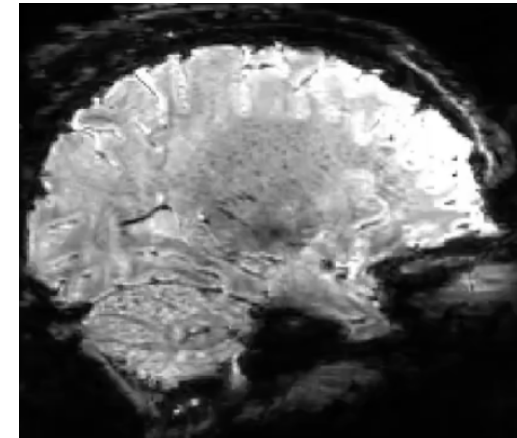
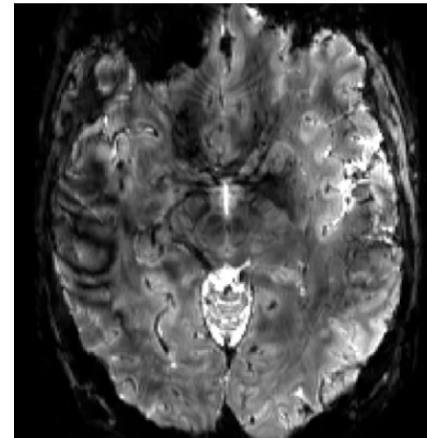
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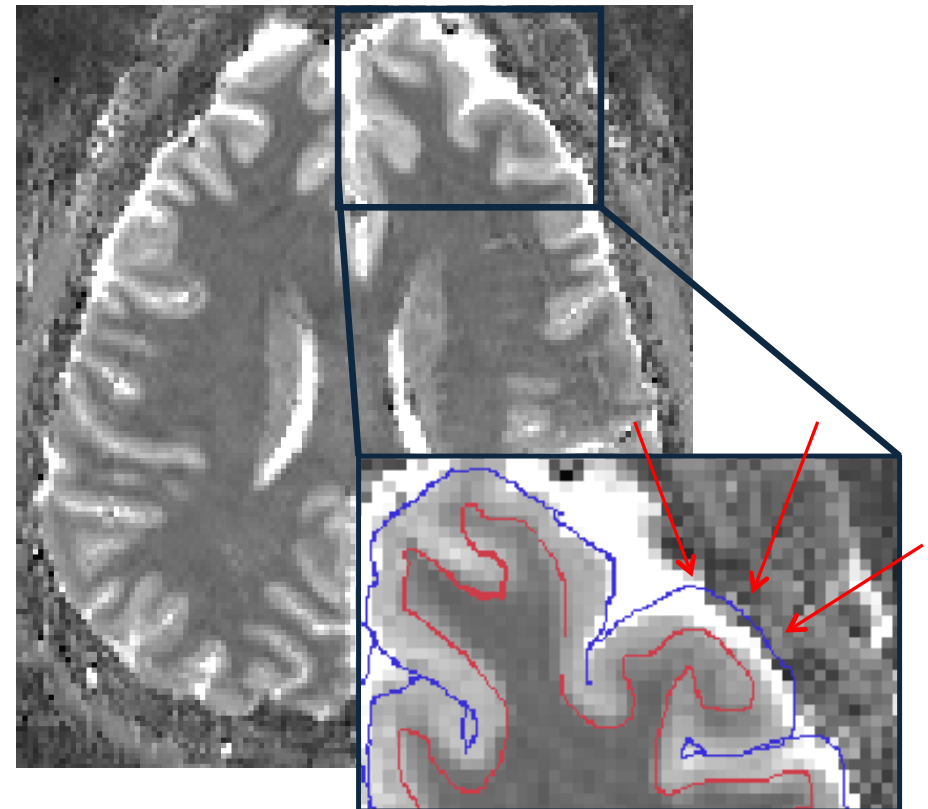
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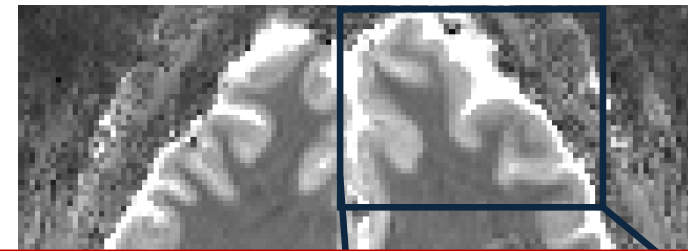
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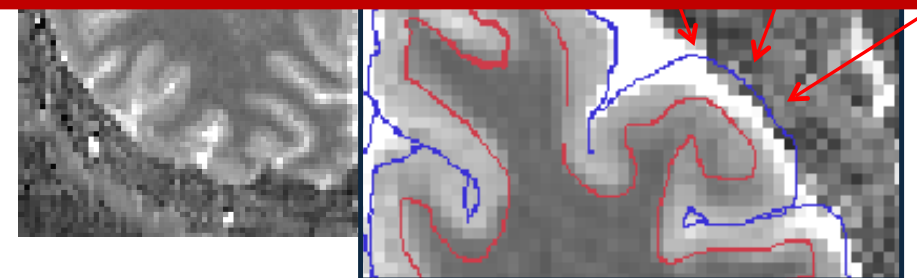


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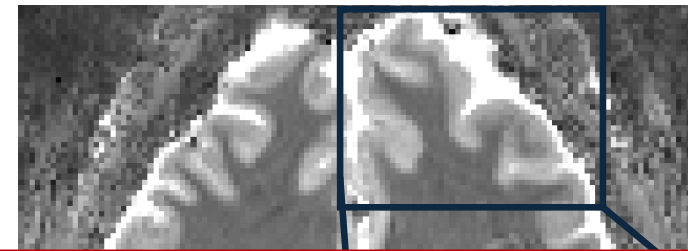


So... can't we just scan faster???

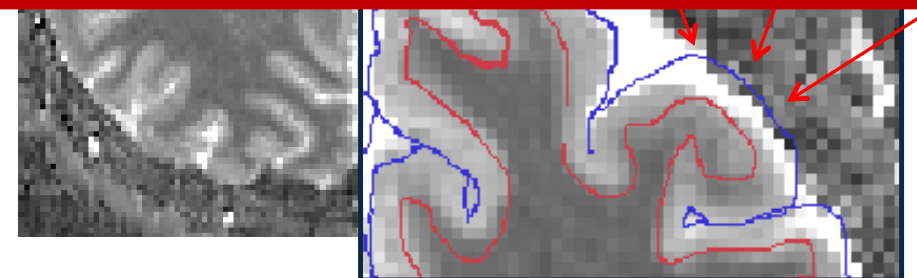


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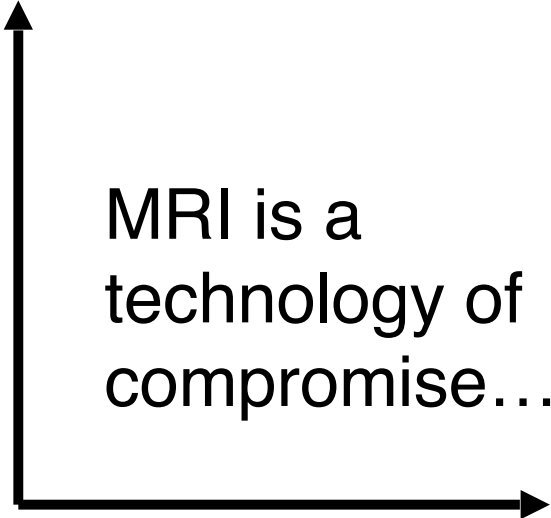


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How do we image faster and increase resolution?

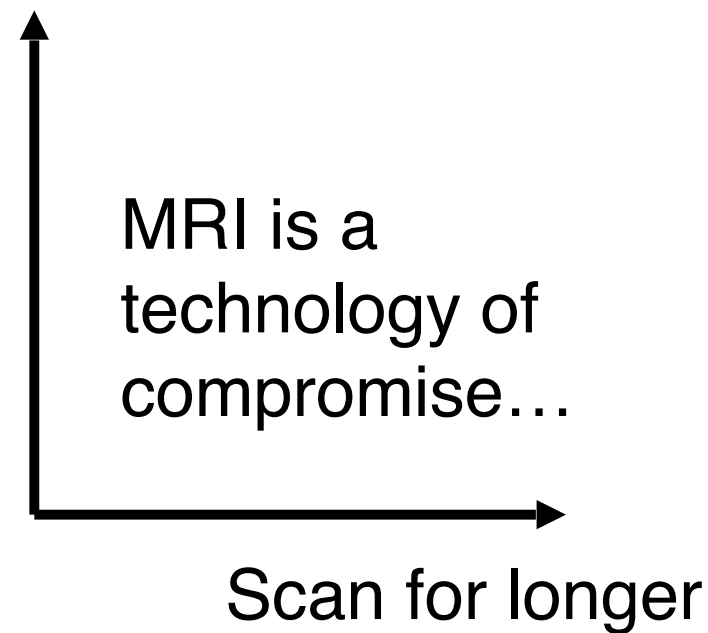
7T



MRI is a
technology of
compromise...

How do we image faster and increase resolution?

7T

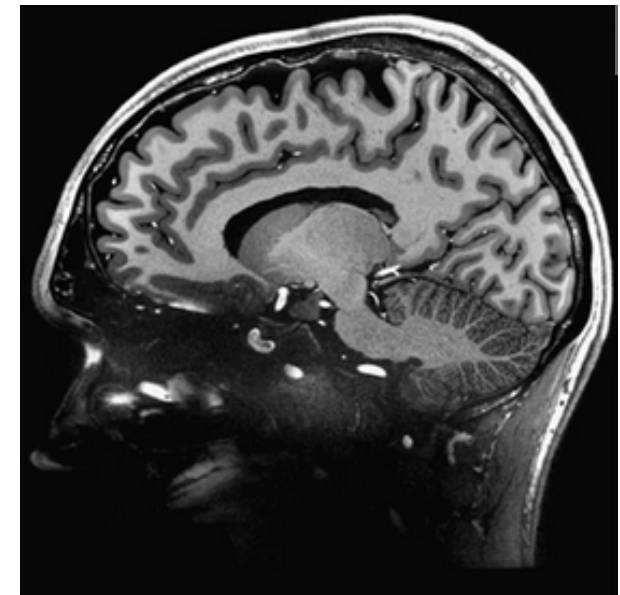


***Remember our
lecture on
Deep Sampling!***

How do we image faster and increase resolution?

MRI is a
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Scan for longer

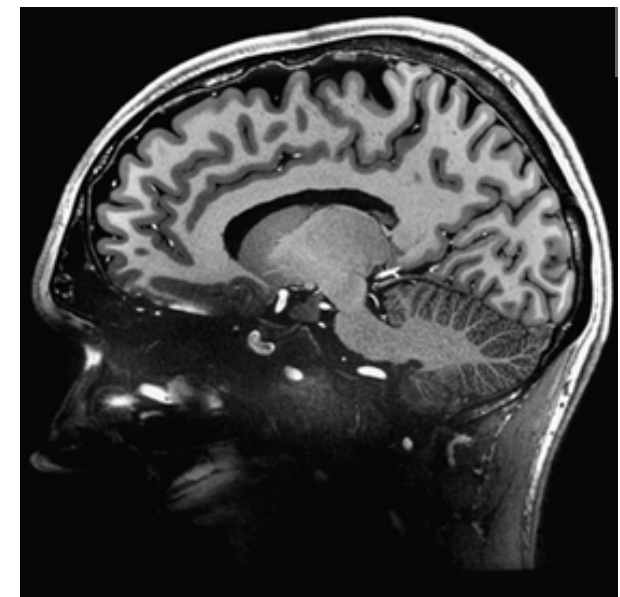
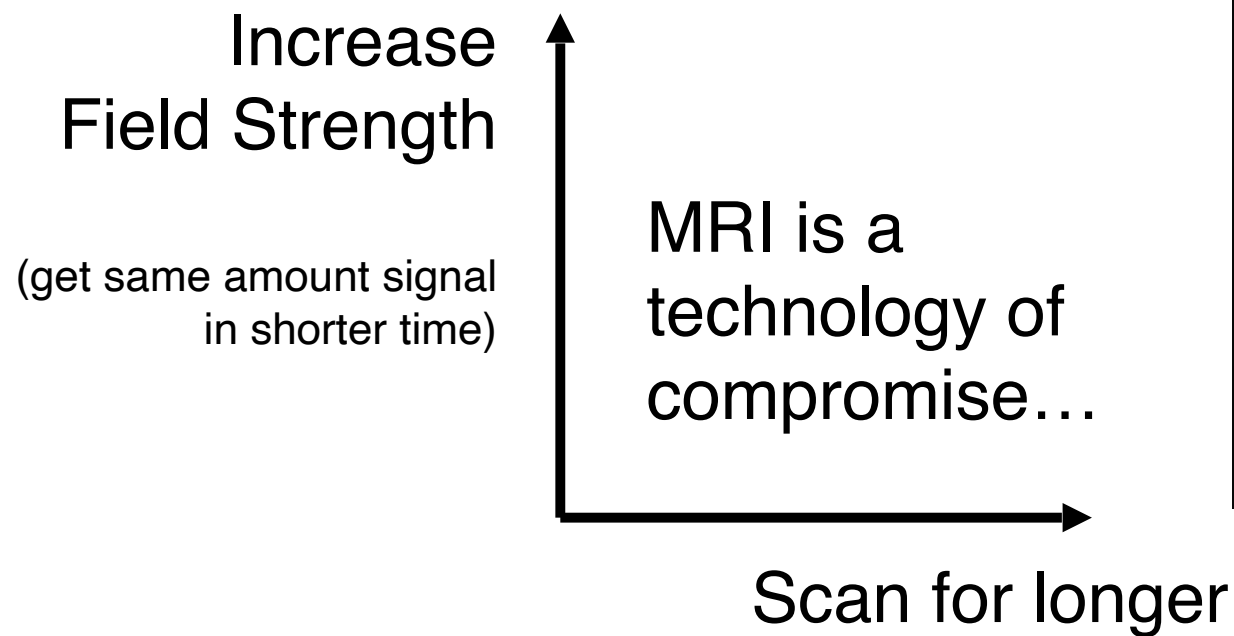


7T

250 um, but **3.5**
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Lüsebrink, et al. 2017

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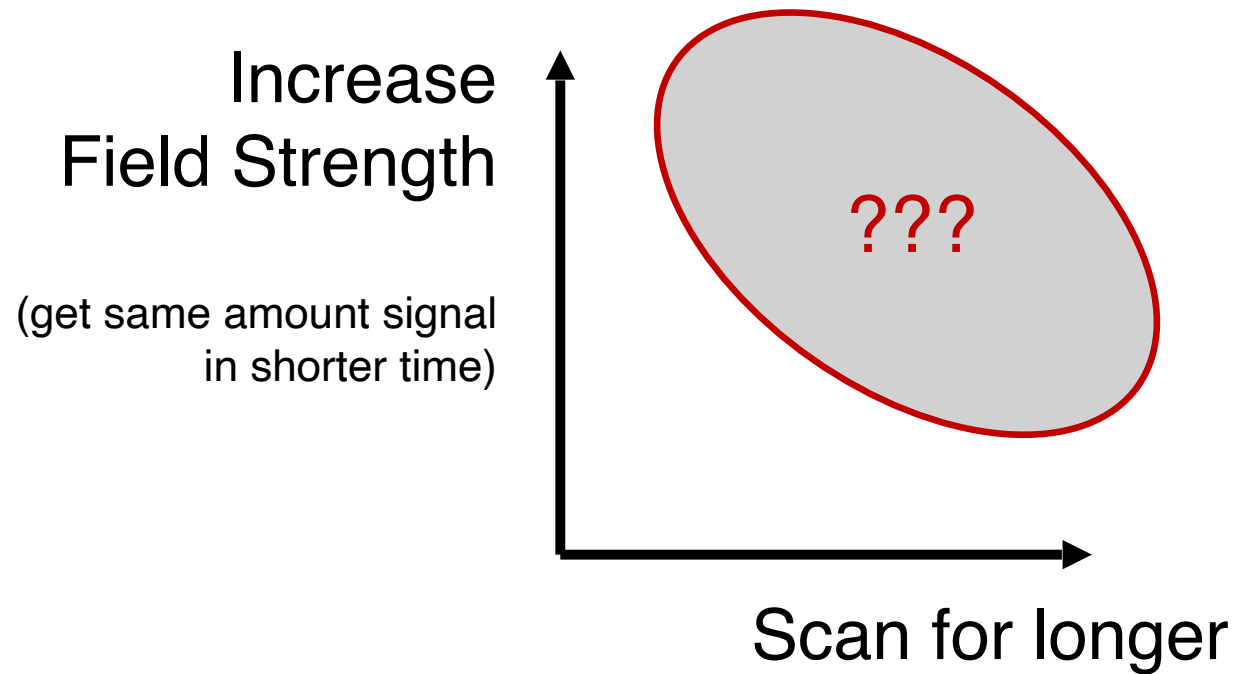


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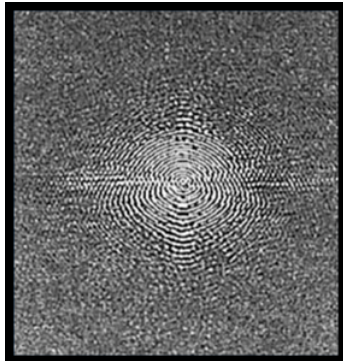
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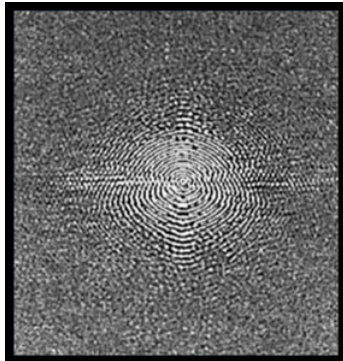
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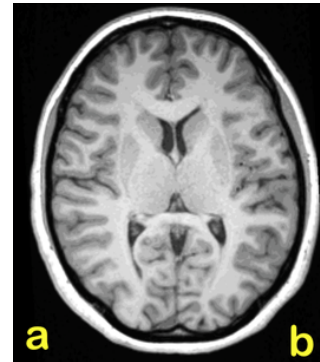


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Fourier
Transform
↔

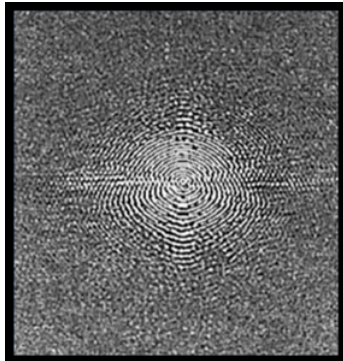


To reconstruct our
images

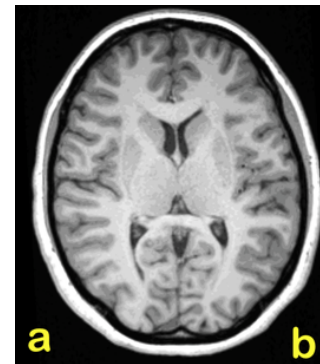
****See Lecture 3
by Vinai**

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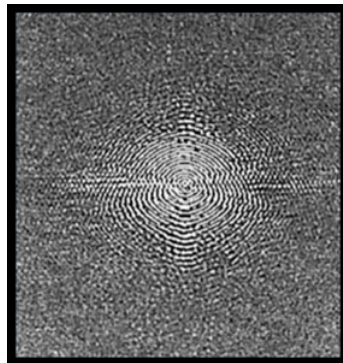
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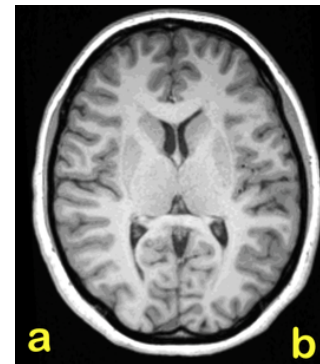
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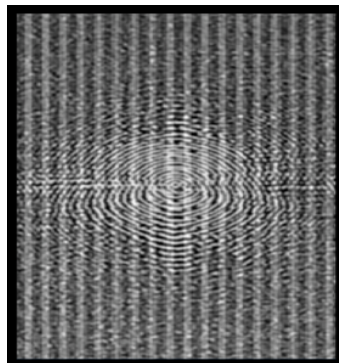


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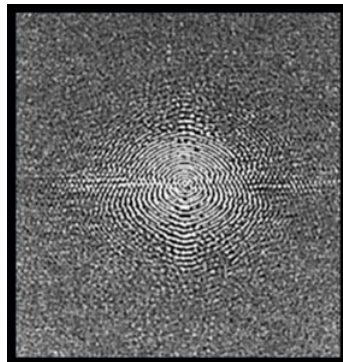
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It would be great
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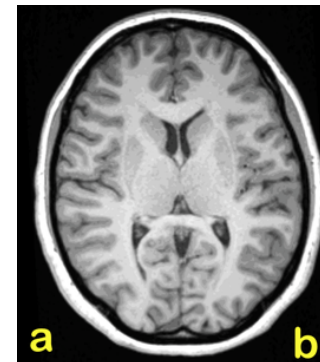


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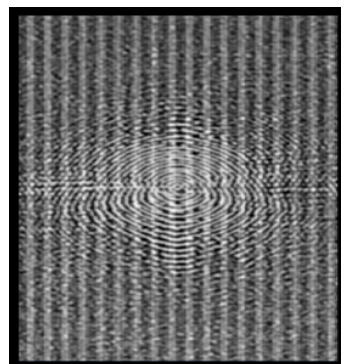


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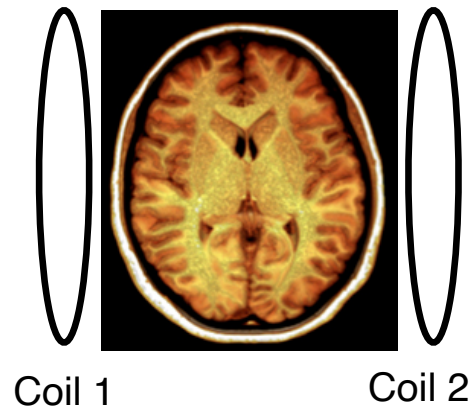
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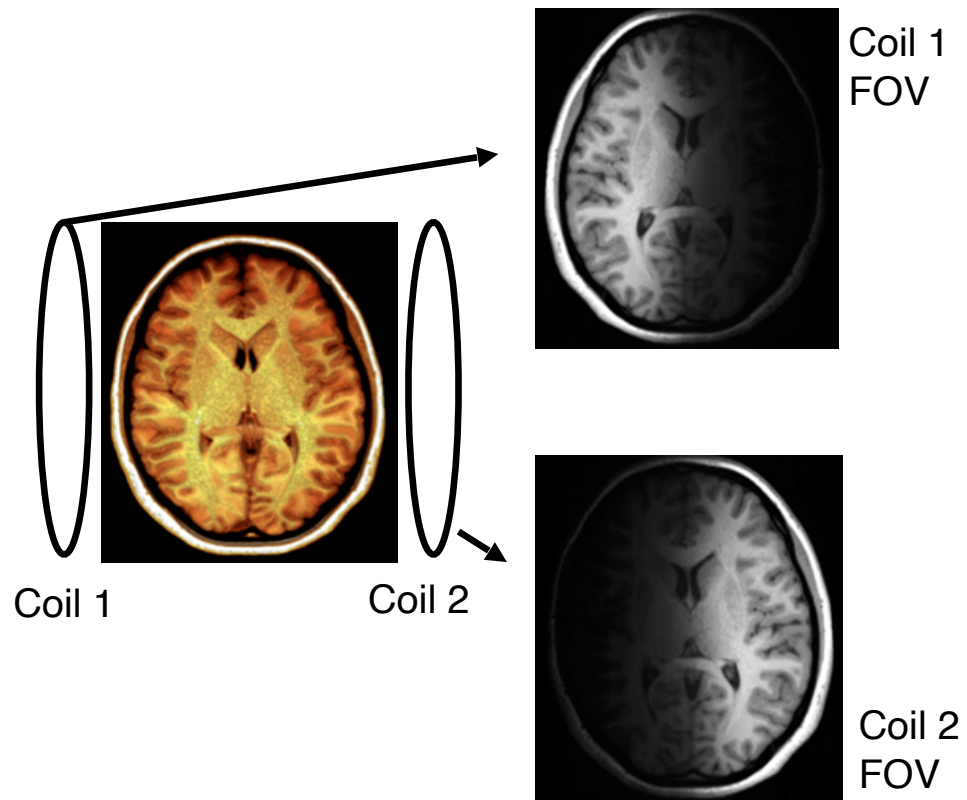
But then we are left
with reduced FOV and
wrapping artifacts!

Enter... Parallel Imaging

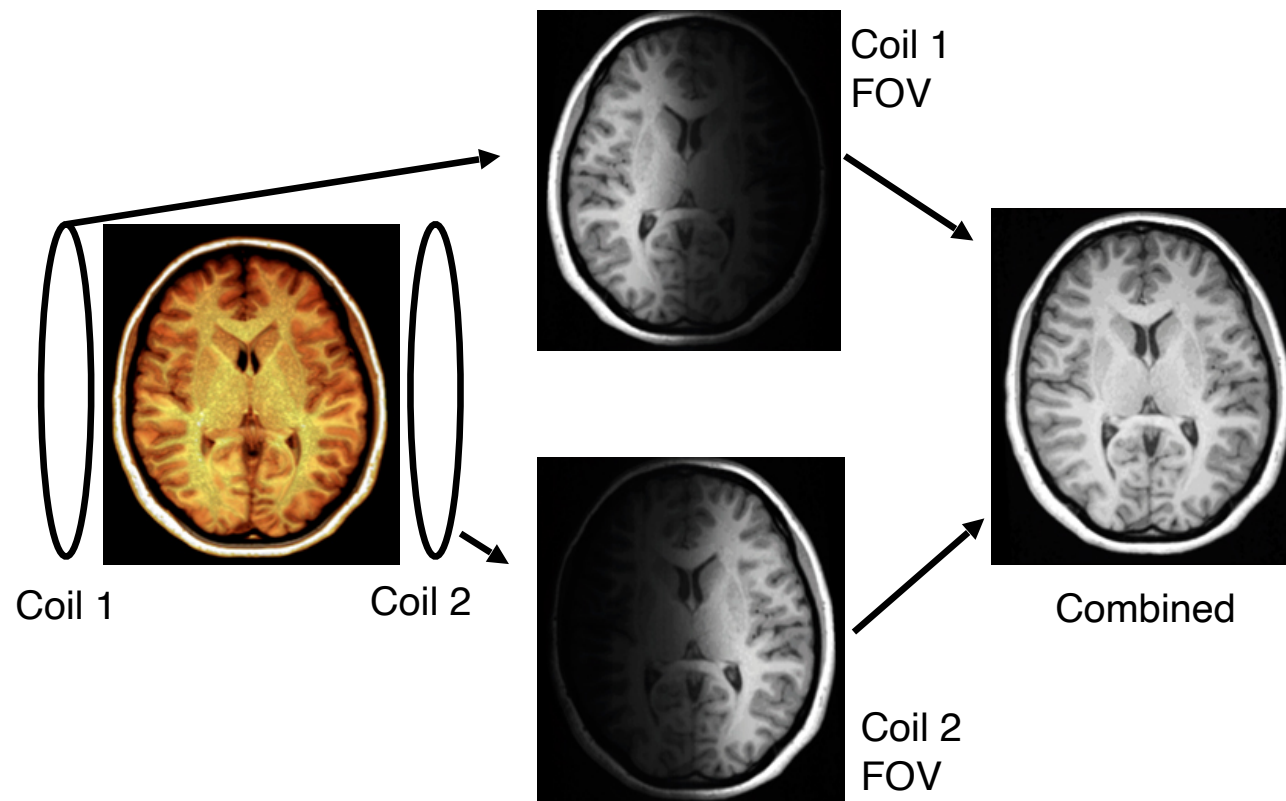
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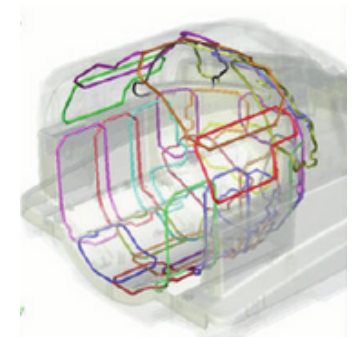
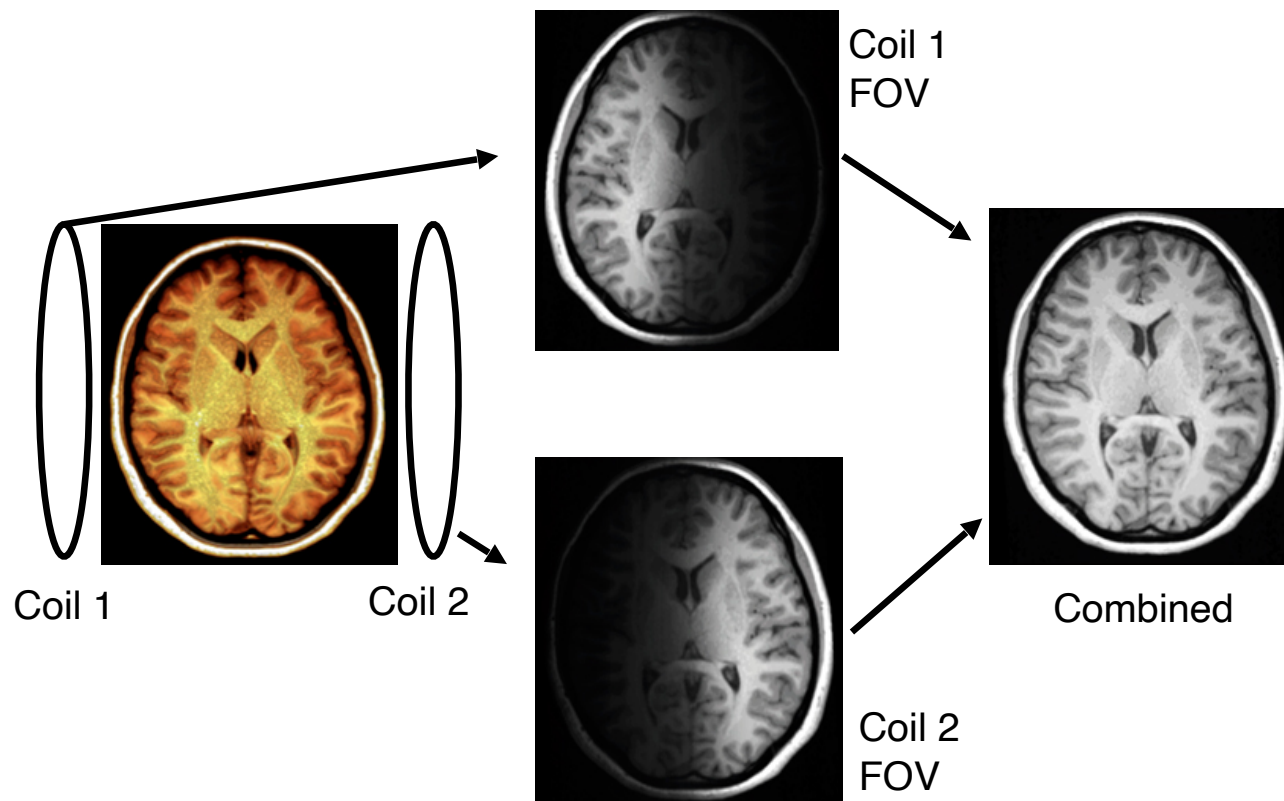
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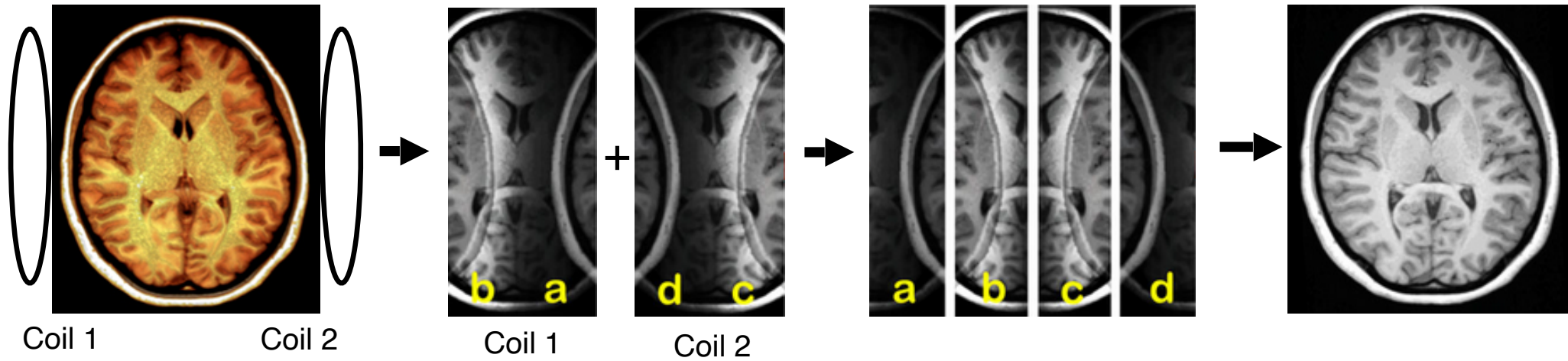


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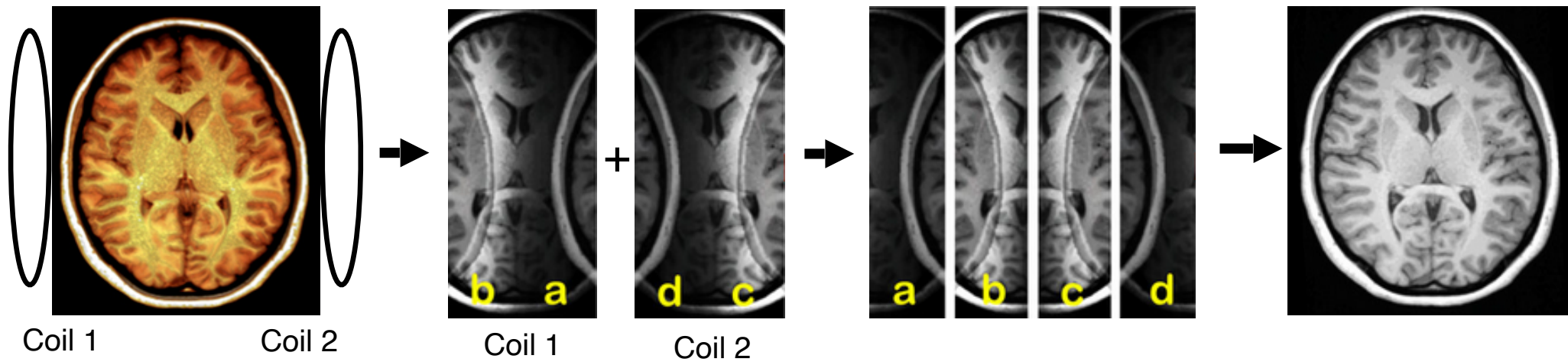


MRI Questions; Paolini, et al. 2015

The Acceleration Problem

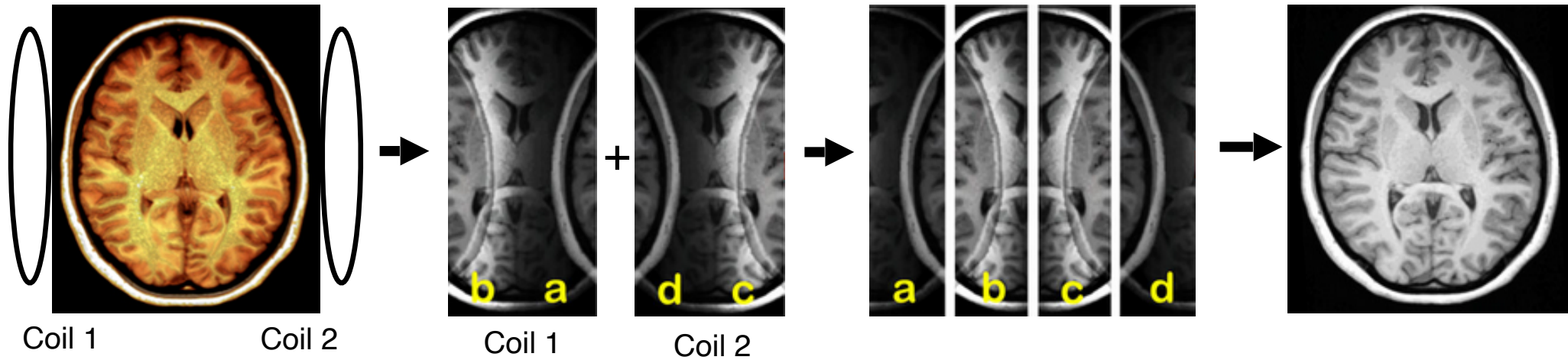


The Acceleration Problem



So how do we
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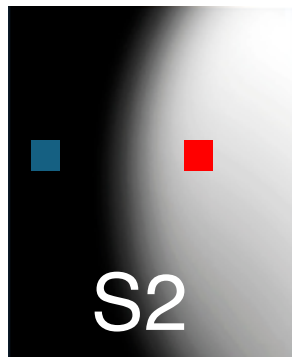
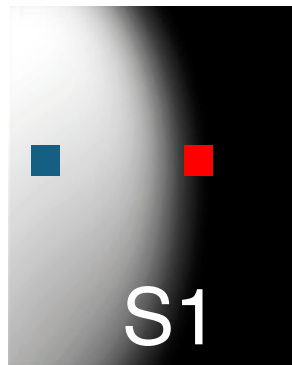
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So how do we
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To this???

SENSE / ASSET

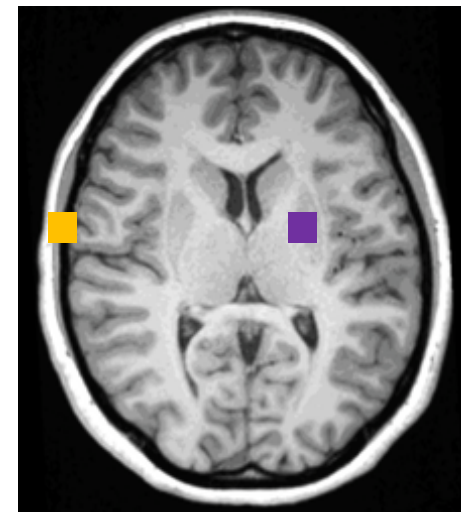


Coil Sensitivity Maps



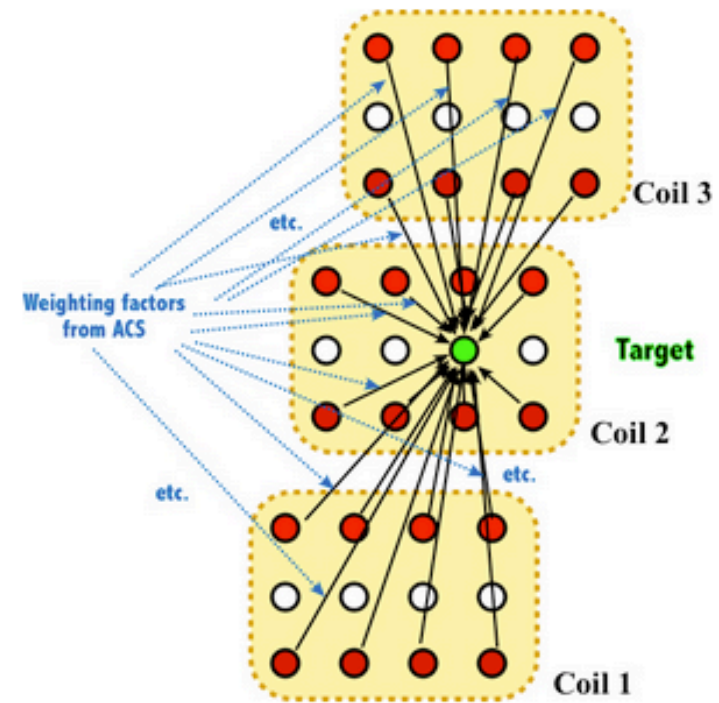
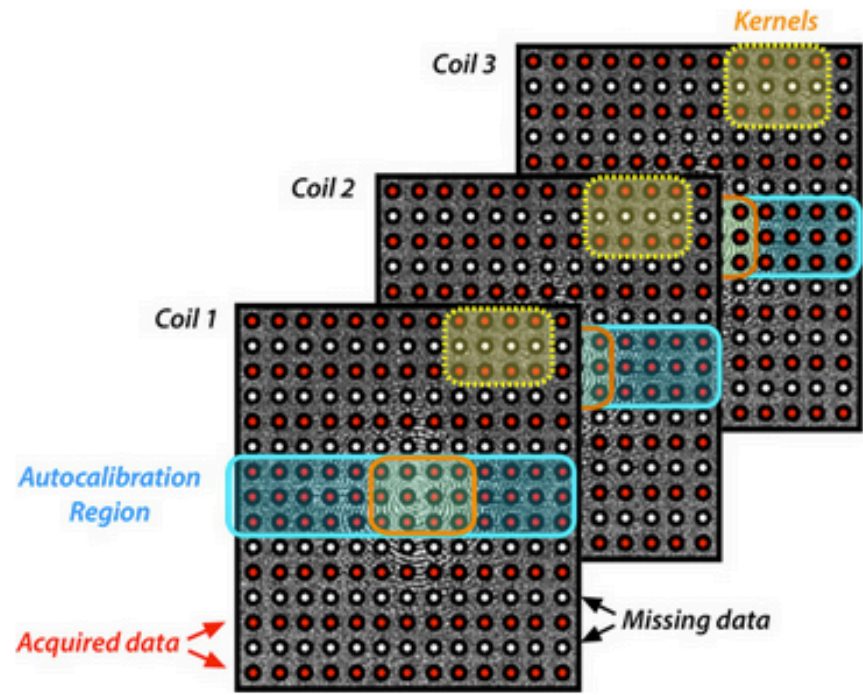
Measured Images

$$\begin{aligned} S1 \text{ (green)} &= \text{blue} \cdot \text{yellow} + \text{red} \cdot \text{purple} \\ S2 \text{ (green)} &= \text{blue} \cdot \text{yellow} + \text{red} \cdot \text{purple} \end{aligned}$$



Full FOV Image

GRAPPA / ARC

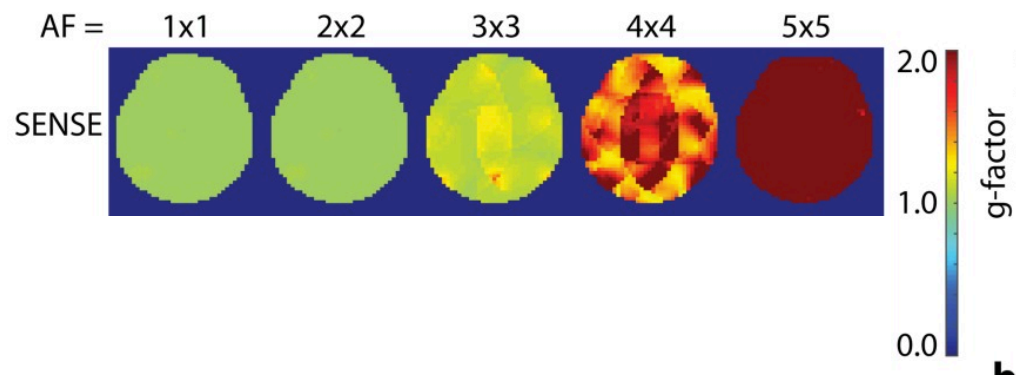


What are the limitations of acceleration?

- All Parallel Imaging techniques are limited by the number of receiver coils, and their arrangement!

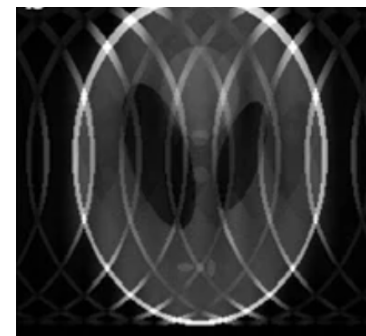
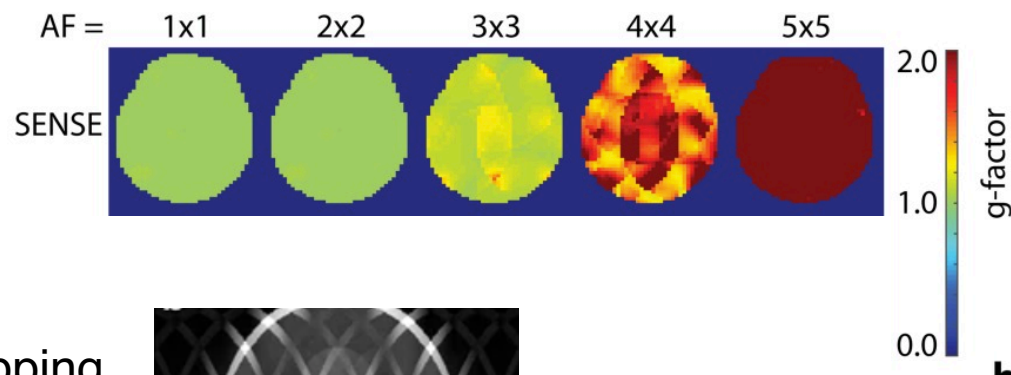
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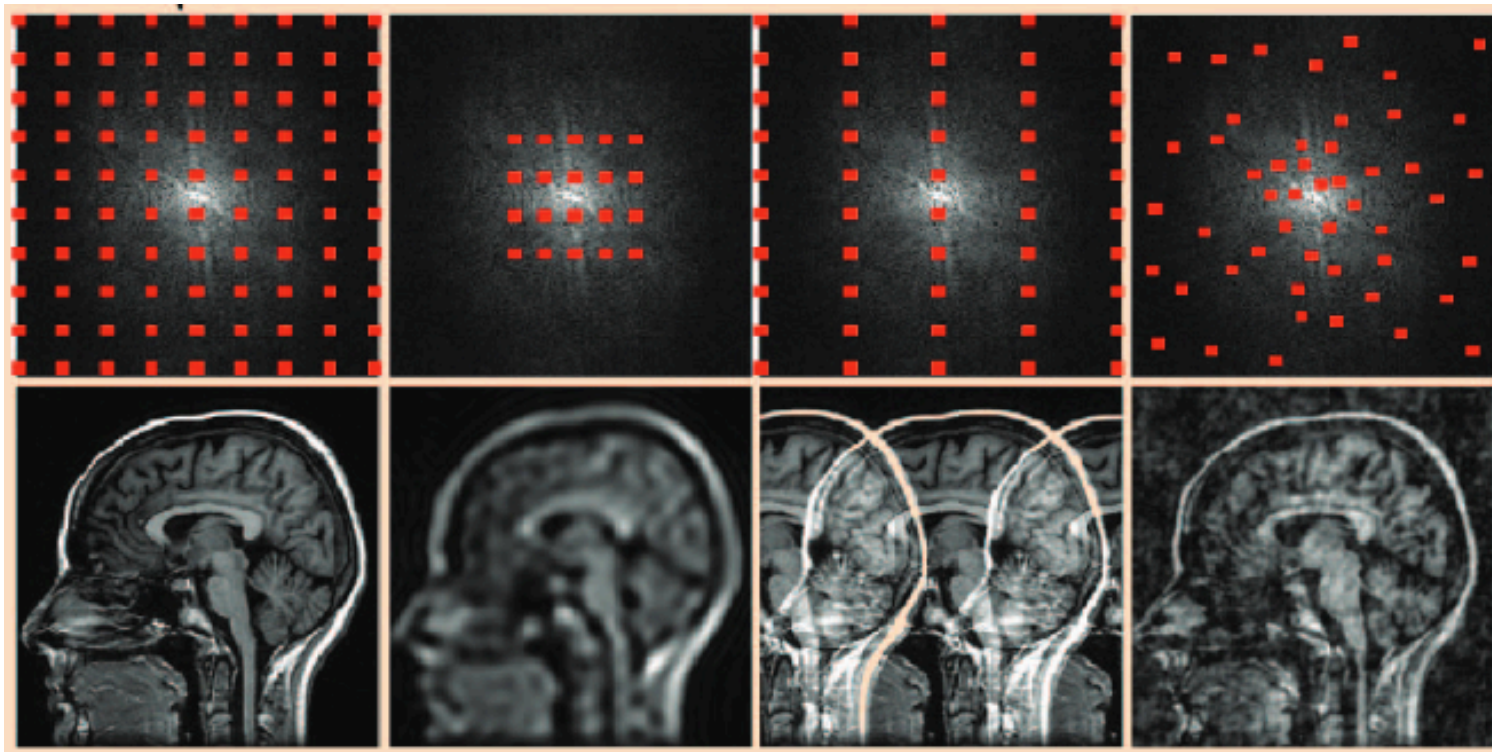


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- Noise is cumulative! Voxels with similar sensitivity across all coils are harder to untangle (G-Factor penalty).
- Algorithms are never perfect.... some wrapping artifacts will always be present



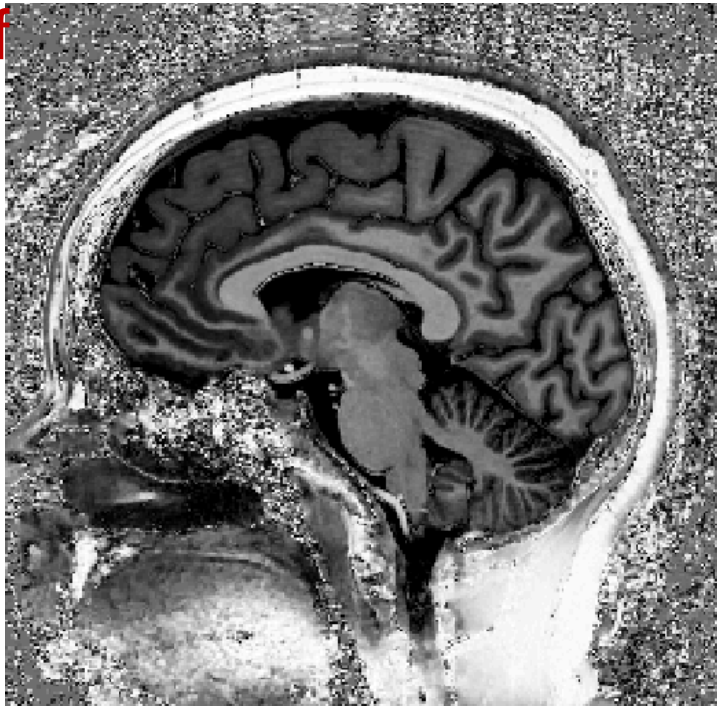
Reducing Artefact Coherence (Compressed Sensing)



Lustig, et al. 2008

Compressed Sensing (0.75 mm anatomical scans at NIH)

~18% of
k-space



CS – USx5.1
(6:04)

~35%
of
k-space

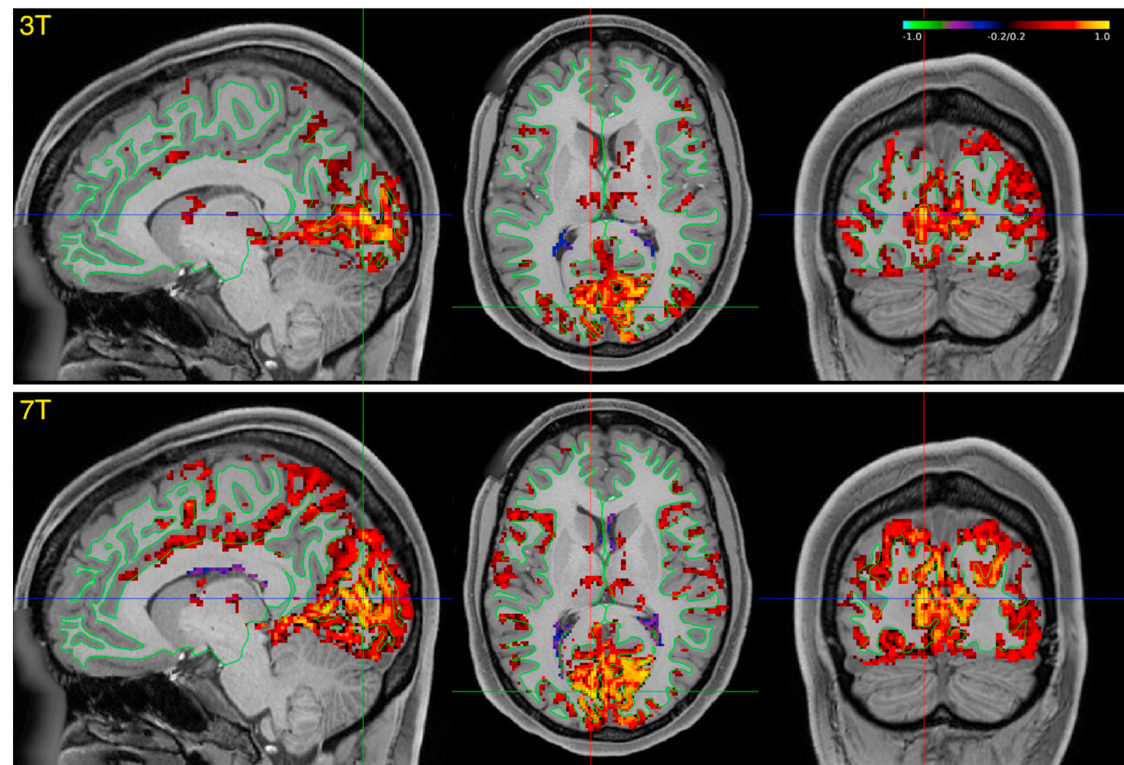


GRAPPA 3
(9:37)

Collected on 7TB

Okay, but is 7T better for fMRI?

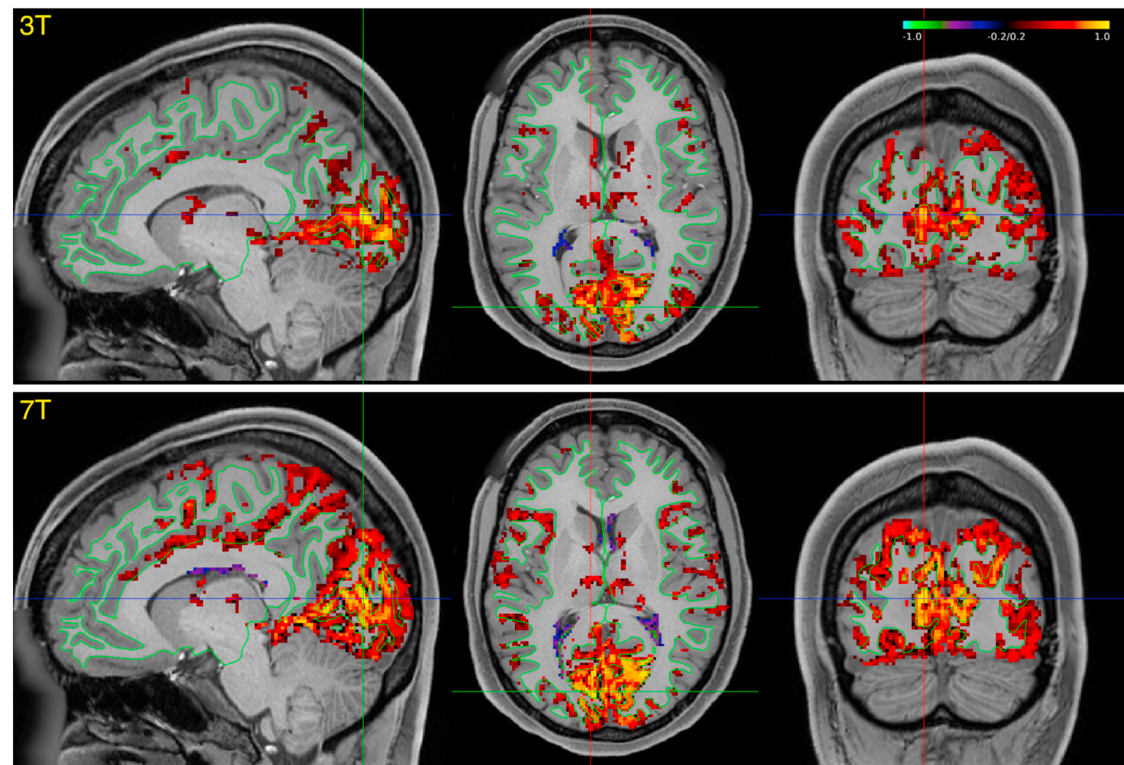
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Vu, et al. 2017 (Human Connectome Project)

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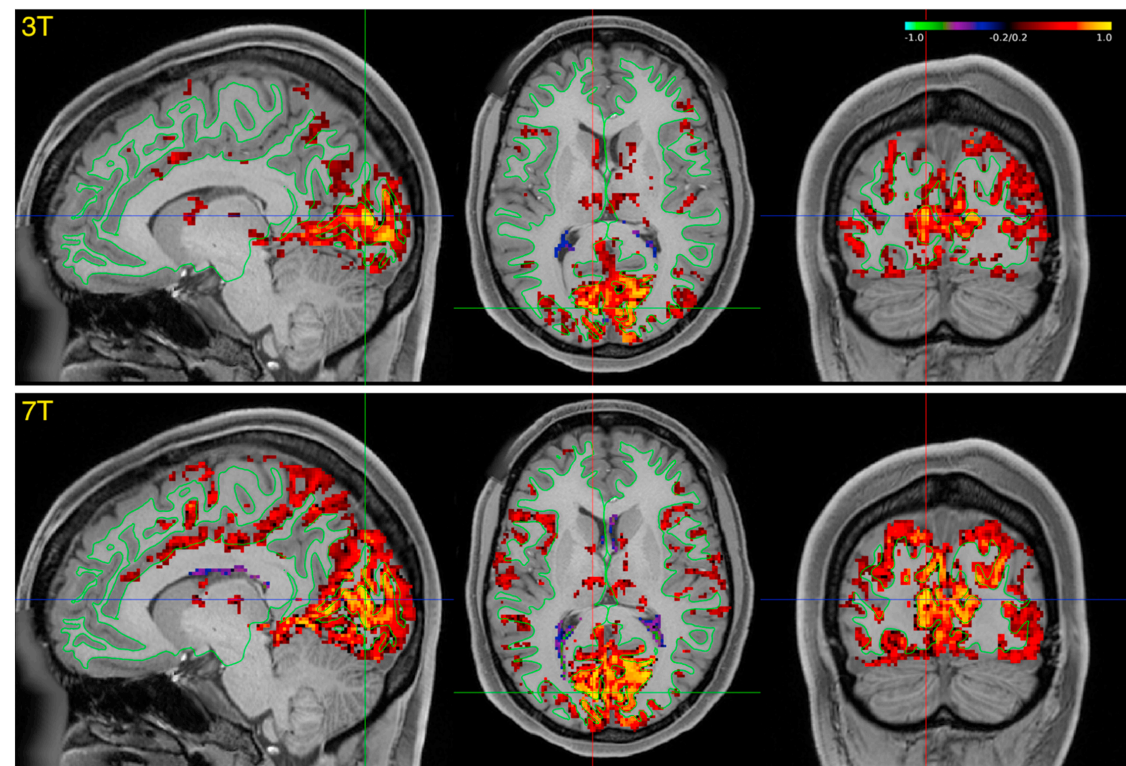
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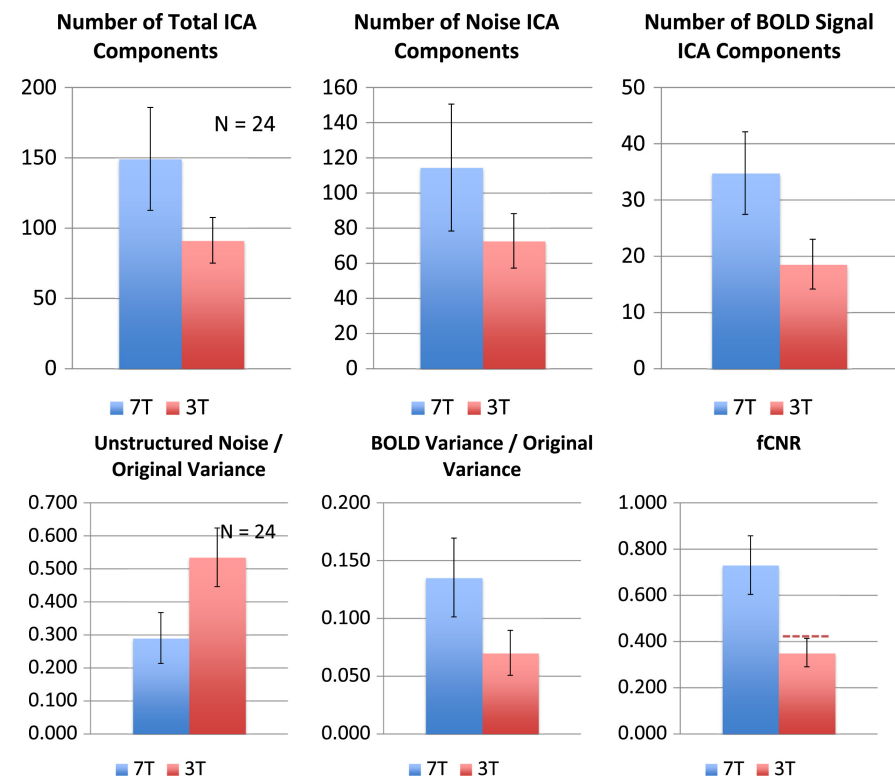
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 1. Better functional contrast
 2. More extensive functional components



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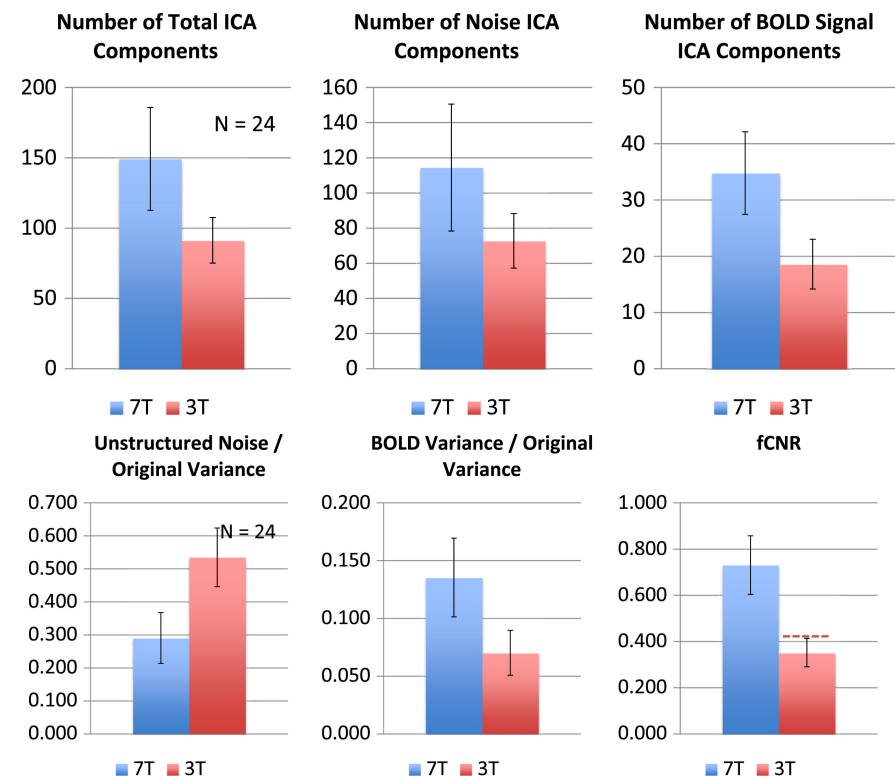
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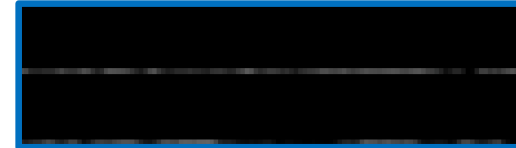
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But we need to think about sequences!

3D EPI



2D MB/SMS



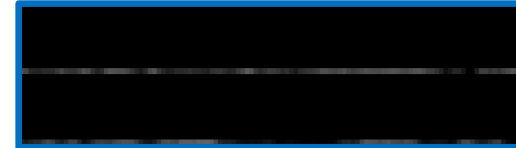
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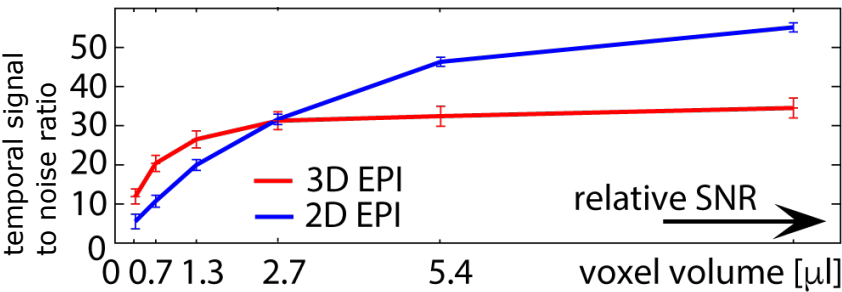
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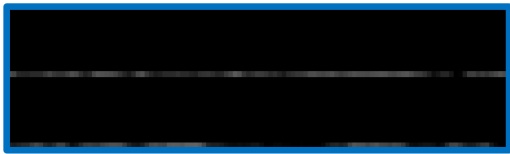
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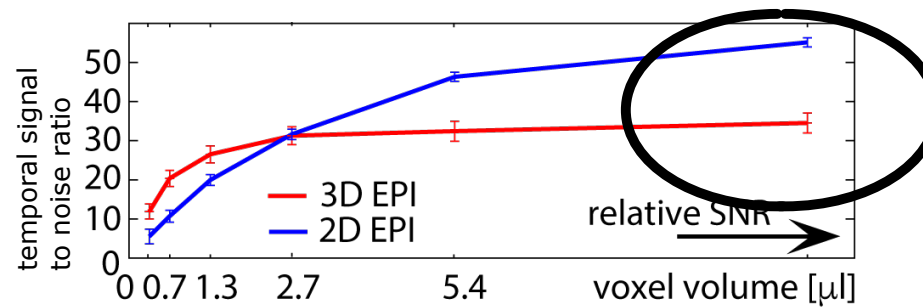


2D MB/SMS

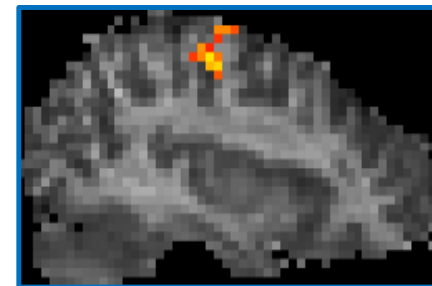
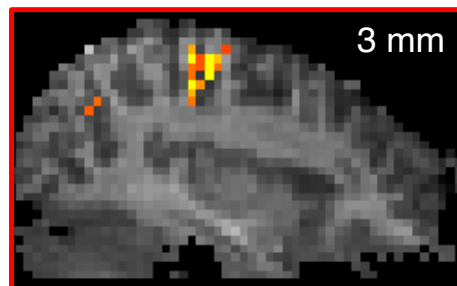
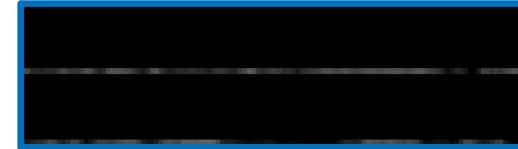


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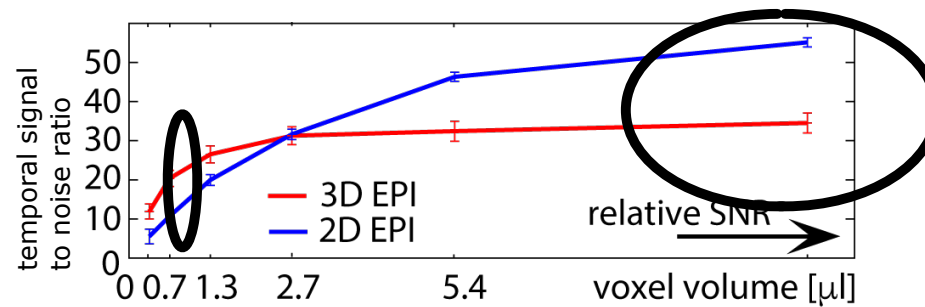
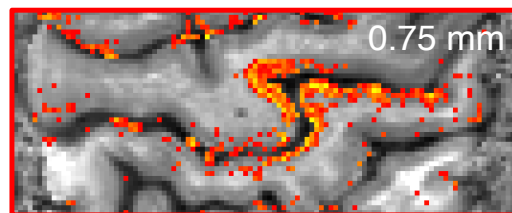
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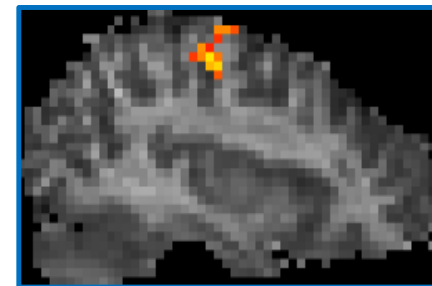
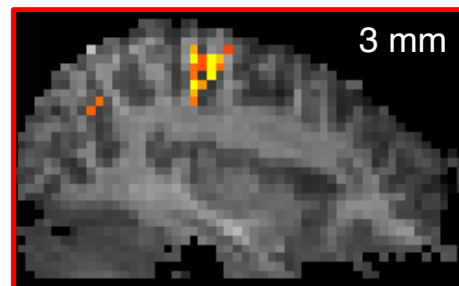
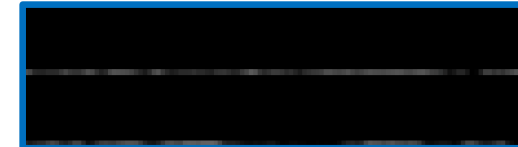
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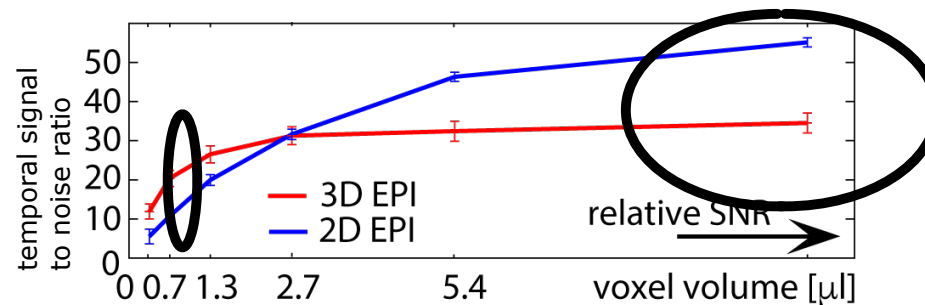
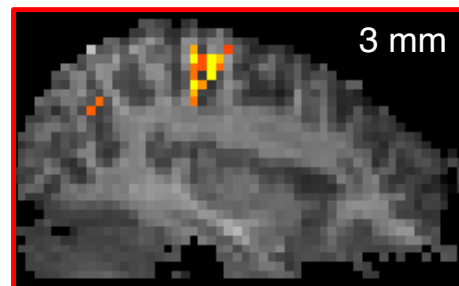
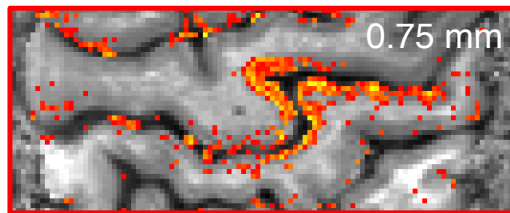
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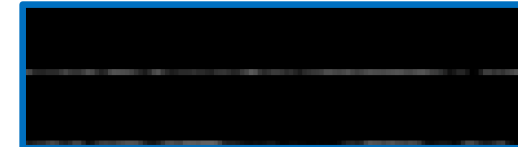
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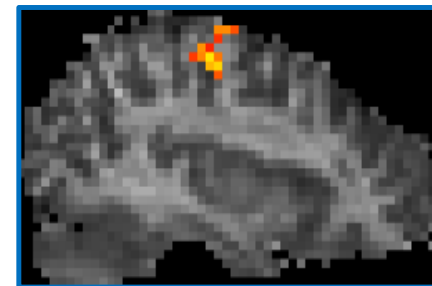
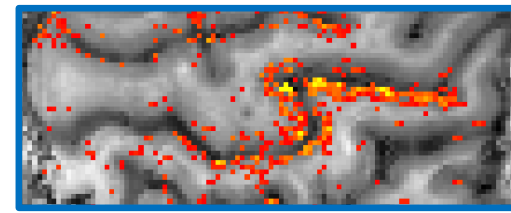
- Higher signal 🥰
- but more motion artefacts 😞
- No slice timing
- Confusion between TR and “VAT”



2D MB/SMS

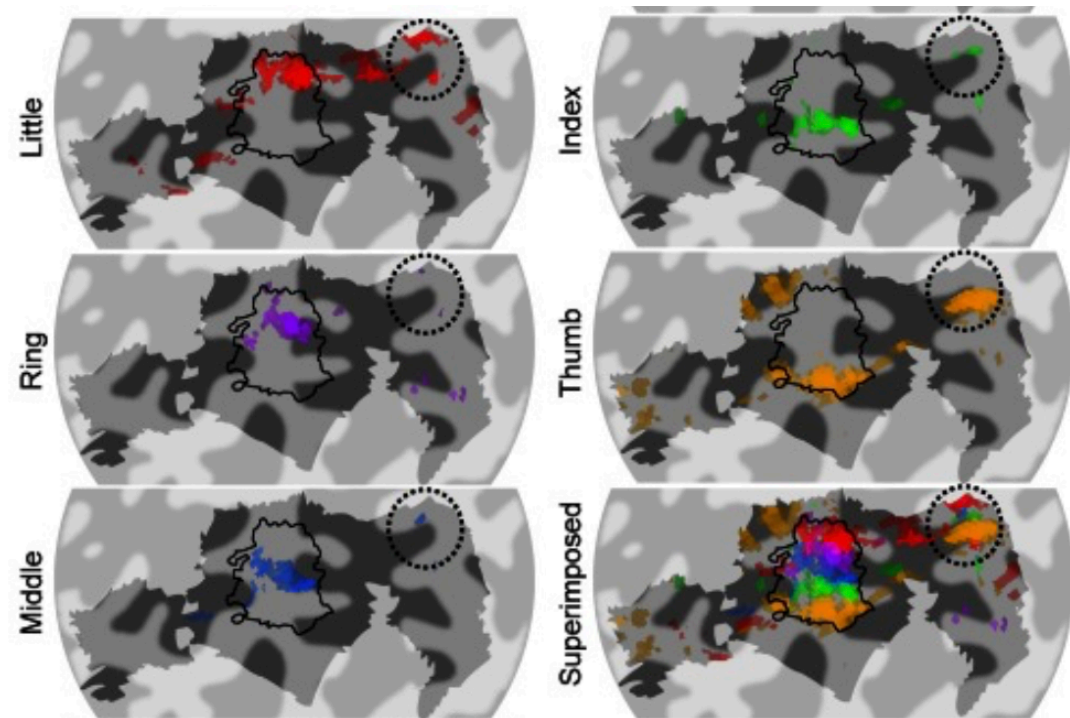


- Lower signal 😞
- but fewer motion artefacts 🥰
- Pretty standard processing



From Renzo Huber

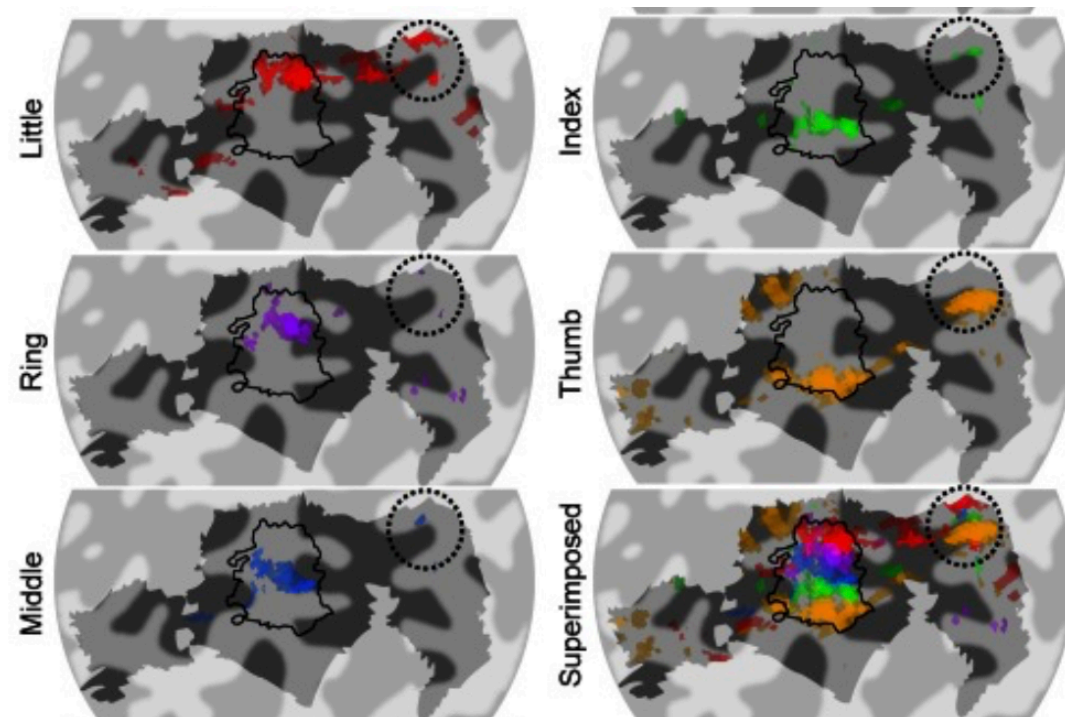
Cortical Columns in fMRI



Martuze, et al. 2012; Besle, et al. 2013; Asghar, et al. 2026

Cortical Columns in fMRI

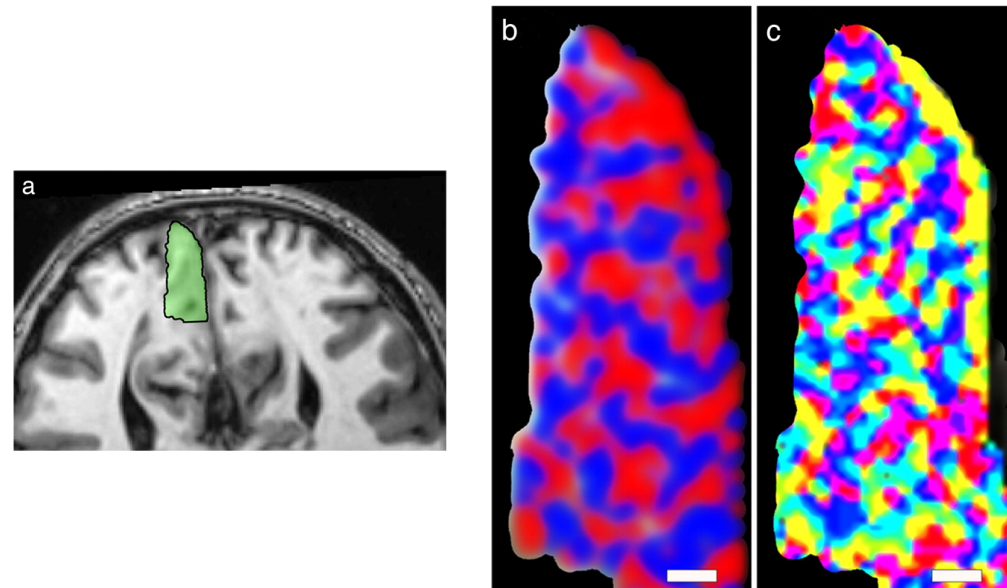
- The specificity of 7T MRI enabled individual finger response mapping in single subjects
- These maps and subsequent experiments have provided valuable information on hand dystonia.



Martuze, et al. 2012; Besle, et al. 2013; Asghar, et al. 2026

Cortical Columns in fMRI

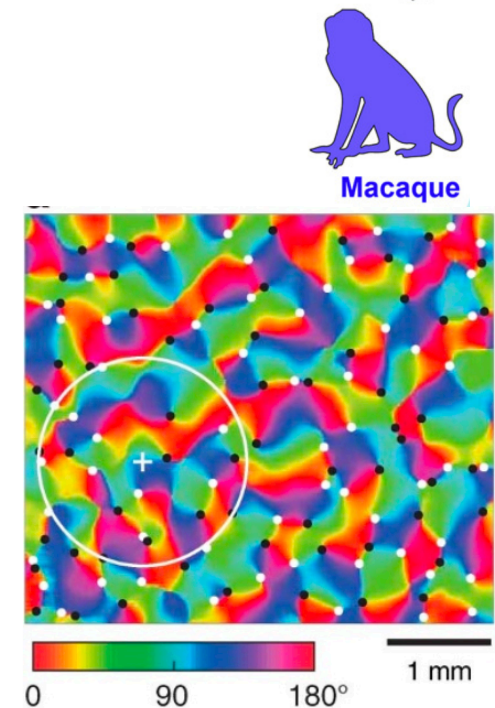
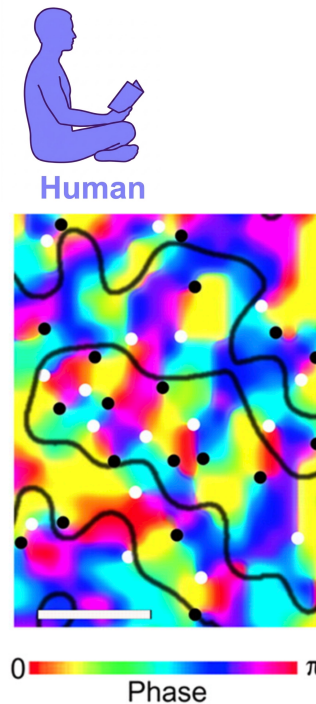
- Yacoub (2008) showed that it was possible to see cortical columns using fMRI
- In a flat portion of cortex, they mapped ocular dominance and orientation selectivity in V1



Yacoub, et al. 2008

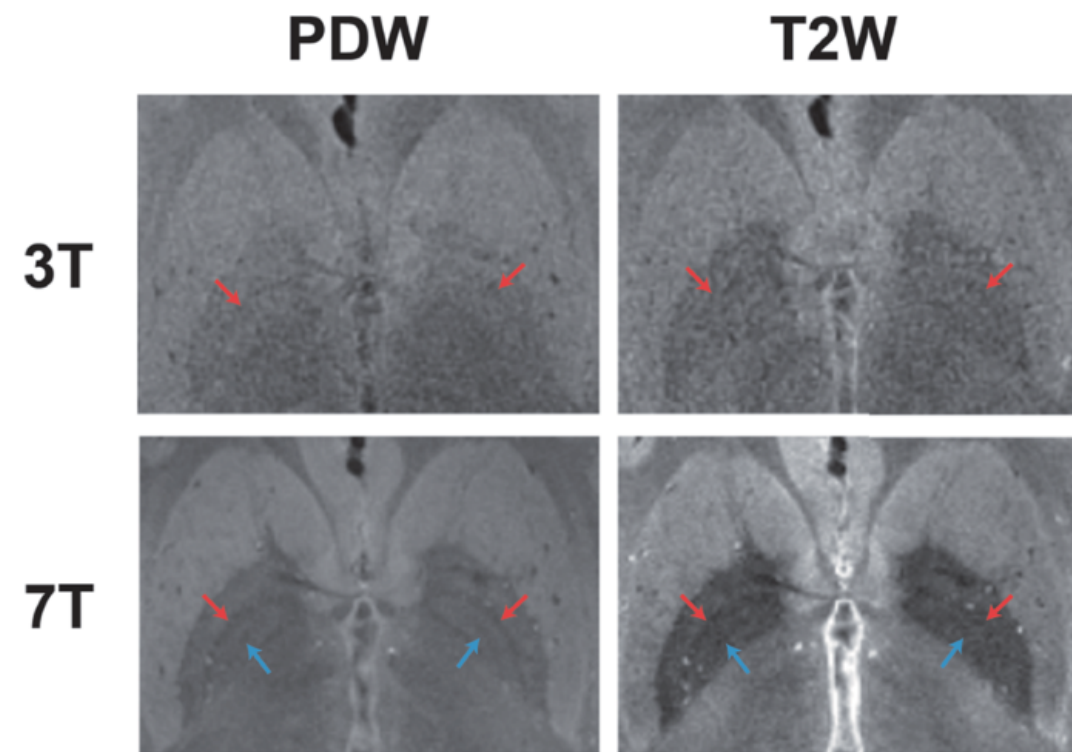
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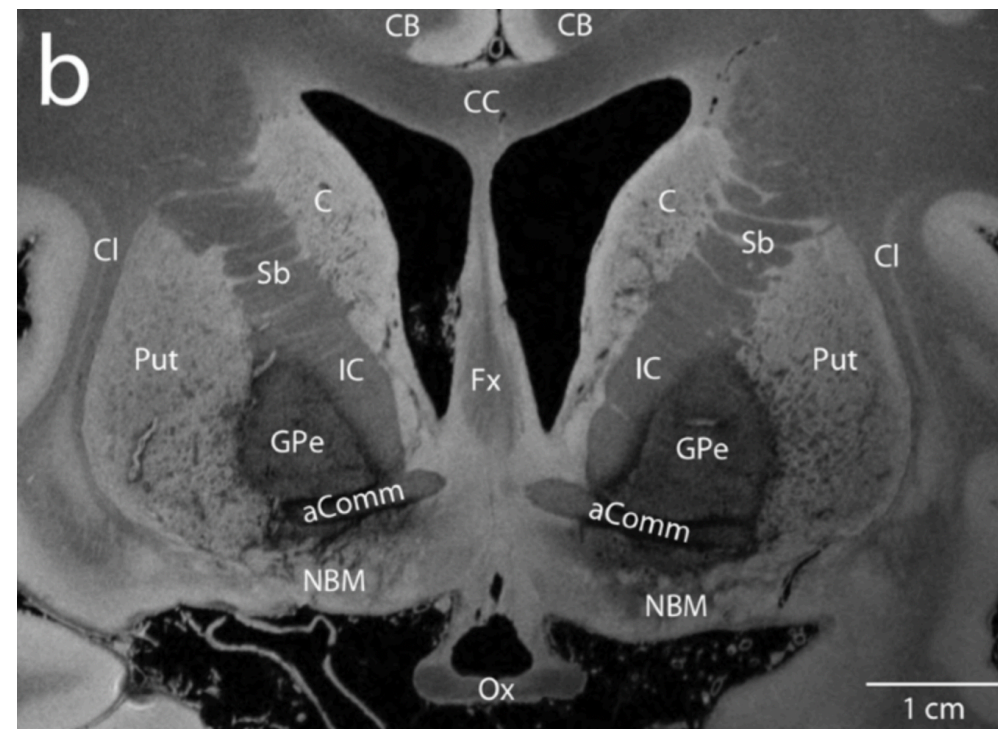
Anatomical Mapping of Small Brain Structures



Maruyama, et al. 2019; Edlow, et al. 2019

Anatomical Mapping of Small Brain Structures

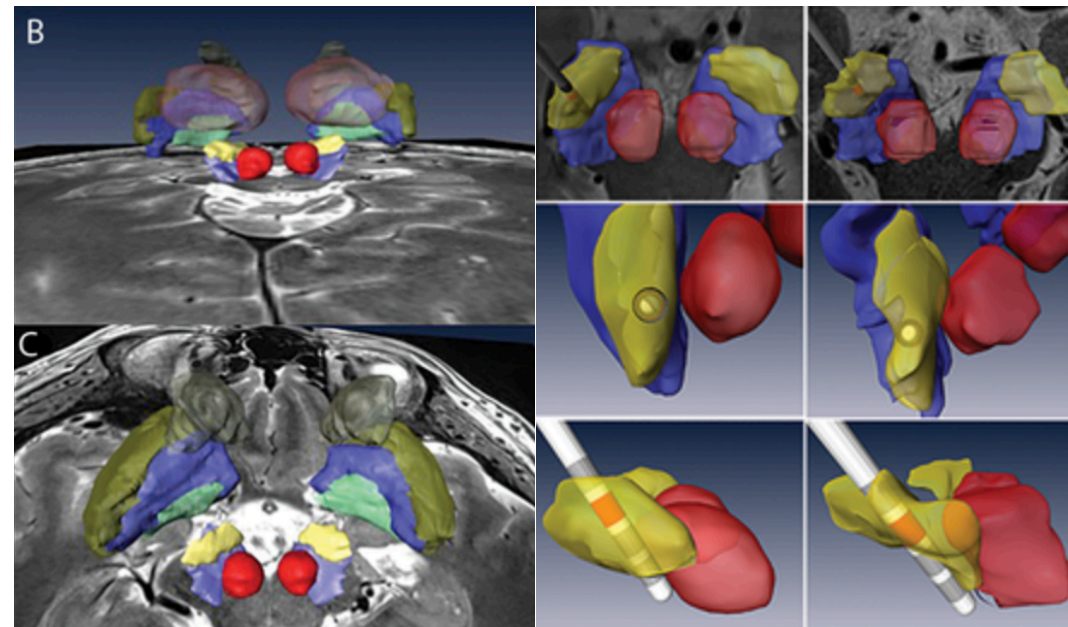
- 7T MRI can be used to create detailed maps of subcortical structures.
- 7T can also deliver unprecedented detail via *ex vivo* brain mapping (100 μ m resolution)



Maruyama, et al. 2019; Edlow, et al. 2019

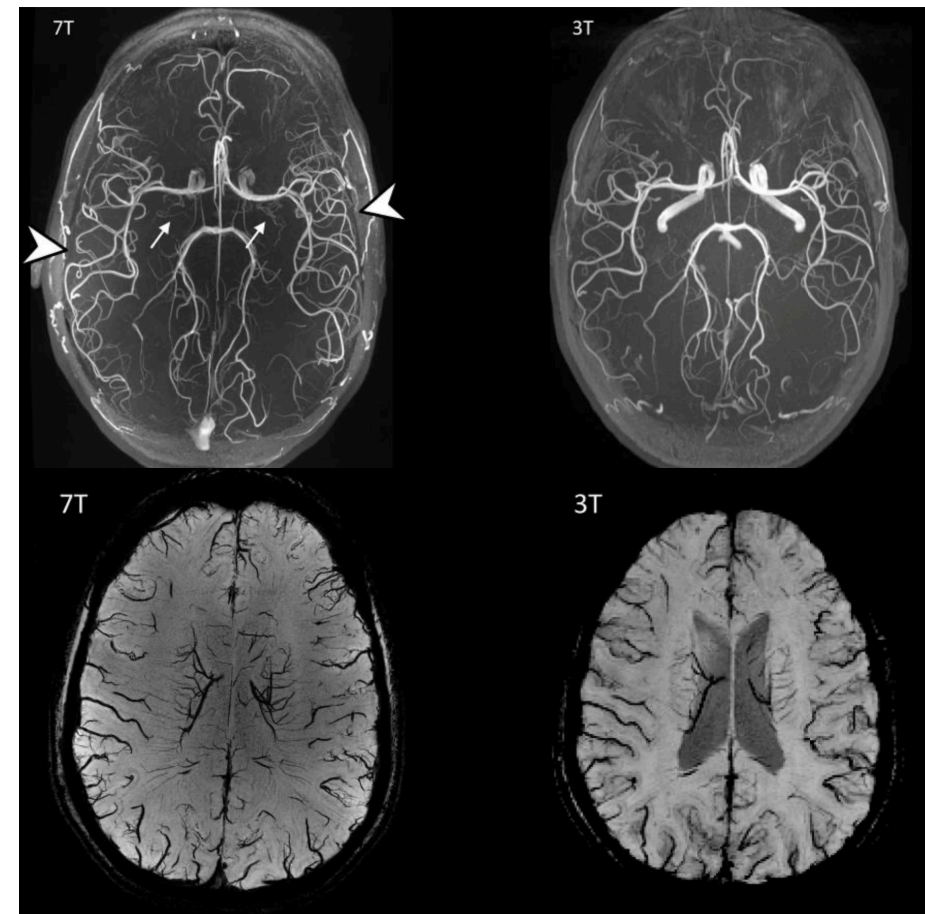
Clinical Use of 7T MRI

- 7T MRI is used in cases where high resolution is important for accurate diagnosis and treatment
- One example is surgical planning and confirmation of deep brain stimulation. This requires accurate differentiation of subthalamic nuclei from the substantia nigra.

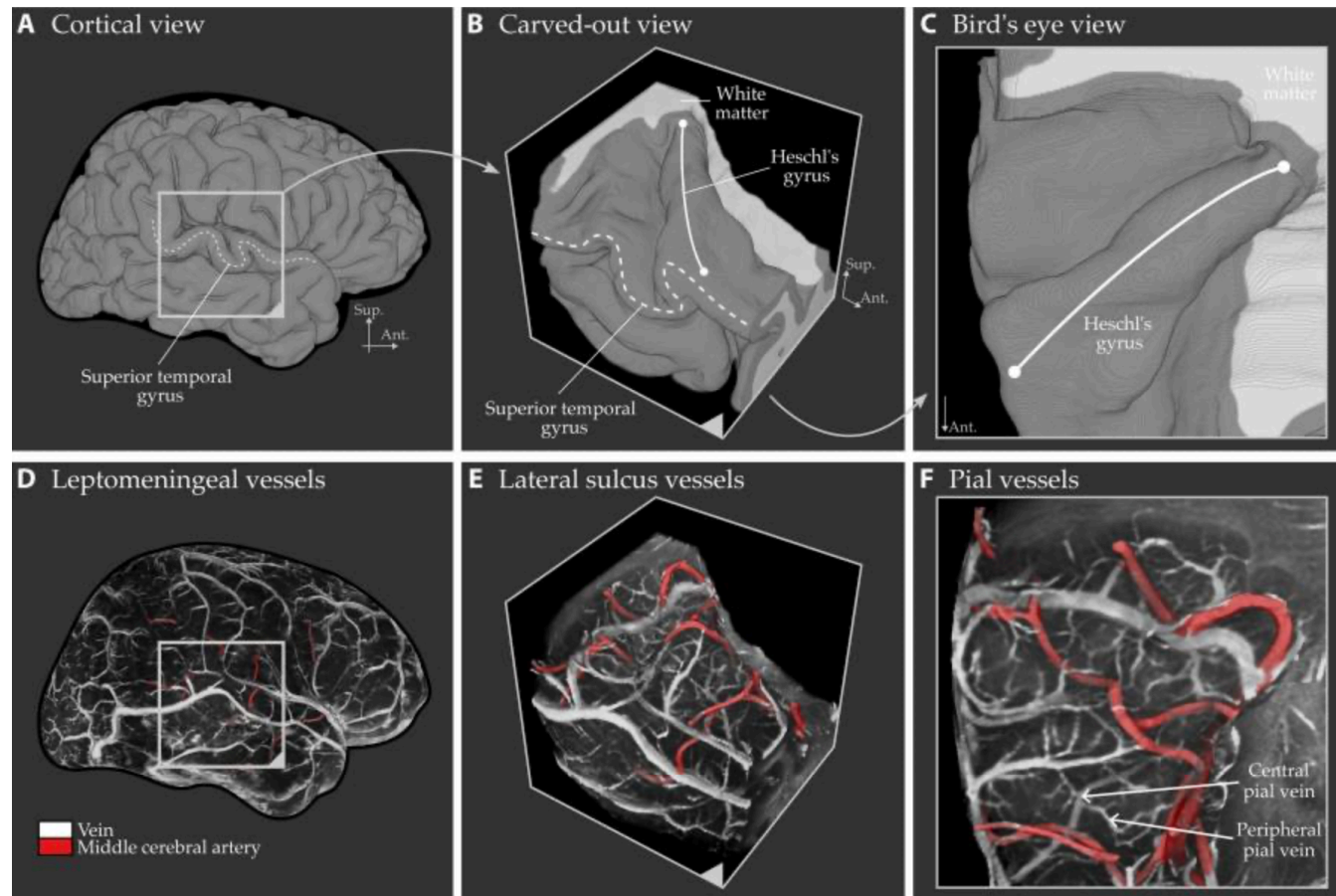


Clinical Use of 7T MRI

- 7T MRI is used in cases where high resolution is important for accurate diagnosis and treatment
- Other examples include stroke and small vessel disease, where the increased detail provided by 7T MRI can be very informative



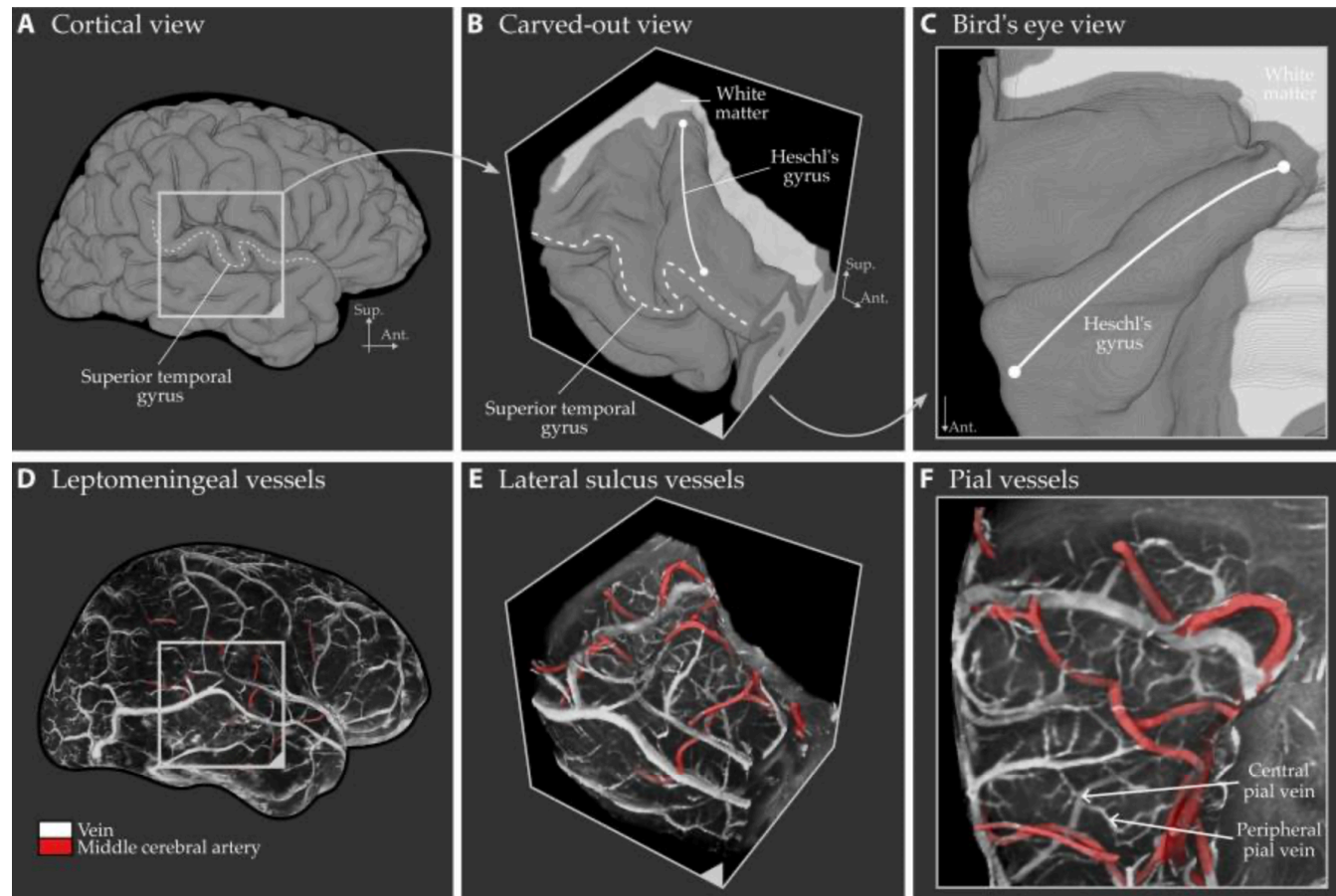
Mesovein protocols



Gulban, et al. 2026

Mesovein protocols

- Vascular protocols can also be used for neuroscientific questions
- Increasingly detail maps of arteries and veins is helping us better interpret fMRI signals by examining their sources



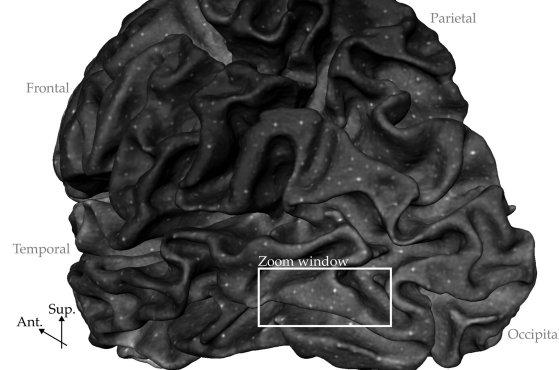
Gulban, et al. 2026

Mesovein protocols

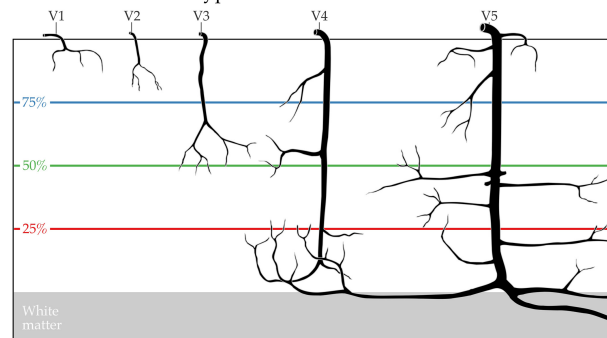
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A Lateral-posterior view cortical surface

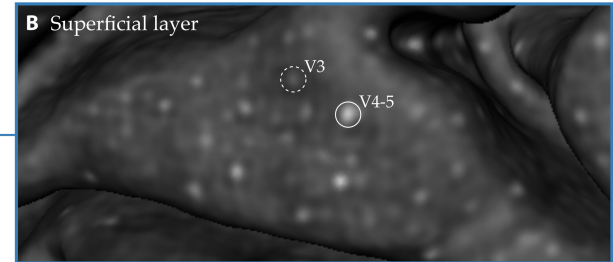
$1/T_2^*$ w contrast
Cortical depth 50%
(mid-thickness)



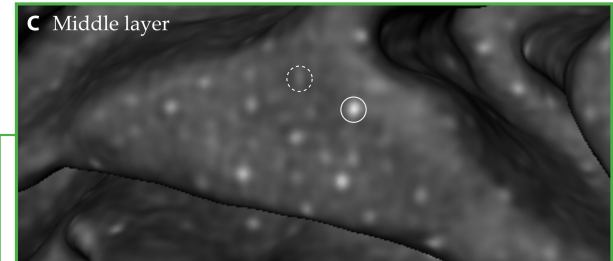
E Intracortical vein types



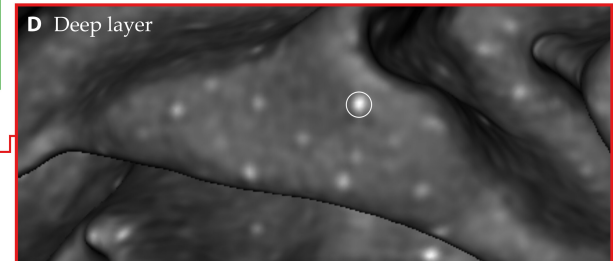
B Superficial layer



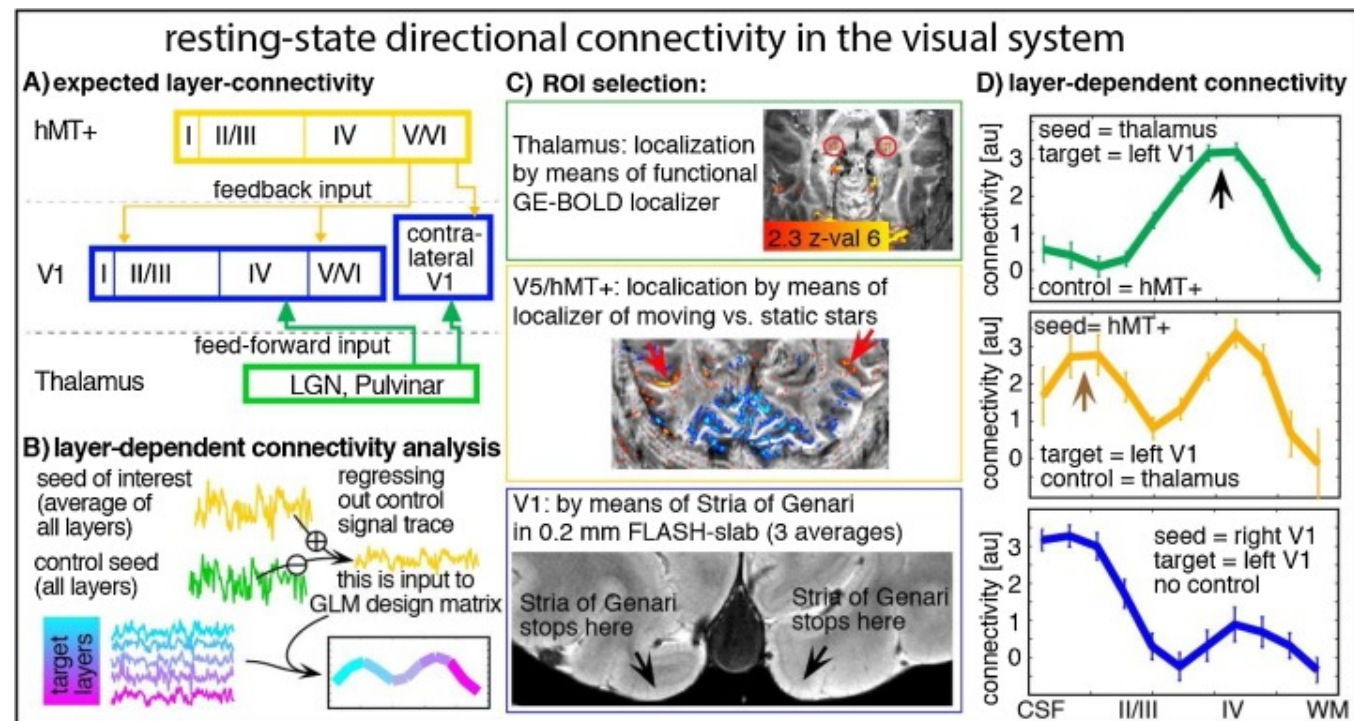
C Middle layer



D Deep layer

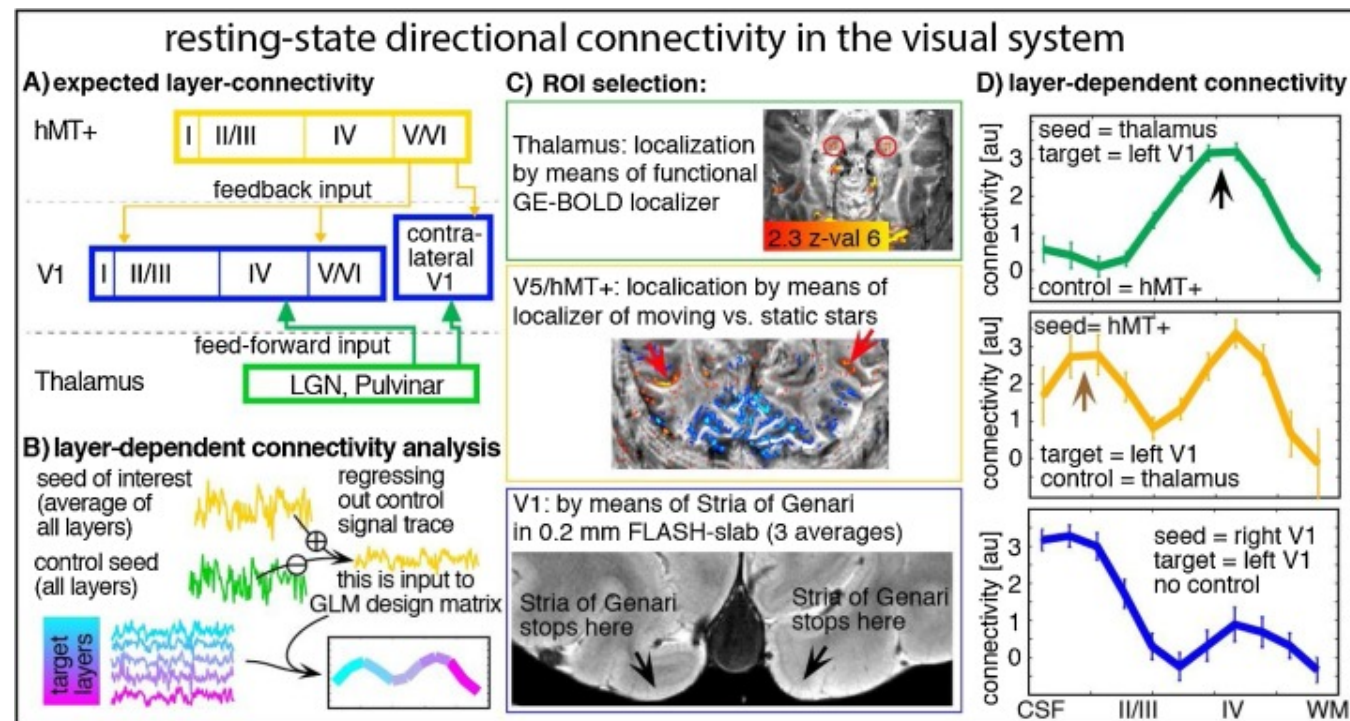


The Promise of Layer fMRI



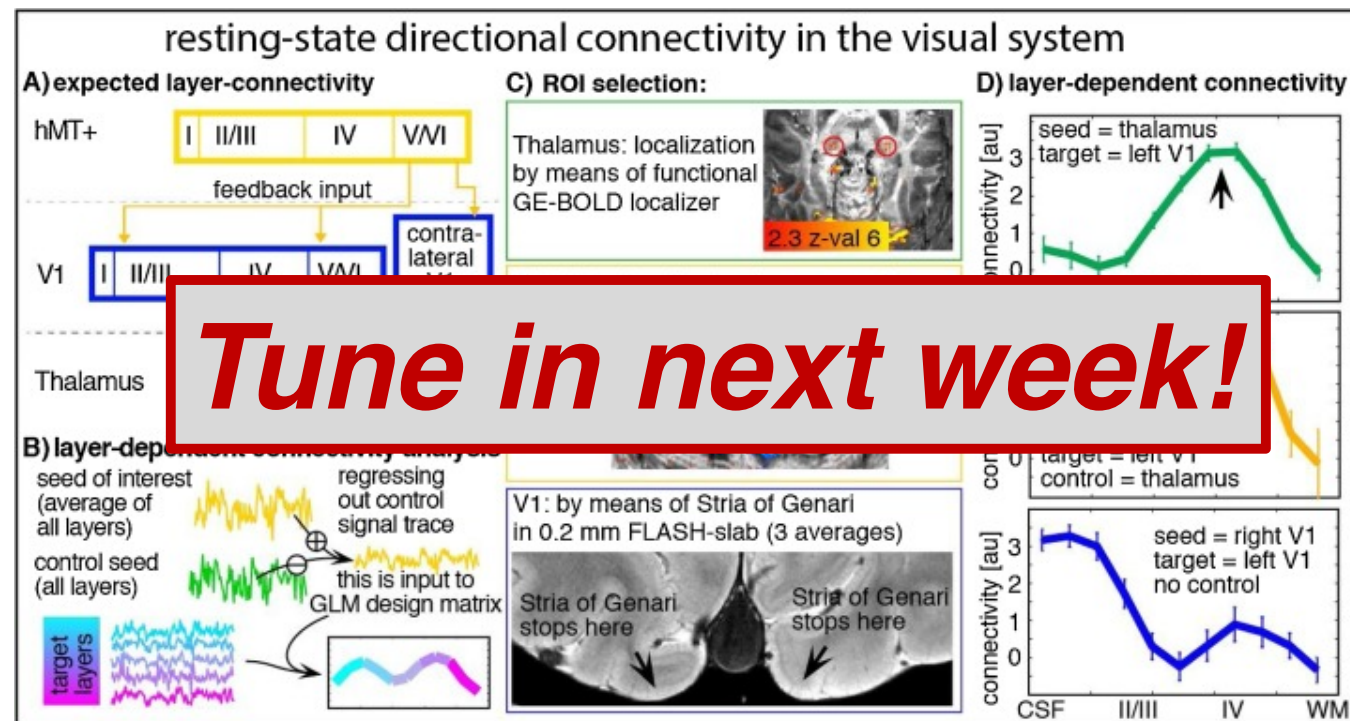
The Promise of Layer fMRI

- There is a lot of excitement surrounding the field of Layer fMRI.
- One of the most promising areas is the idea that layer-specific connectivity patterns may provide clues to the direction of information flow in the human brain...



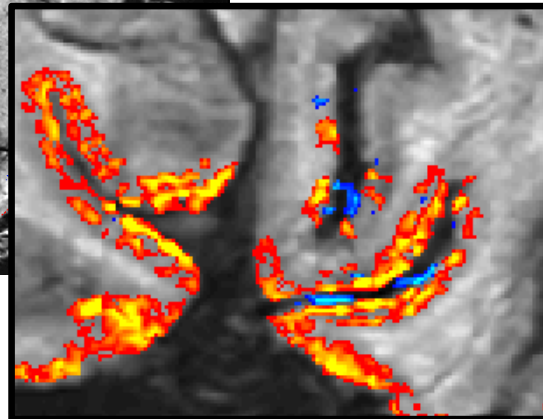
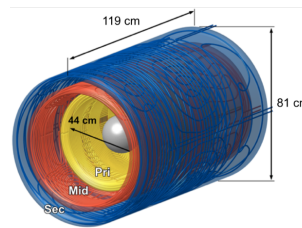
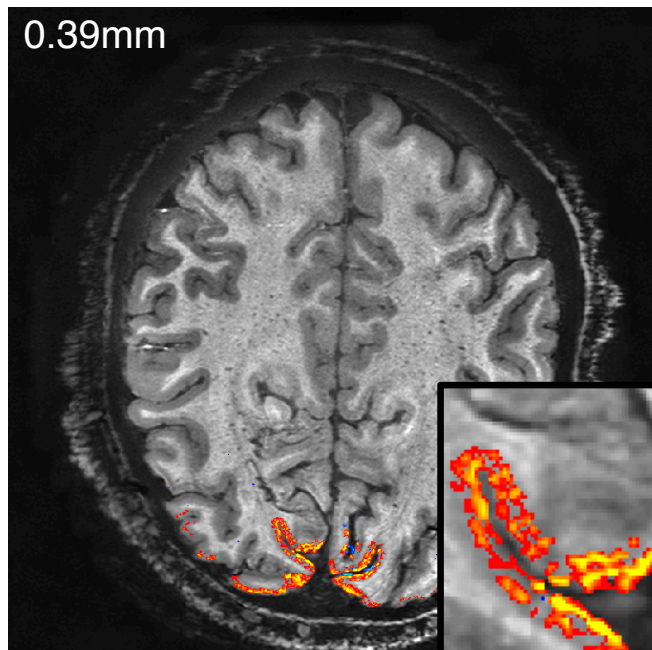
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Tune in next week!

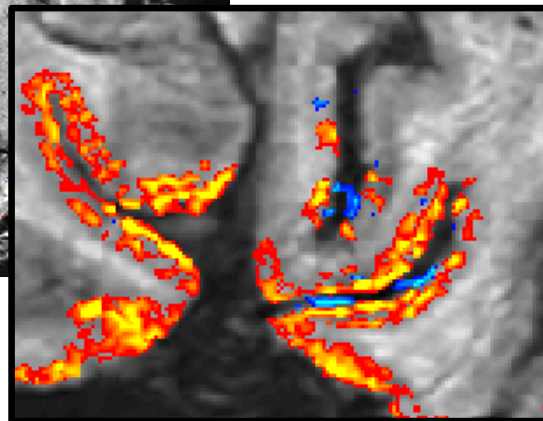
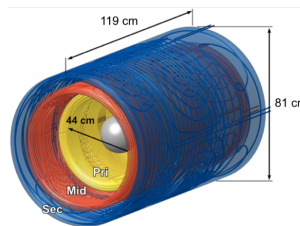
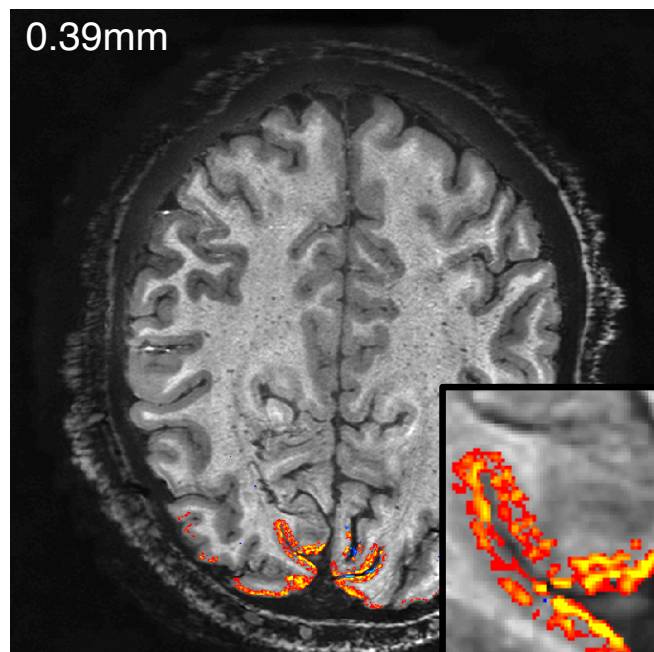
Future Steps to Improve 7T fMRI



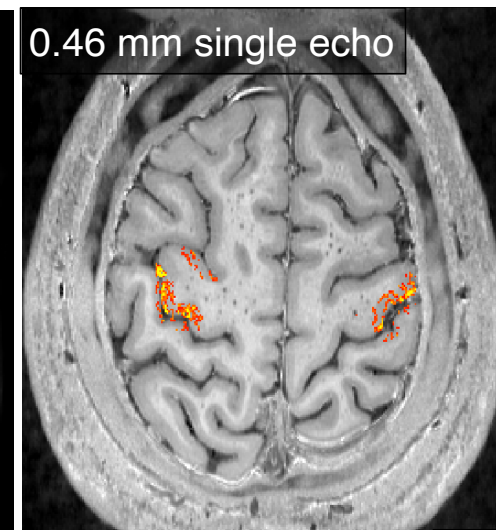
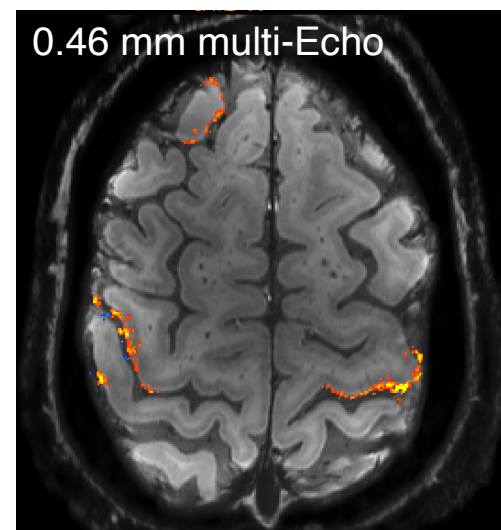
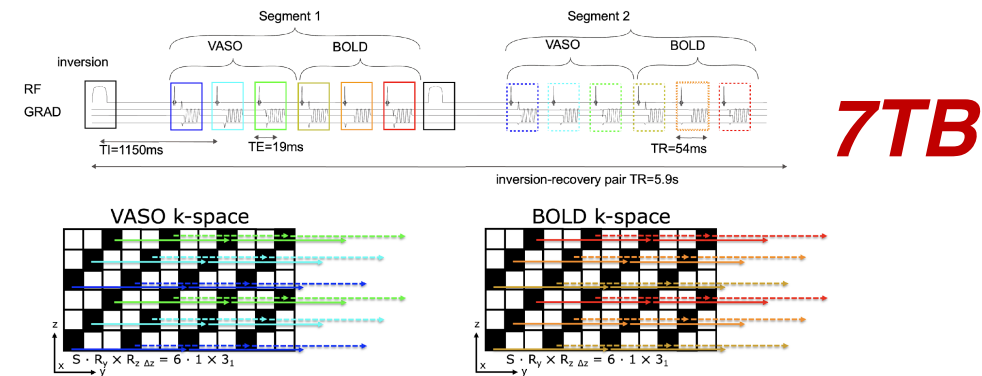
NexGen 7T
UC Berkley

Feinberg, et al. 2023; Huber, et al. 2026

Future Steps to Improve 7T fMRI



NexGen 7T
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Feinberg, et al. 2023; Huber, et al. 2026

High Resolution fMRI Educational Resources

- ISMRM Conference
- ISMRM Brain Function & High Field Study Groups
- Layer fMRI Journal Club (<https://layerfmri.com/seminar/>)
- Layer fMRI Dinners (<https://layerfmri.com/dinners/>)

Cape Town - 2026 ISMRM-ISMRT Annual Meeting and Exhibition - 09-14 May 2026

Plenary Session
Mesoscale MRI

[← Back to the Program-at-a-Glance](#)

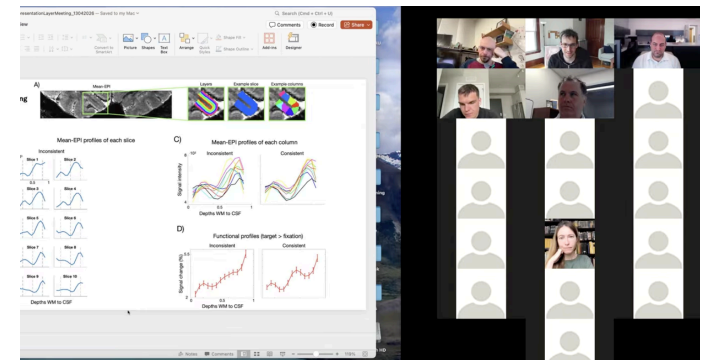
Mesoscale MRI

Plenary Session

Plenaries

Wednesday, 13 May 2026

Plenary Hall (Halls 8-10) CTICC 2	11:10 - 12:10	Moderators: Berkin Bilgic & Christopher Nguyen & Wietske Van der Zwaag
Session Number: 520-02		No CME/CE Credit



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