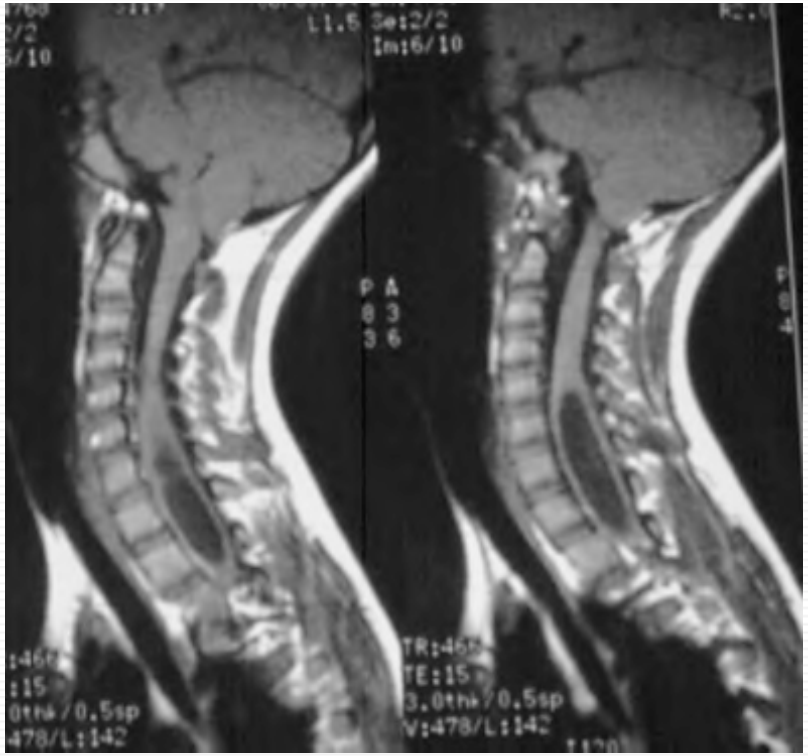
IMAGE QUALITY / ARTIFACTS

Syringomyelia



Source http://gait.aidi.udel.edu/res695/homepage/pd_ortho/educate/clincase/syrsco.htm

Surgery is usually recommended for syringomyelia patients. The main goal of surgery is to provide more space for the cerebellum (Chiari malformation) at the base of the skull and upper neck, without entering the brain or spinal cord. This results in flattening or disappearance of the primary cavity. If a tumor is causing syringomyelia, removal of the tumor is the treatment of choice and almost always eliminates the syrinx.

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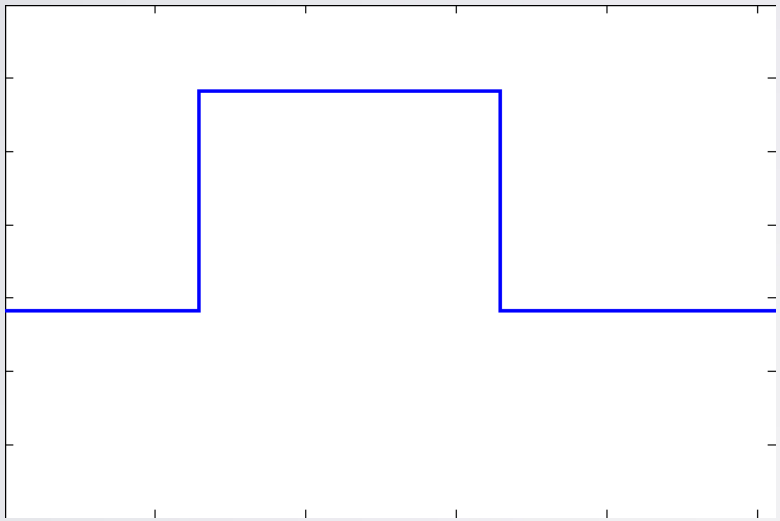
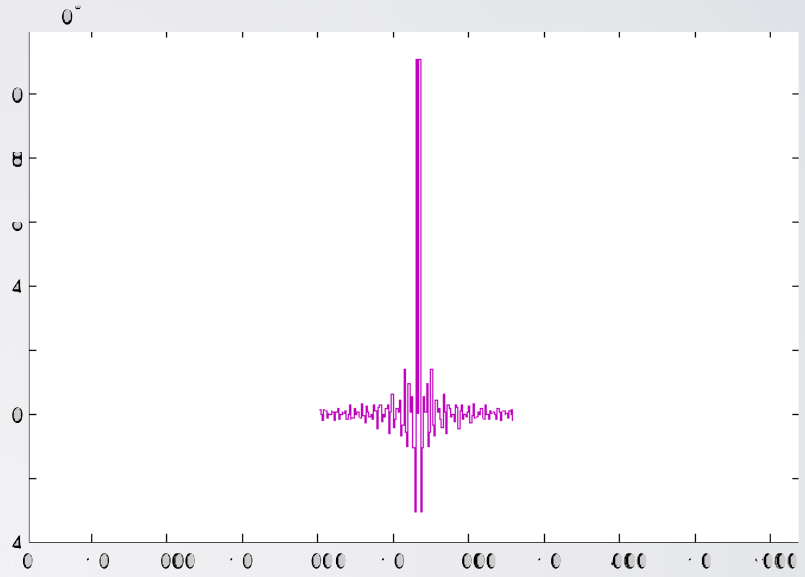
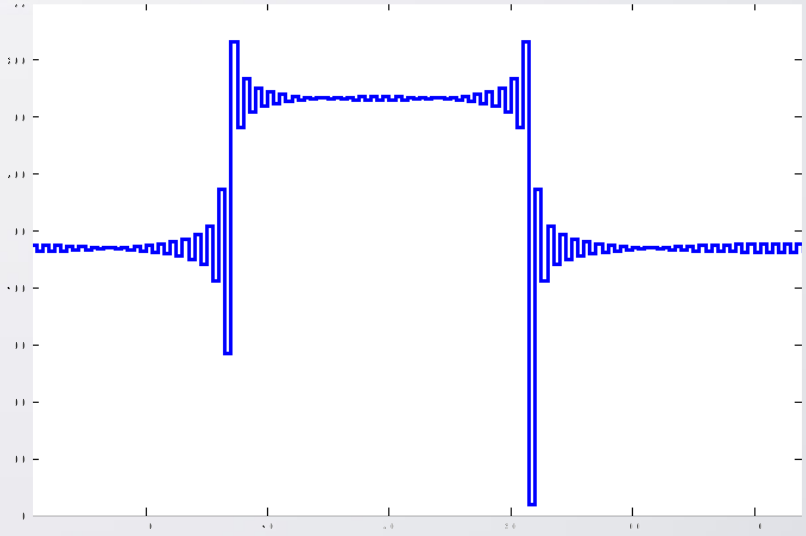
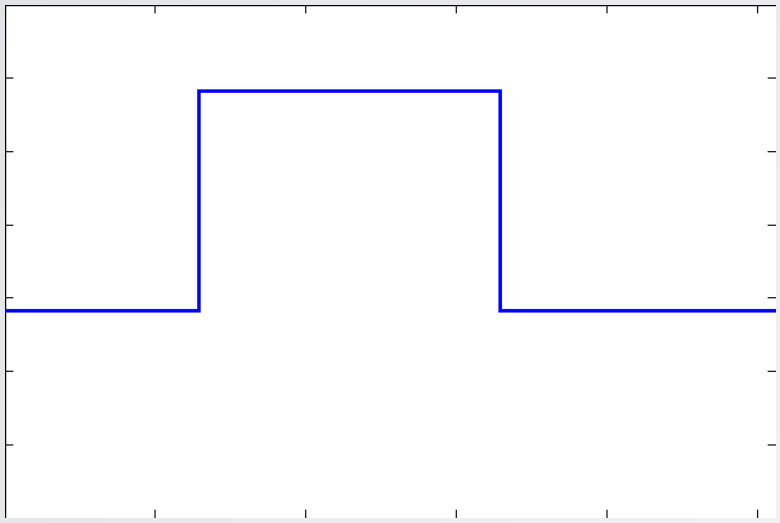
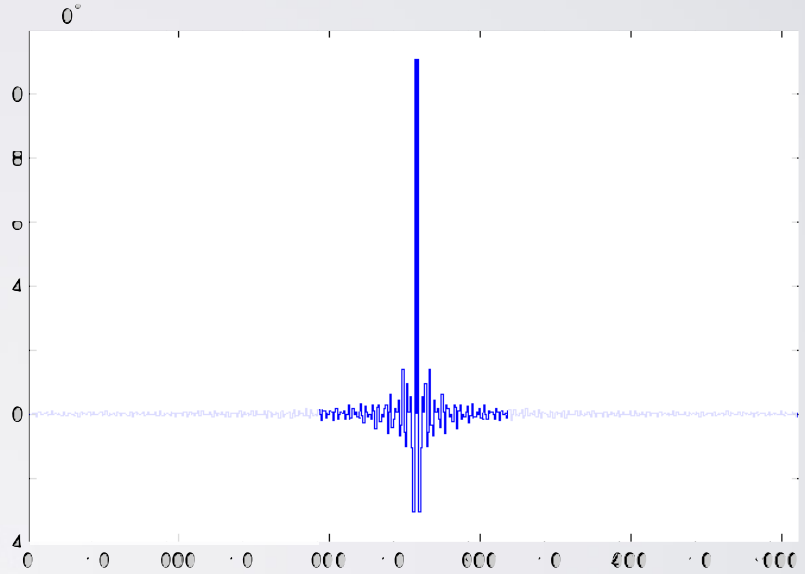




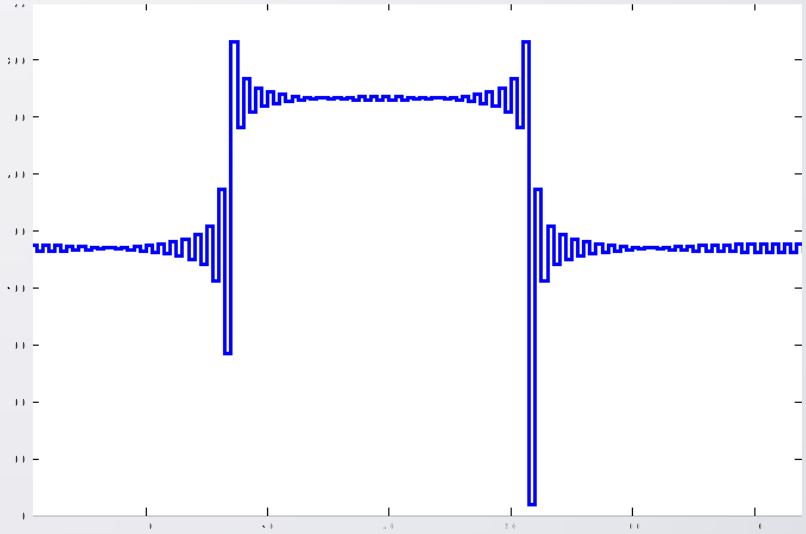
Truncating the Fourier Data Results in Distortions (edge ringing) of High Spatial Frequencies



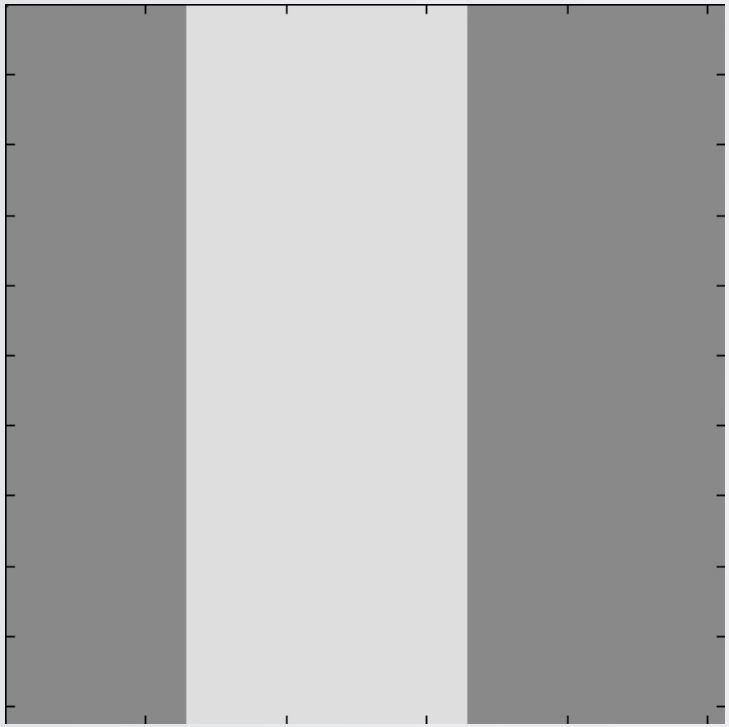




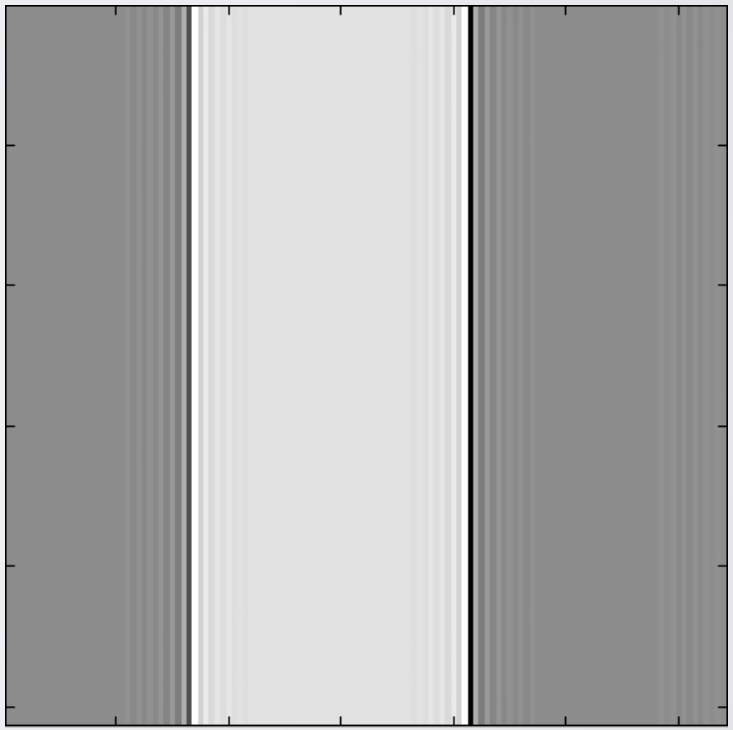
This is equivalent to sampling only a portion of the raw data.



TRUNCATED RAW DATA

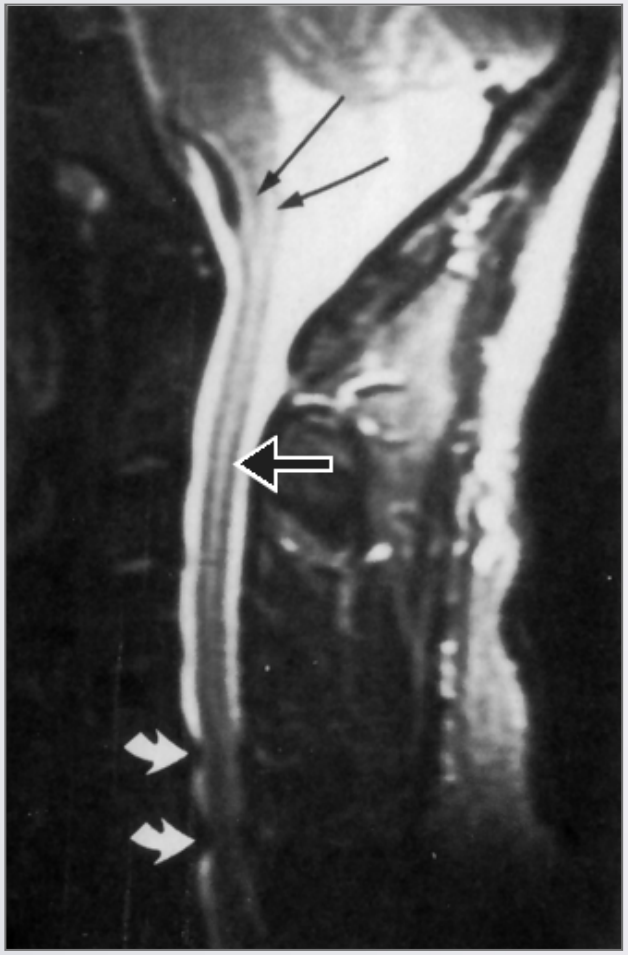


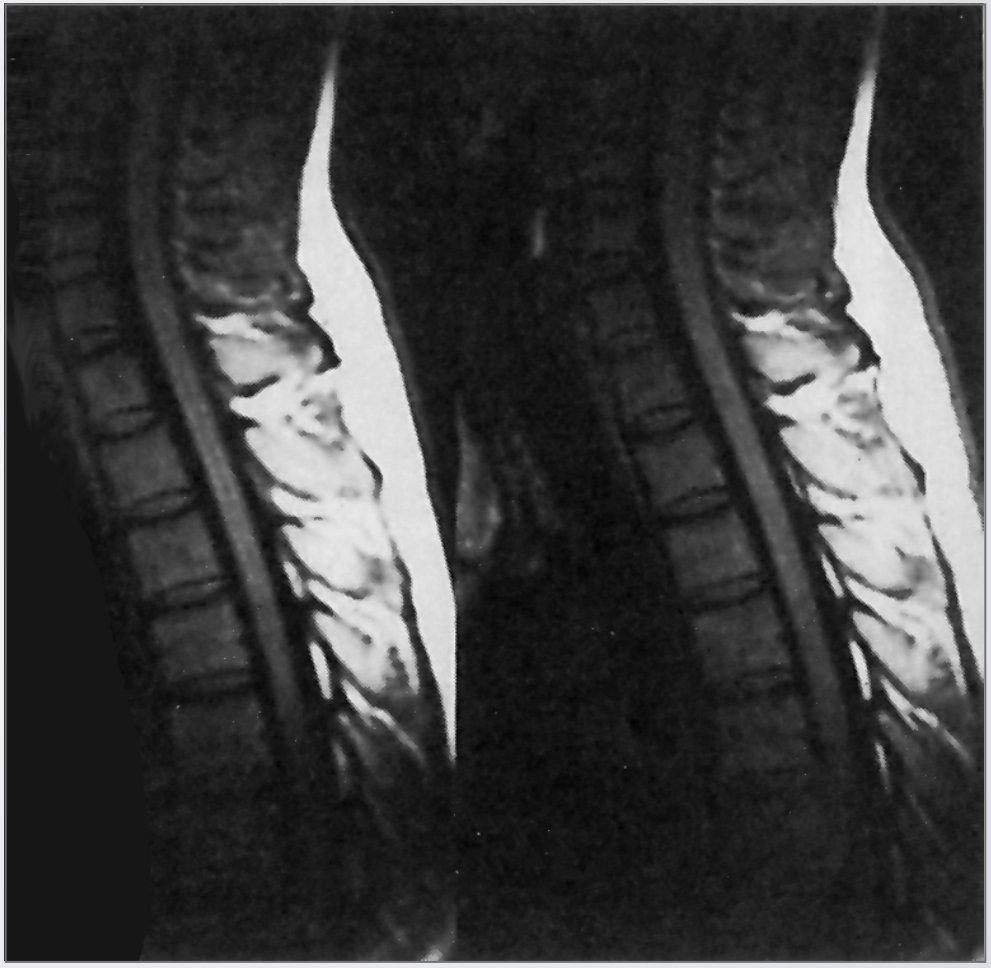
Actual Object



MR Image

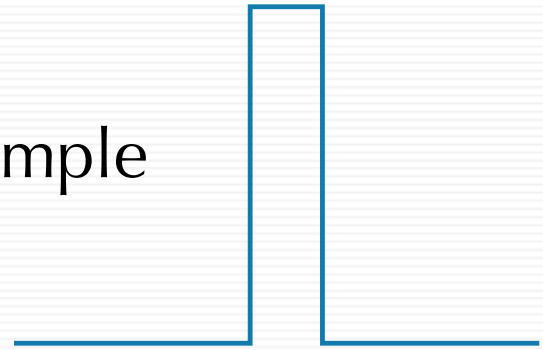
THE SYRINGOMYELIA EPIDEMIC





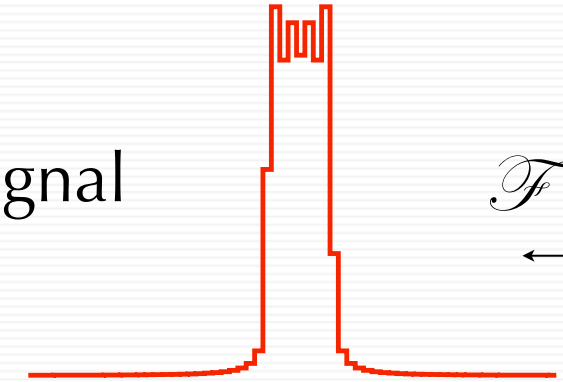
Truncation in Fourier Domain

Original Sample



Frequency-encoded Signal

Apparent Signal



$\mathcal{F}^{-1}(s)$

Truncated Series

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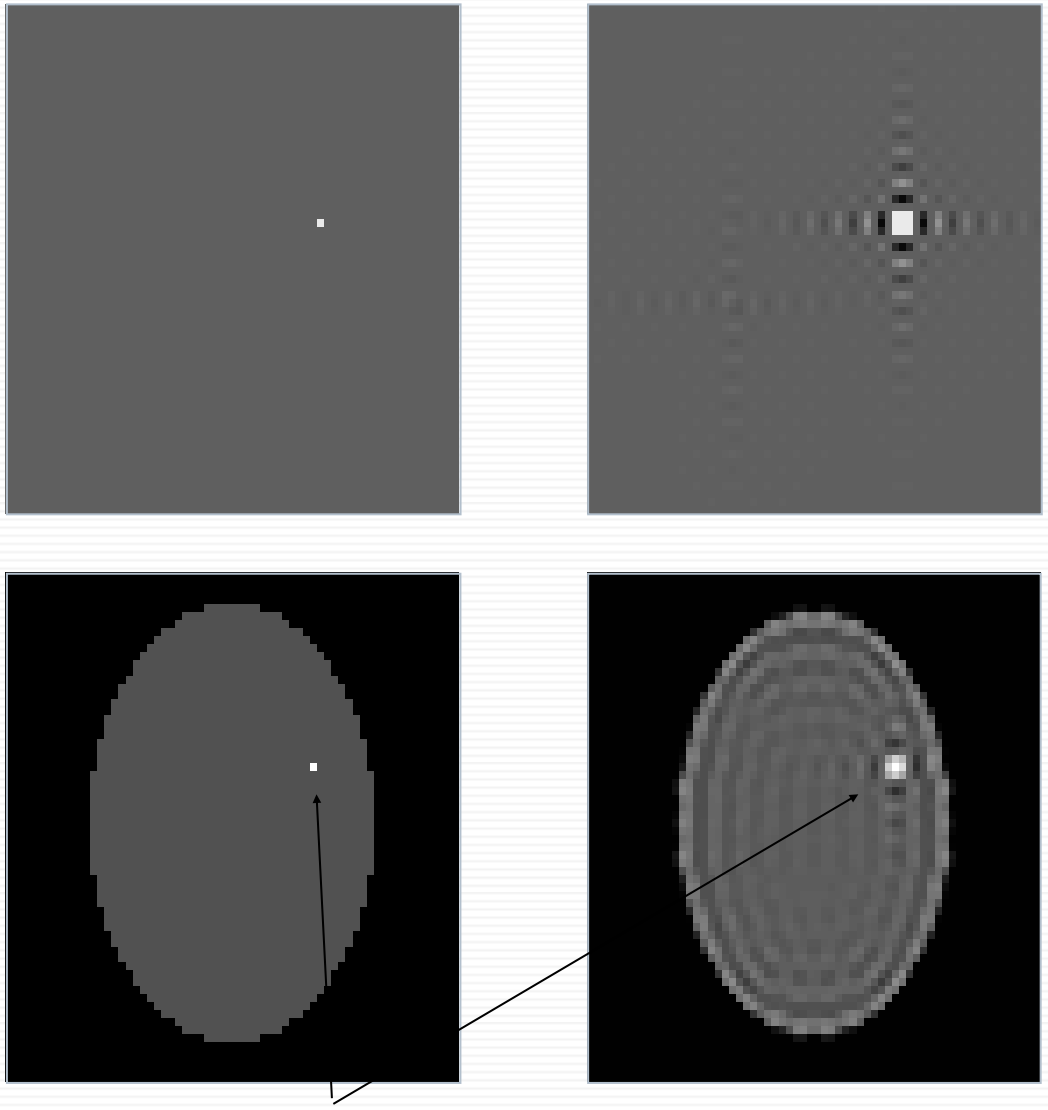
What is the actual resolution of MRI?



Original Data

MR Image

Single pixel “activation”

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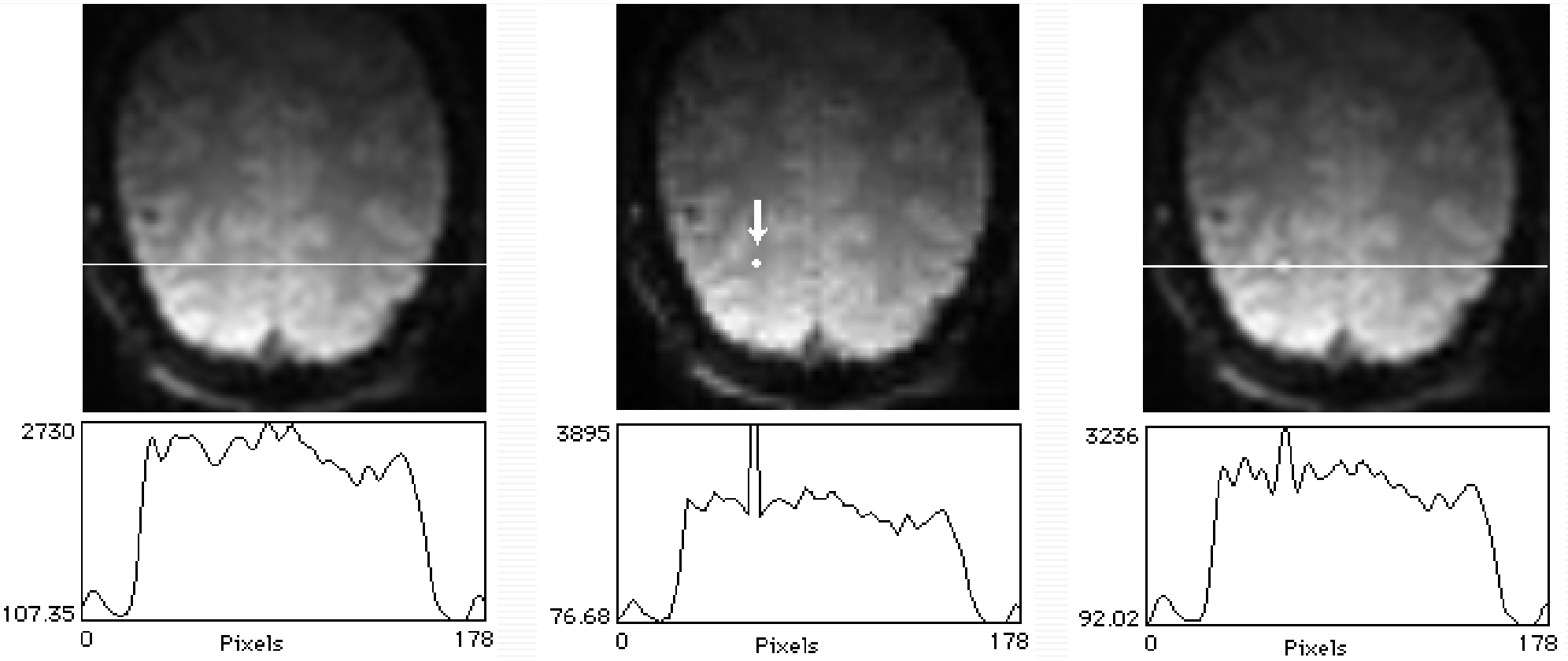
The Actual Resolution of *f*MRI



http://ccn.ucla.edu/BMCweb/SharedCode/MRArtifacts/MRArtifacts.html

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An "Equation" in Resolution

Because MR is an emission modality the temporal resolution, spatial resolution and contrast are inter-dependent:

$$\text{Signal} = kB_0(\text{voxel size})\sqrt{\text{imaging time}}$$
$$-\text{contrast}$$

where B_0 is the field strength.

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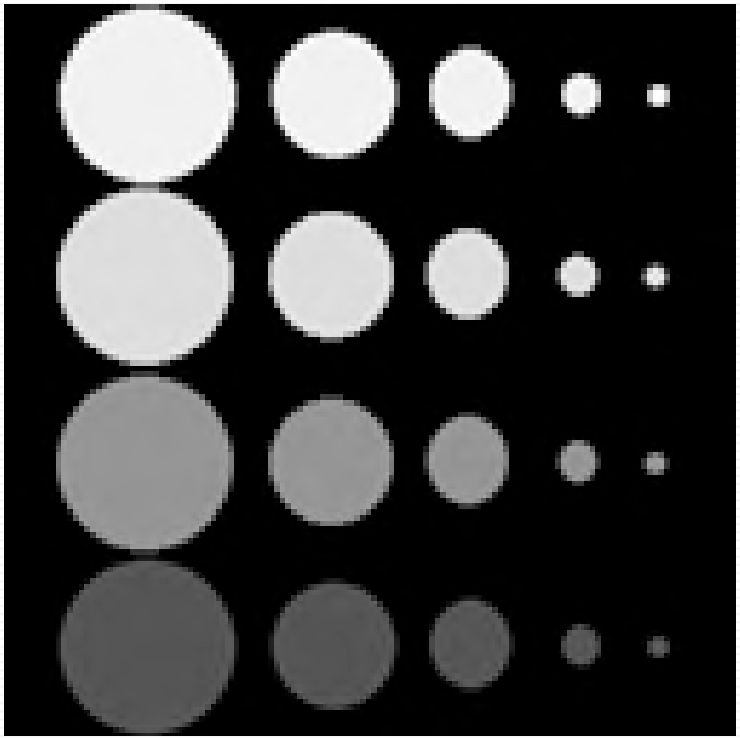
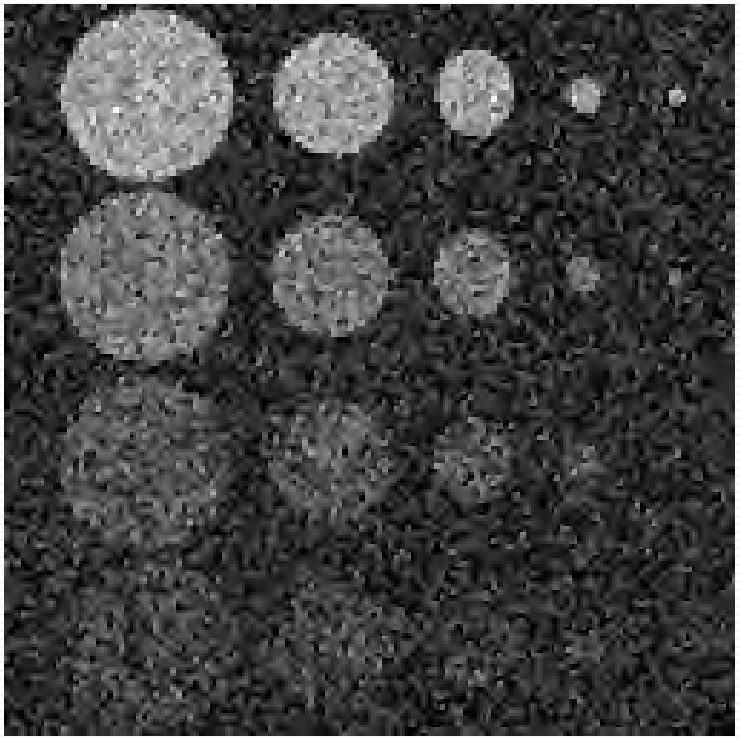
Contrast to Noise Ratio





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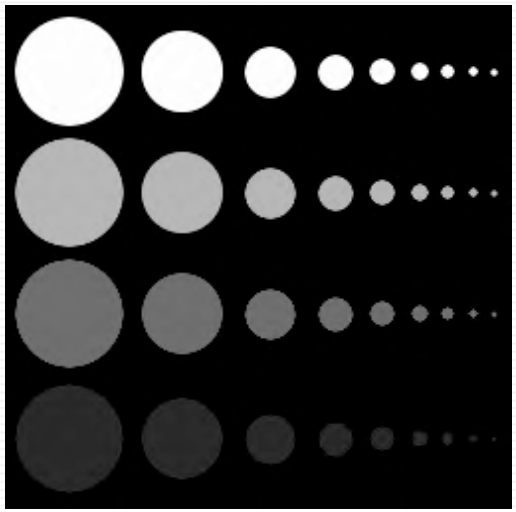
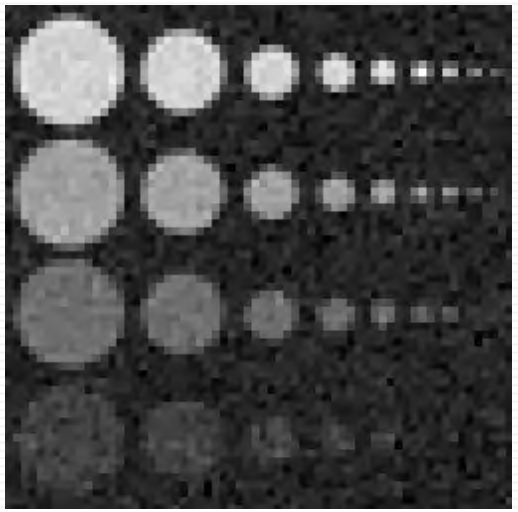
CNR vs. Resolution



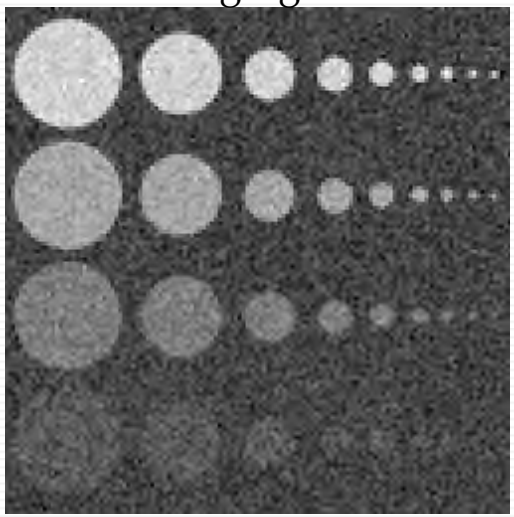
Noise free

Imaging time = 1X



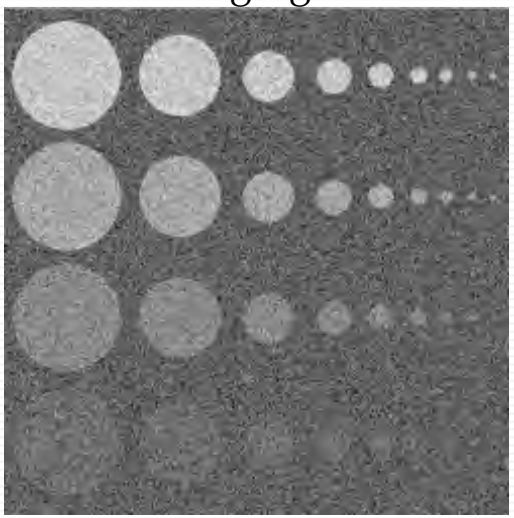
64 X 64

Imaging time = 2X



128 X 128

Imaging time = 4X



256 X 256

Minimum Imaging Time

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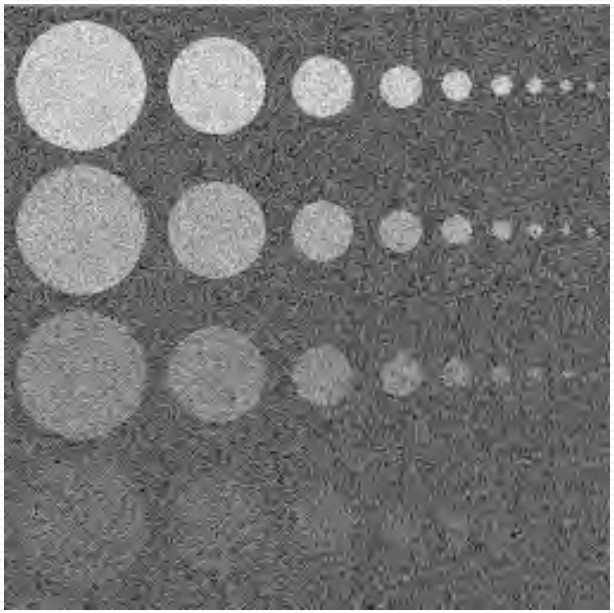
CNR vs. Resolution

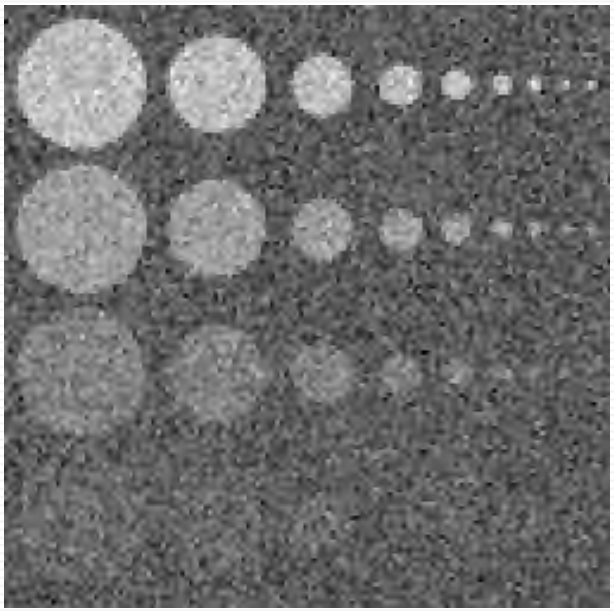
Signal/Noise Ratio Held Constant

256 X 256



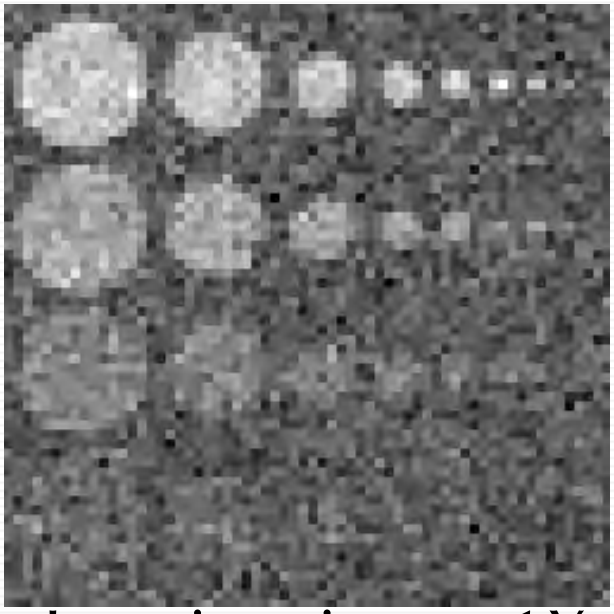
Imaging time = 16X

128 X 128



Imaging time = 4X

64 X 64



Imaging time = 1X

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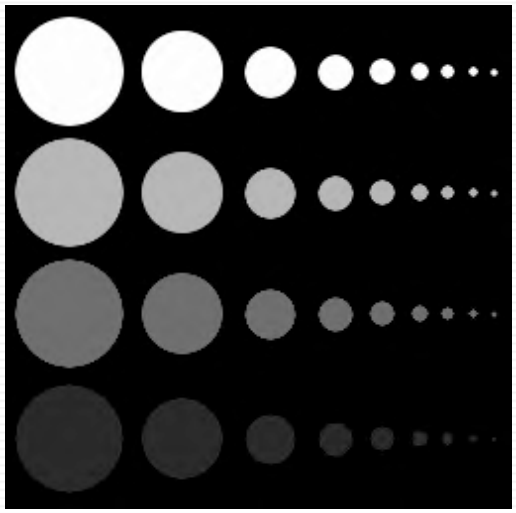
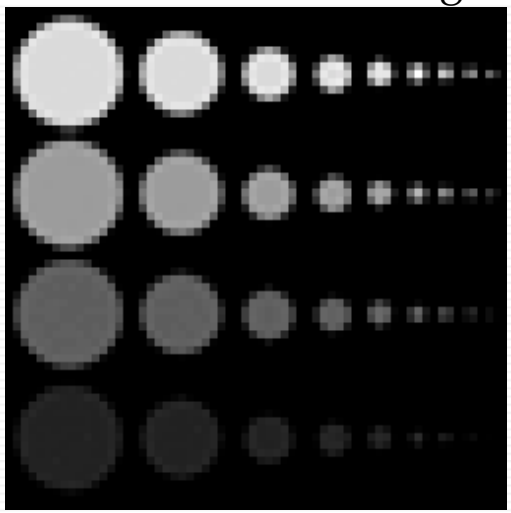
CNR vs. Resolution



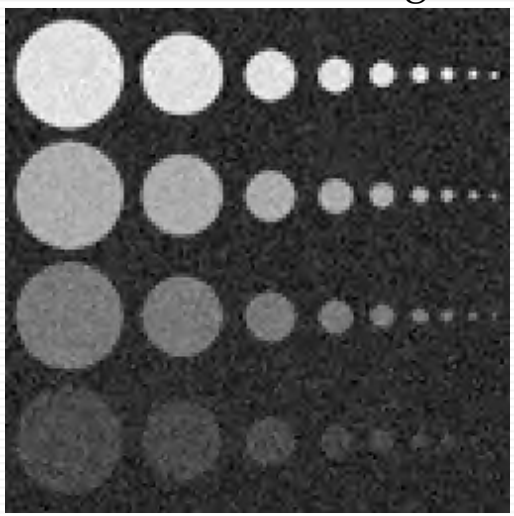
Noise free

16 averages



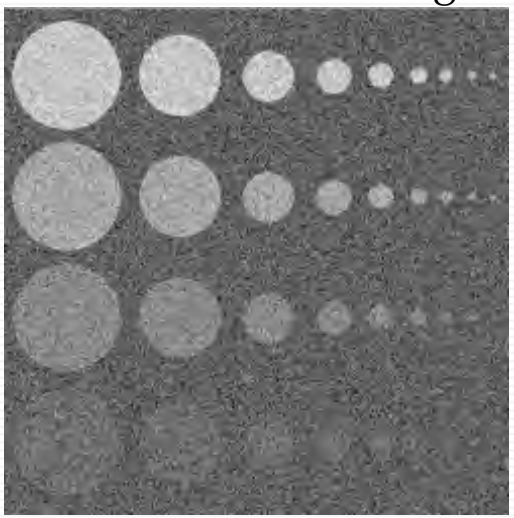
64 X 64

4 averages



128 X 128

1 average



256 X 256

Imaging Time Held Constant

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Bandwidth and Readout

- Position is encoded by FREQUENCY
- Bandwidth refers to the Frequency Difference from the center of the image to its edge:

$$\textit{Frequency per pixel} = \frac{2 * \textit{Bandwidth}}{\textit{number of pixels}} = \frac{1}{\textit{readout duration}}$$

- Bandwidth decreases with readout duration:

$$\textit{Bandwidth} = \frac{\textit{number of pixels}}{2 * \textit{readout duration}}$$

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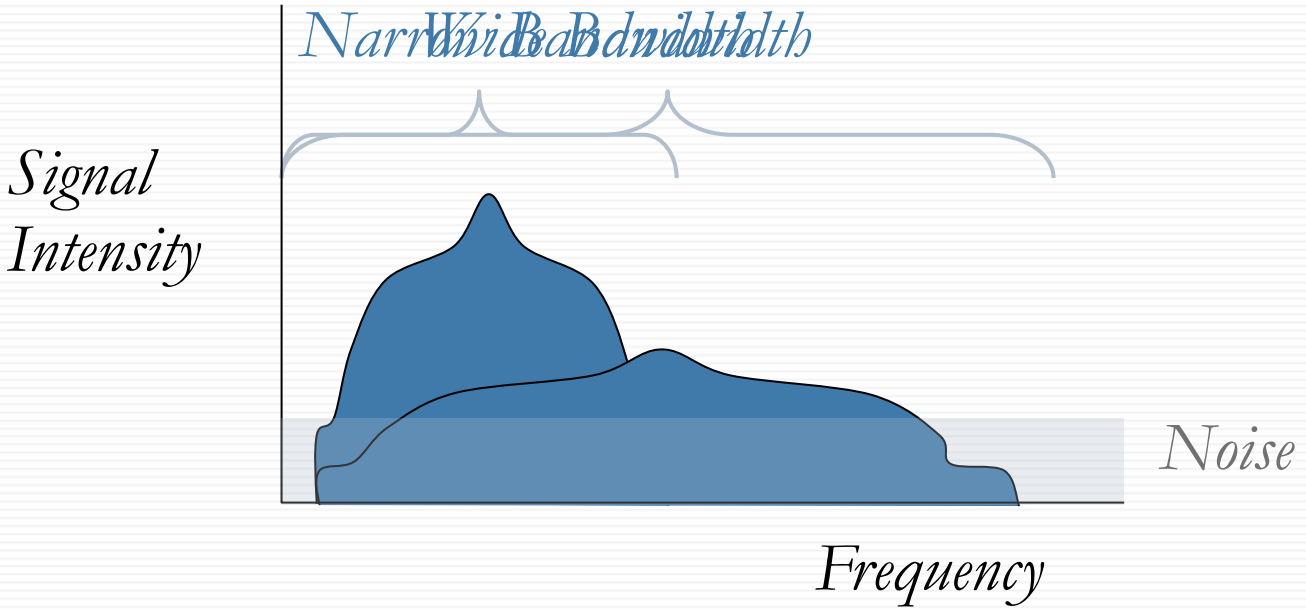
Bandwidth and SNR

Decreasing the Bandwidth Improves SNR:

Imaging Time is INCREASED and high frequency noise is excluded



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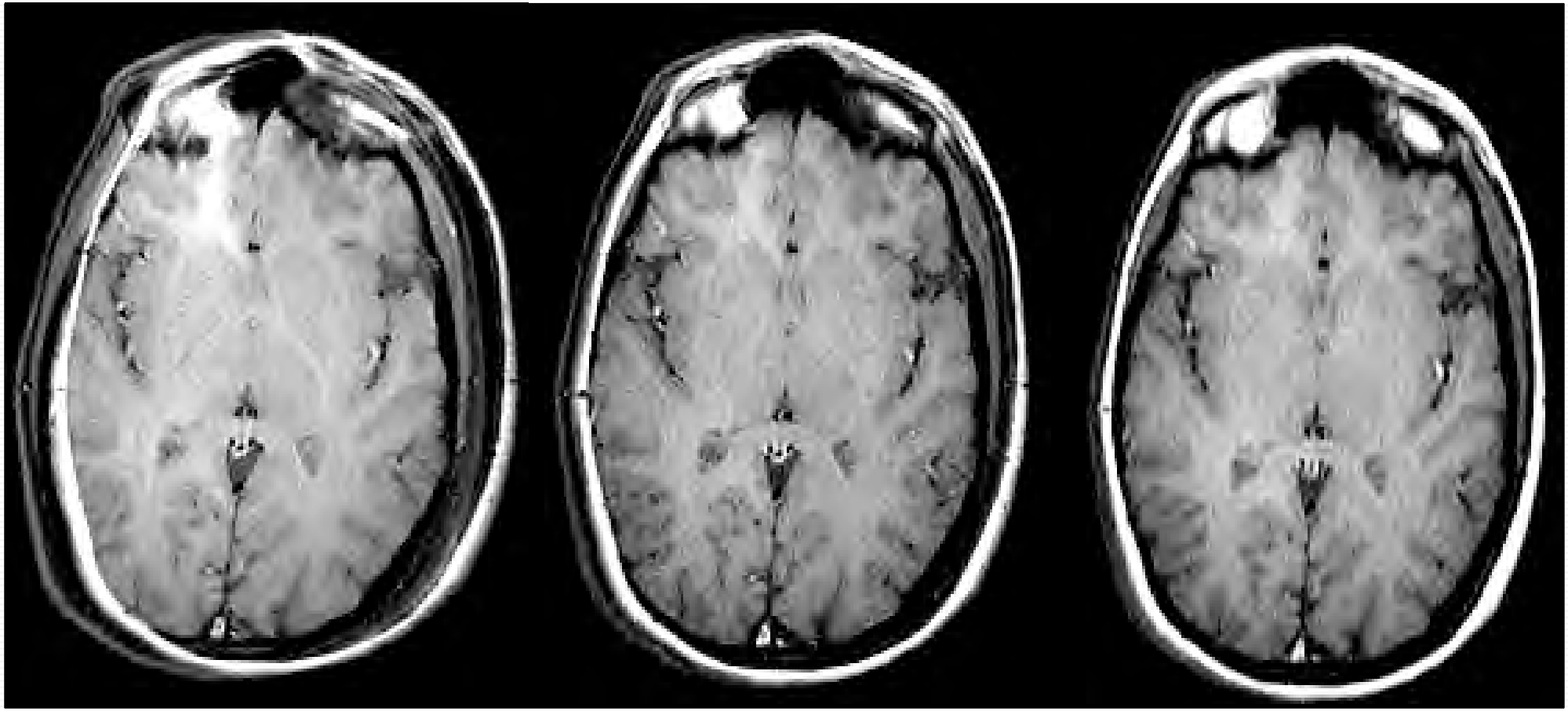
Bandwidth



BW=4kHz

BW=8kHz

BW=16kHz

TE=11-14
TR=500

NEX=1
Matrix=256x256

Thick=3mm

NeuroImaging Training Program

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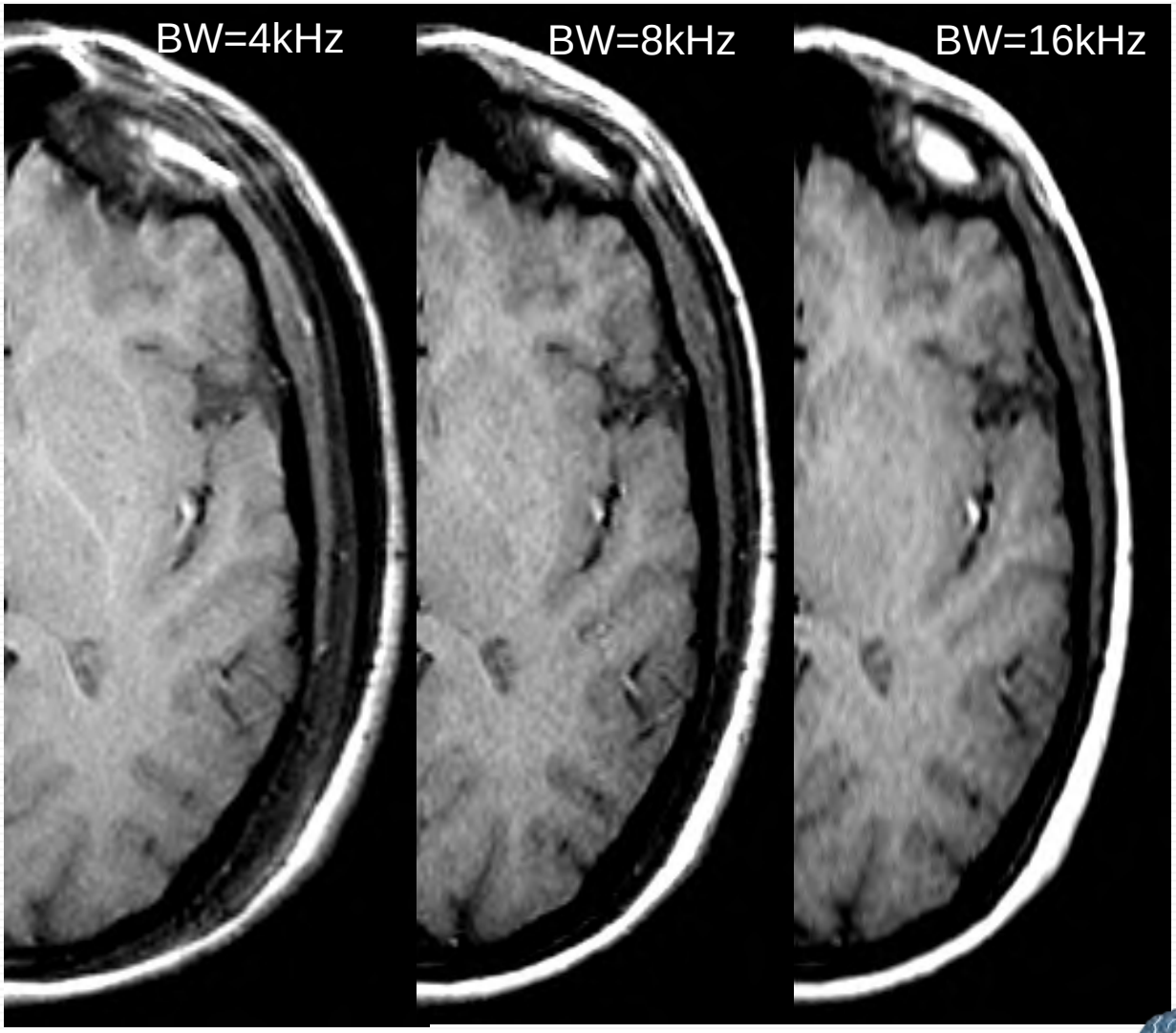
www.brainmapping.org

Center for Cognitive Neuroscience

Bandwidth



TE=11-14
NEX=1
Thick=3mm
TR=500
Matrix=256x256

NeuroImaging Training Program
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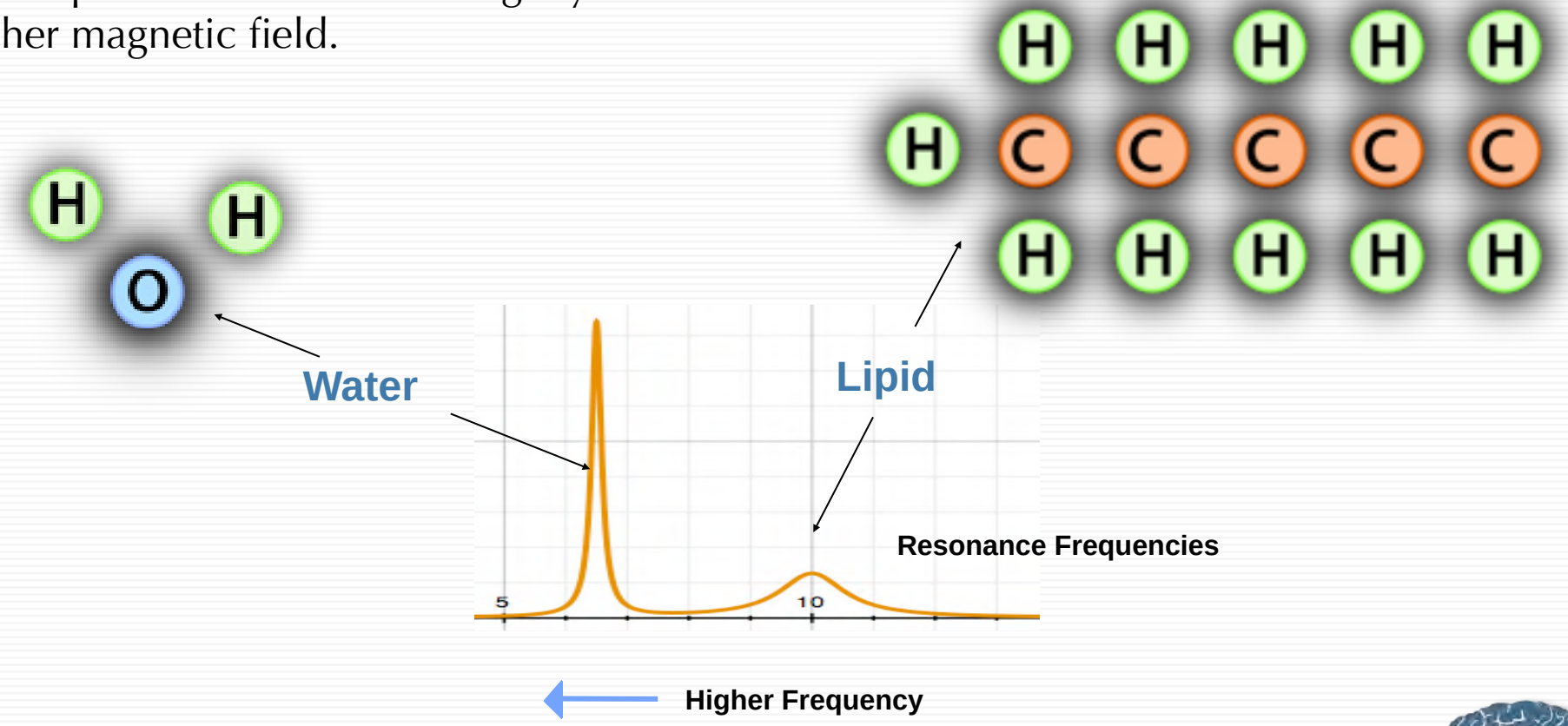
The Origin of Chemical Shift

In water, electrons move from Hydrogen towards Oxygen.

This exposes the Proton to a slightly higher magnetic field.

Electrons in lipid are shared equally between Hydrogen and Oxygen



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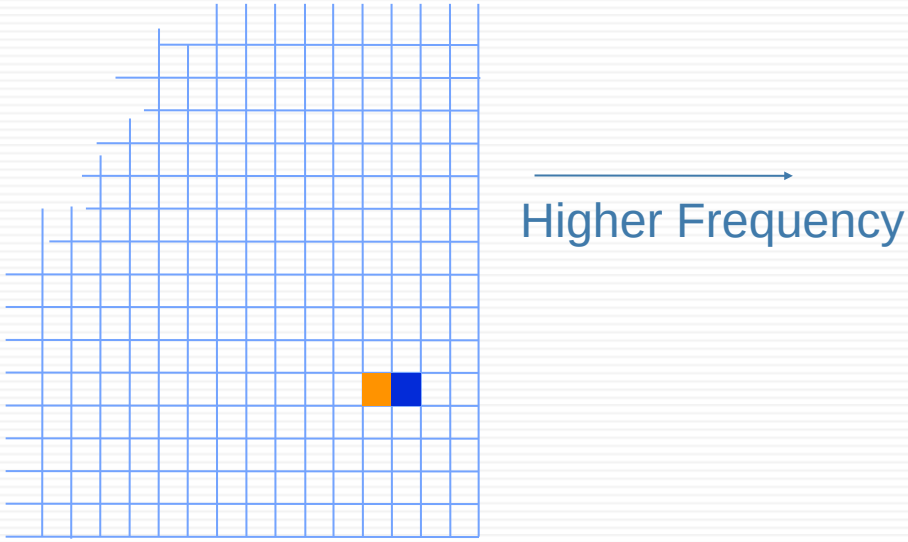
Chemical Shift Artifact



If the frequency *width* of each pixel is less than the frequency *difference* between water and lipid, then water and lipid will appear in separate pixels

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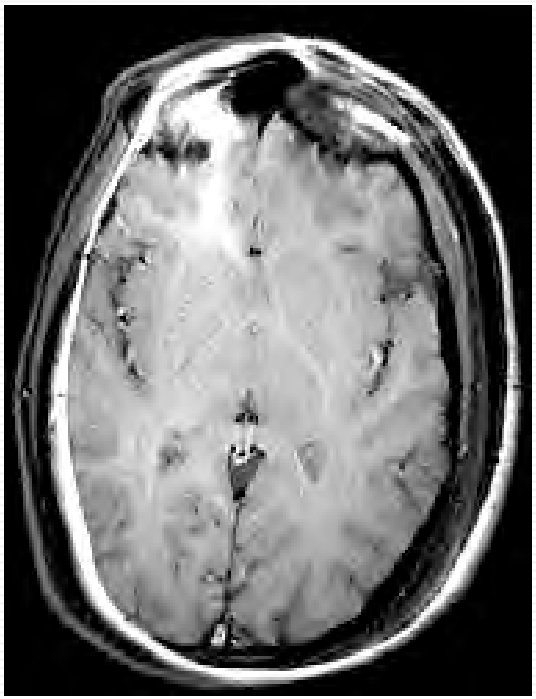
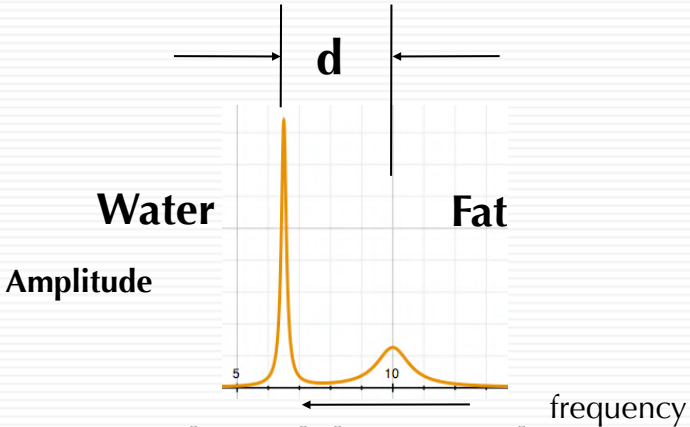
Chemical Shift

The Fat-Water chemical shift is about 3.5 ppm or:

Which is:	*with a 32 kHz readout*
75 Hz @ 0.5 Tesla	< 1 pixel
150 Hz @ 1.0 Tesla	≈ 1 pixel
220 Hz @ 1.5 Tesla	> 1 pixel
440 Hz @ 3.0 Tesla	≈ 3.5 pixels





Lowering the Bandwidth/pixel increases the Chemical Shift in pixels

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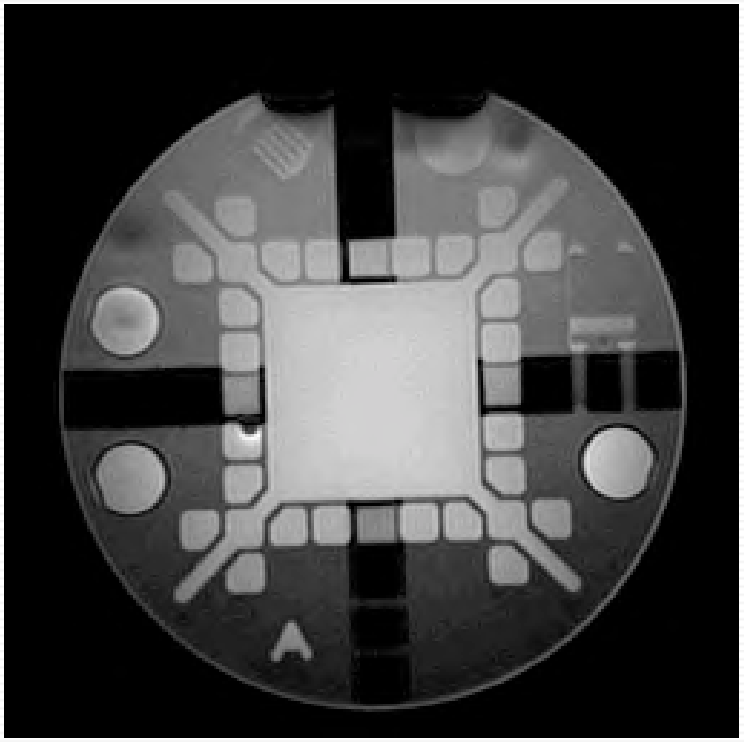
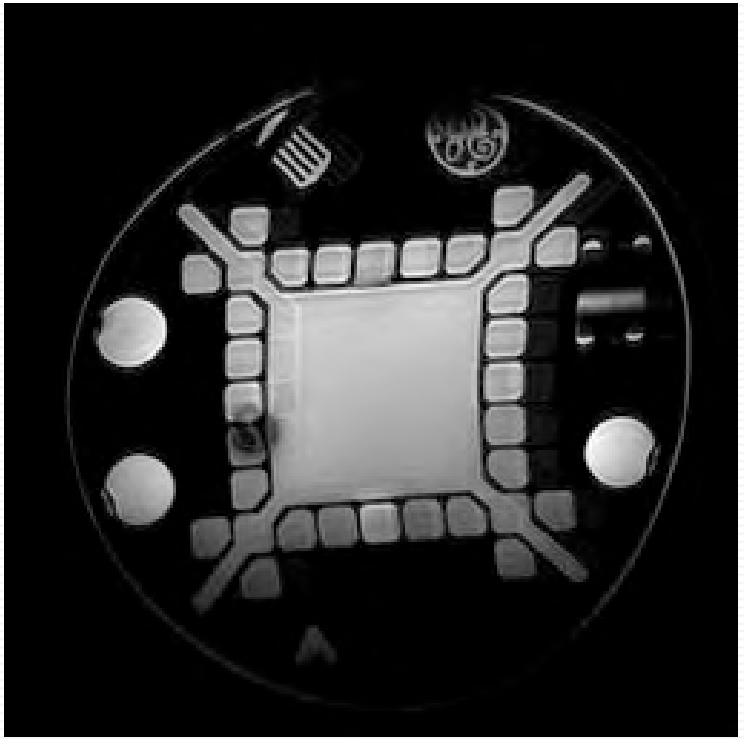
Shape and Bandwidth





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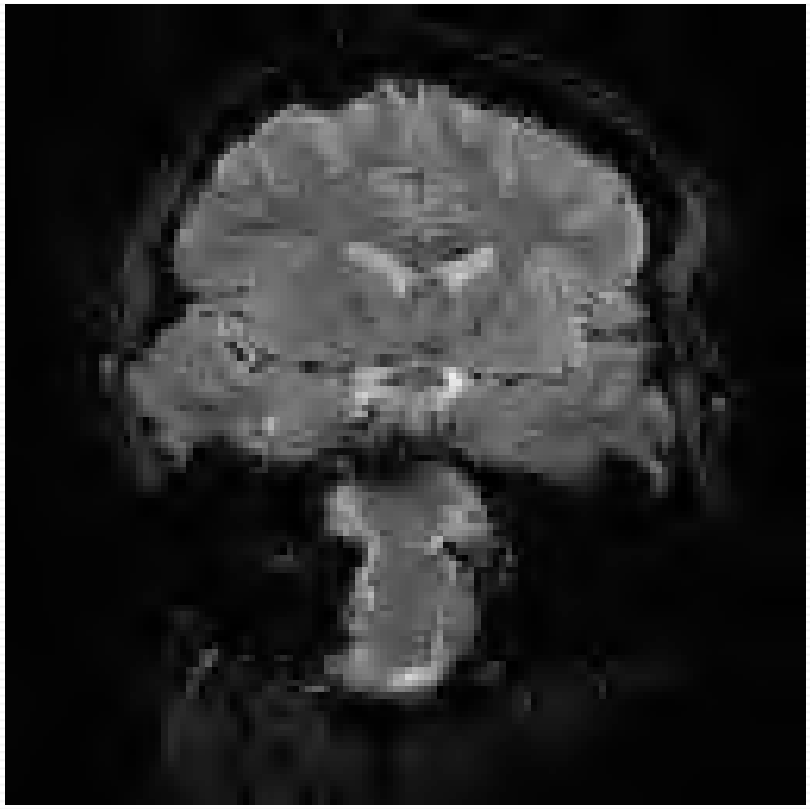
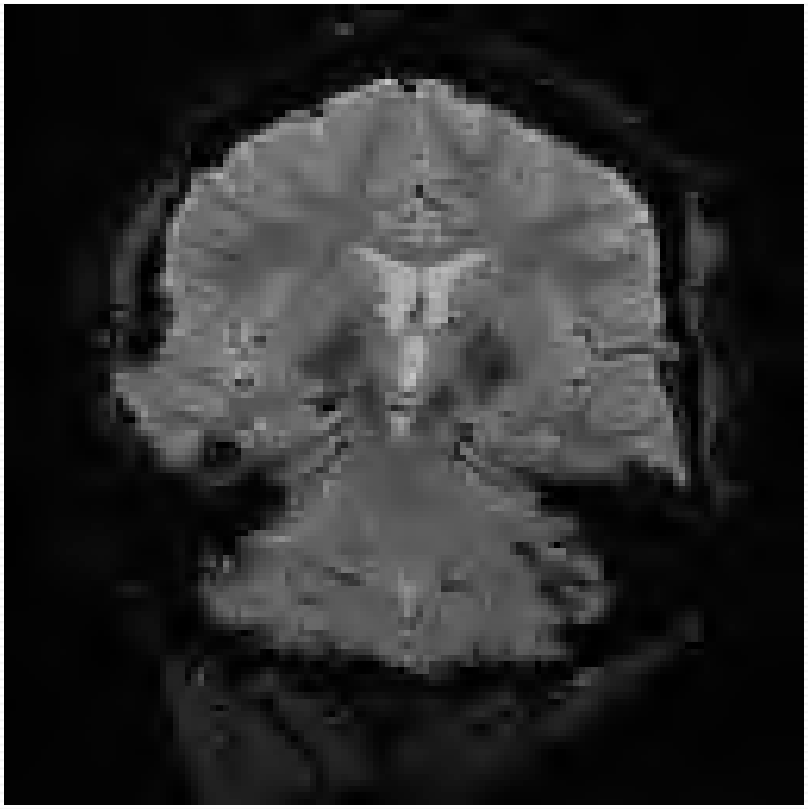
Distortions are More Severe at High Magnetic Field Strength





Variation in sample magnetization of is proportional to field strength.

High Field images lose more signal from field inhomogeneity

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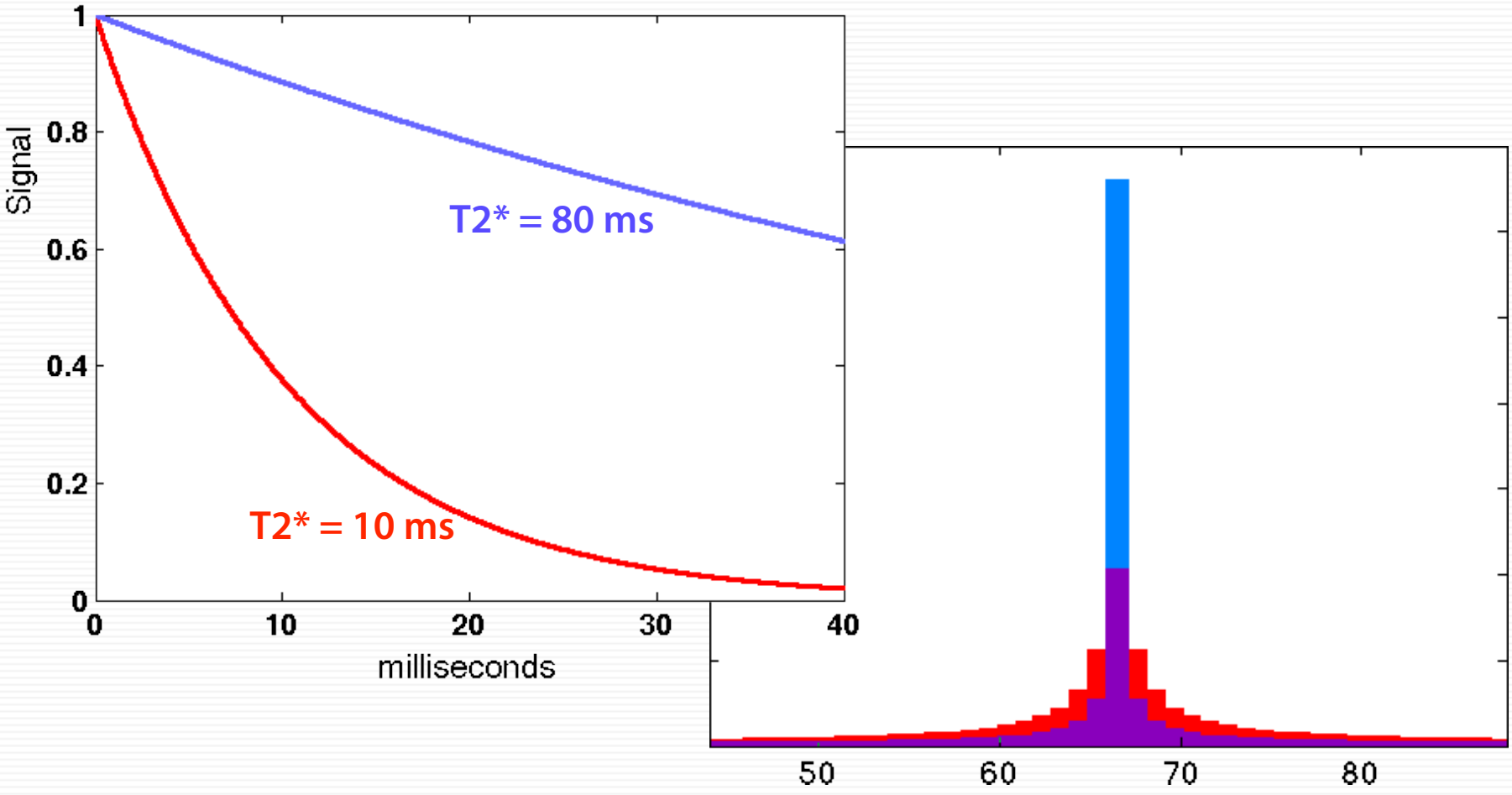
Blurring from T2* Decay



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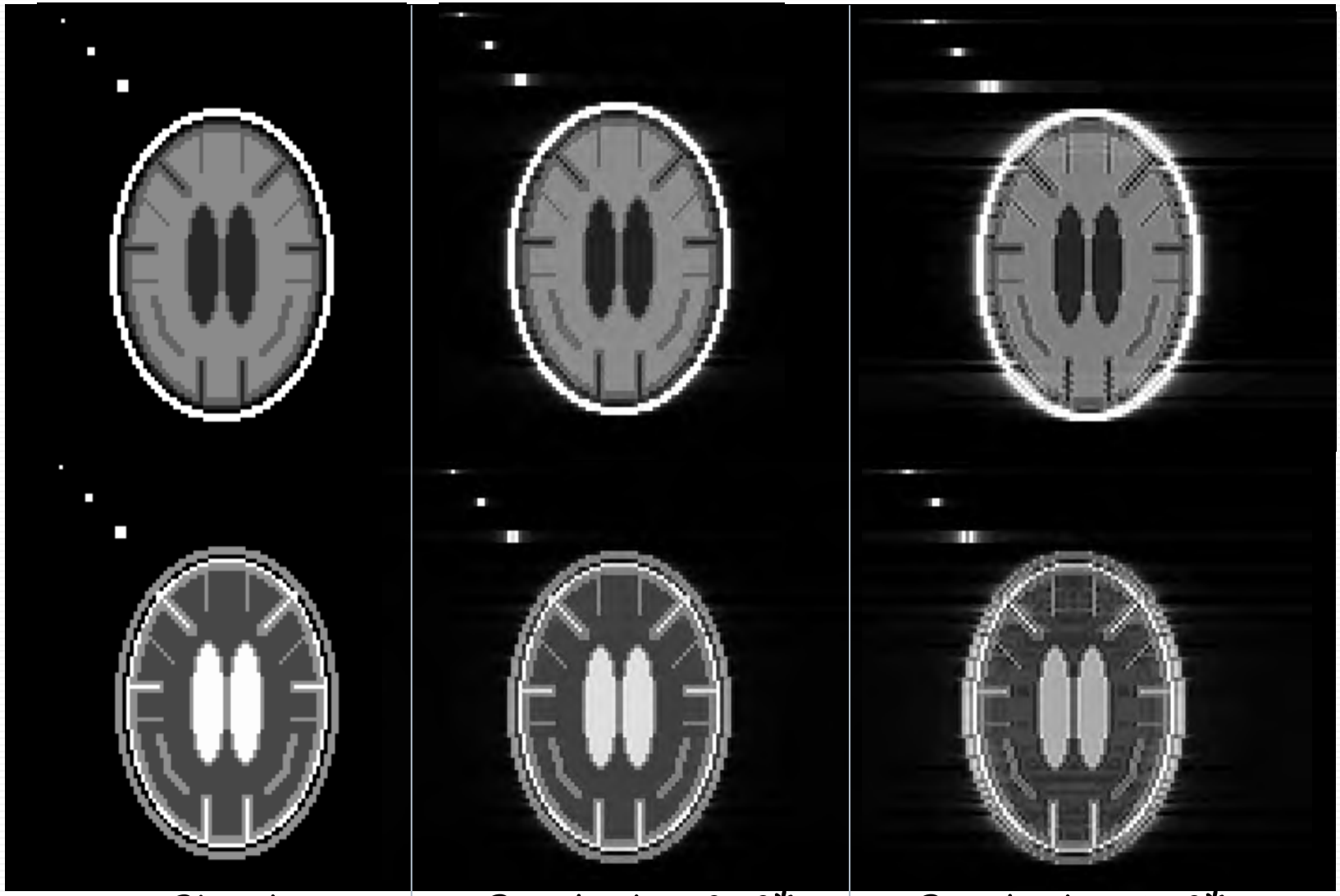
Apodization from Long Readouts



Phantom | Readout = 2T2* | Readout = 4T2*

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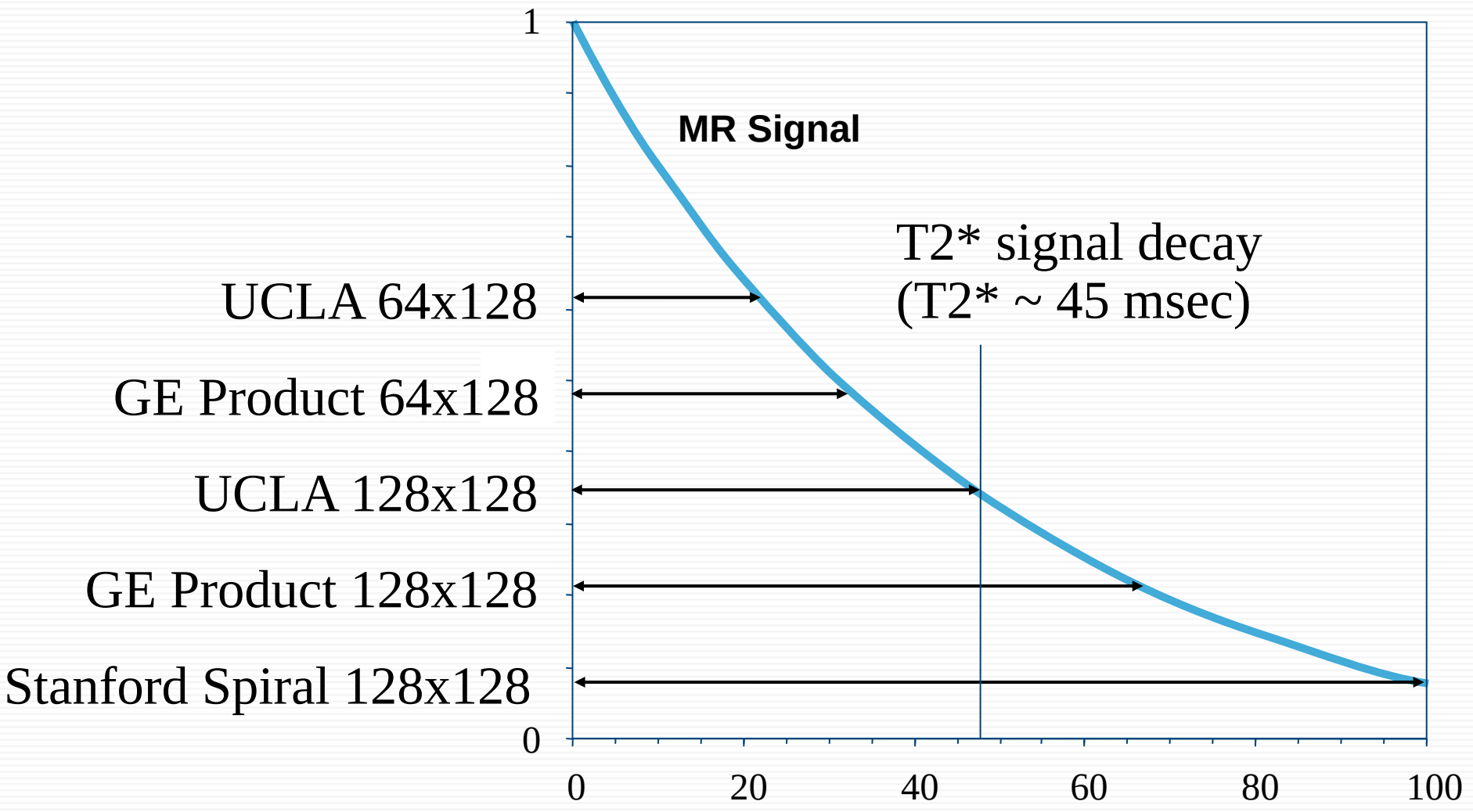
EPI Readout Durations



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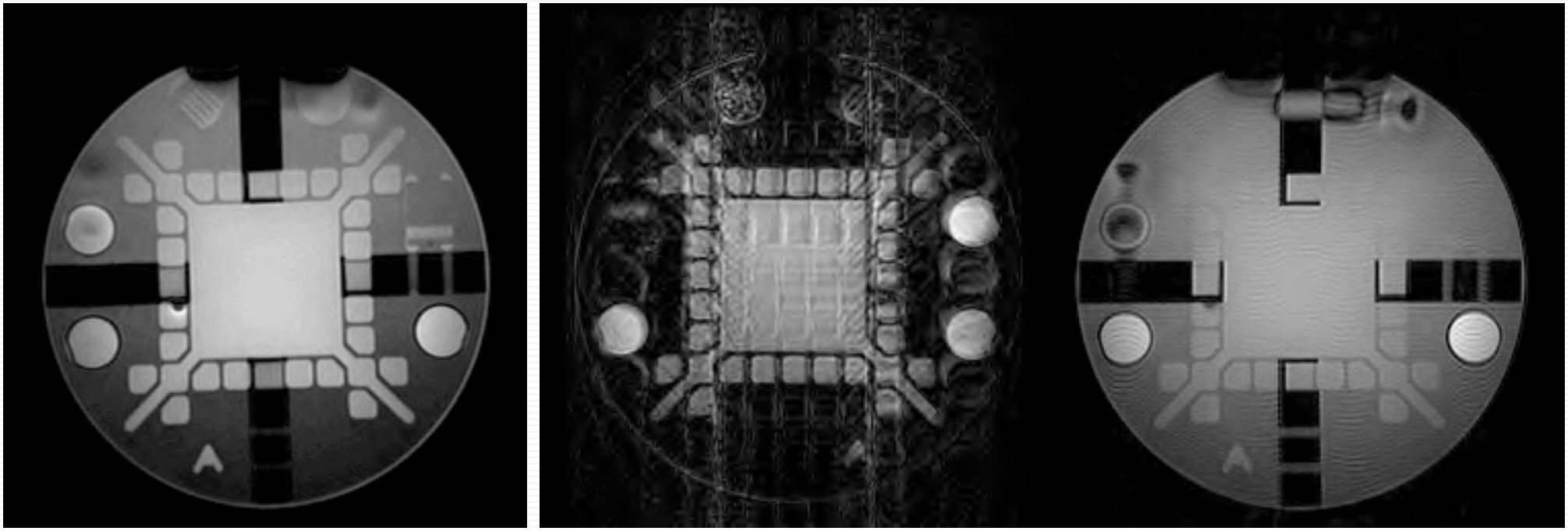
Motion Artifact



http://airto.ccn.ucla.edu/BMCweb/SharedCode/MRArtifacts/MRArtifacts.html

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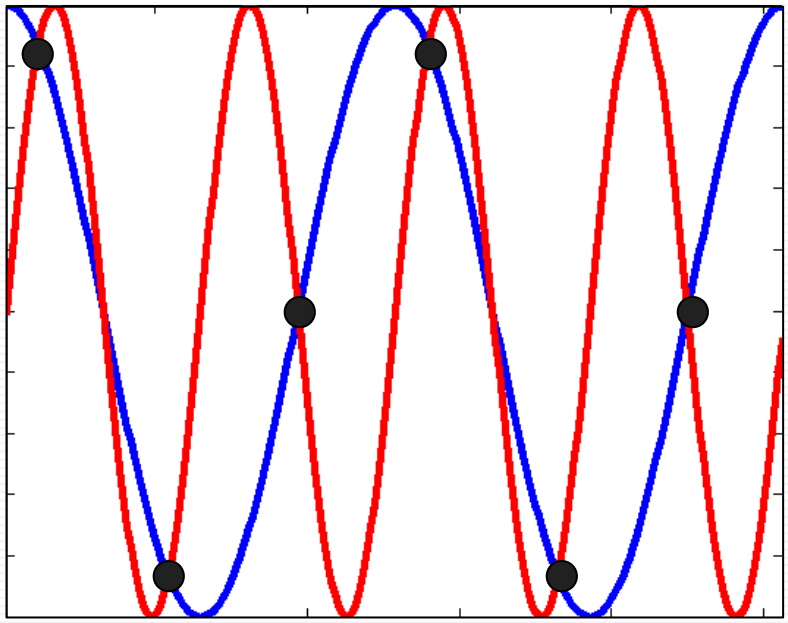
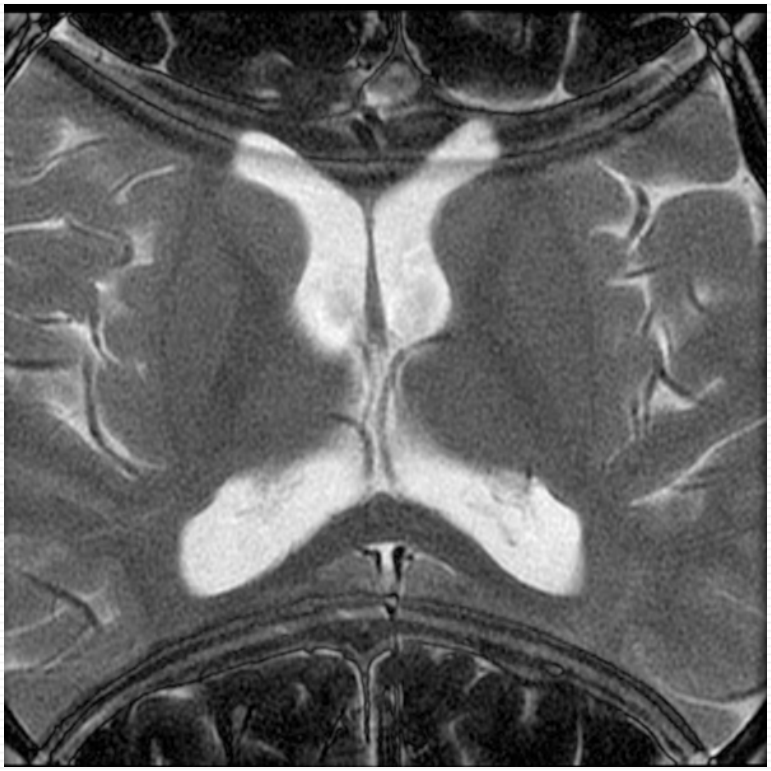
Aliasing





If the Signal Frequency is More than Twice the Sampling Rate, The Apparent Frequency is Ambiguous

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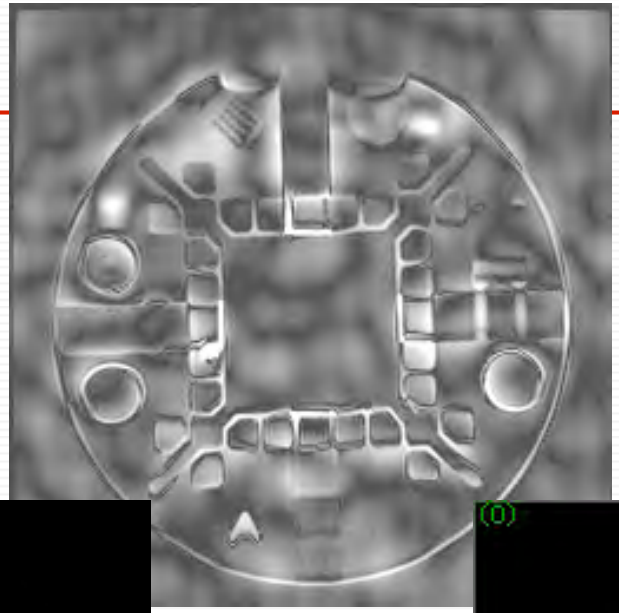
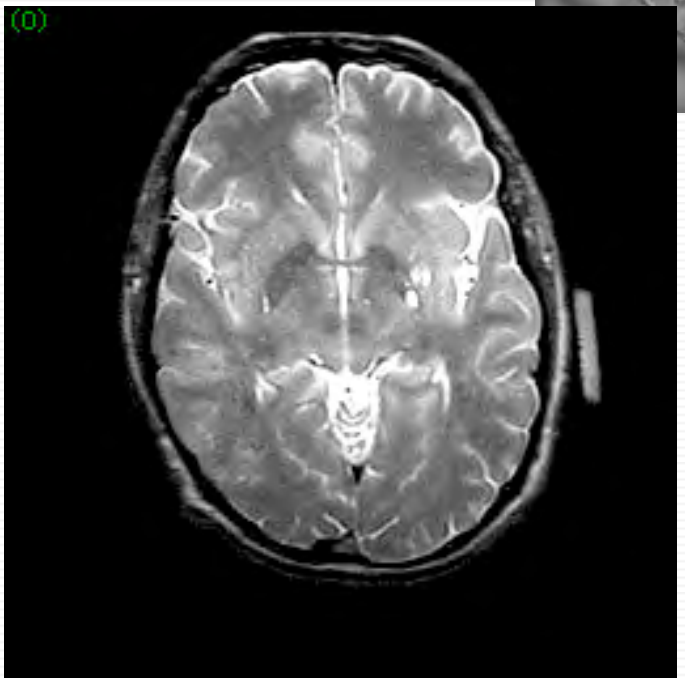
Saturation





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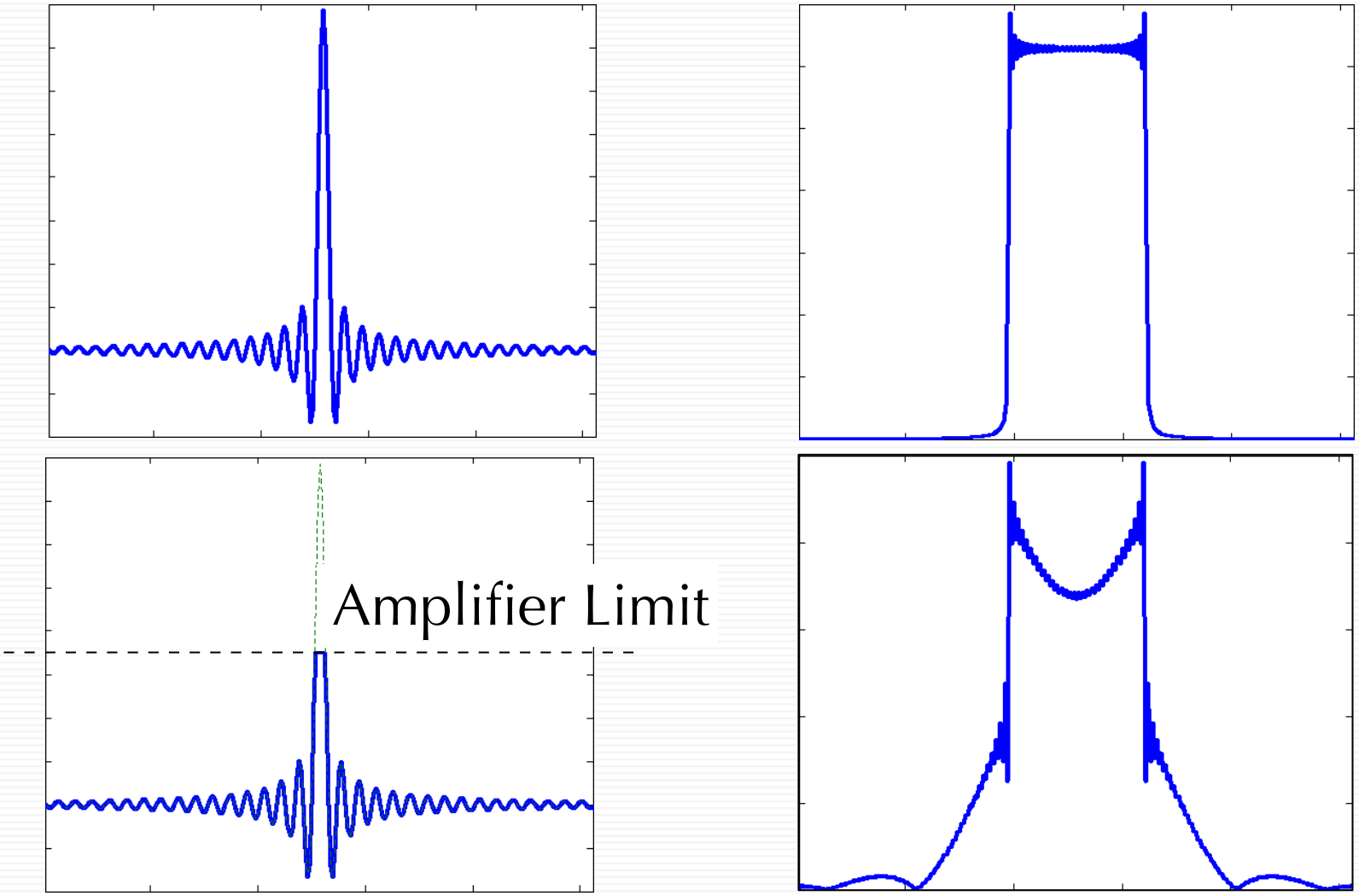
Saturation (clipping)



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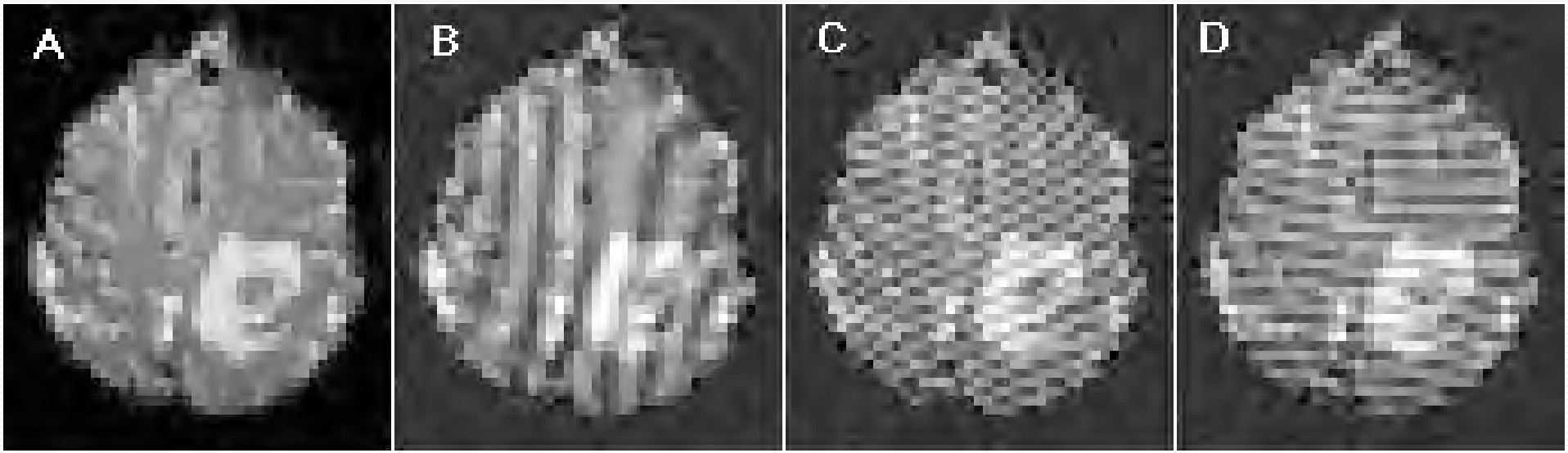
Spikes



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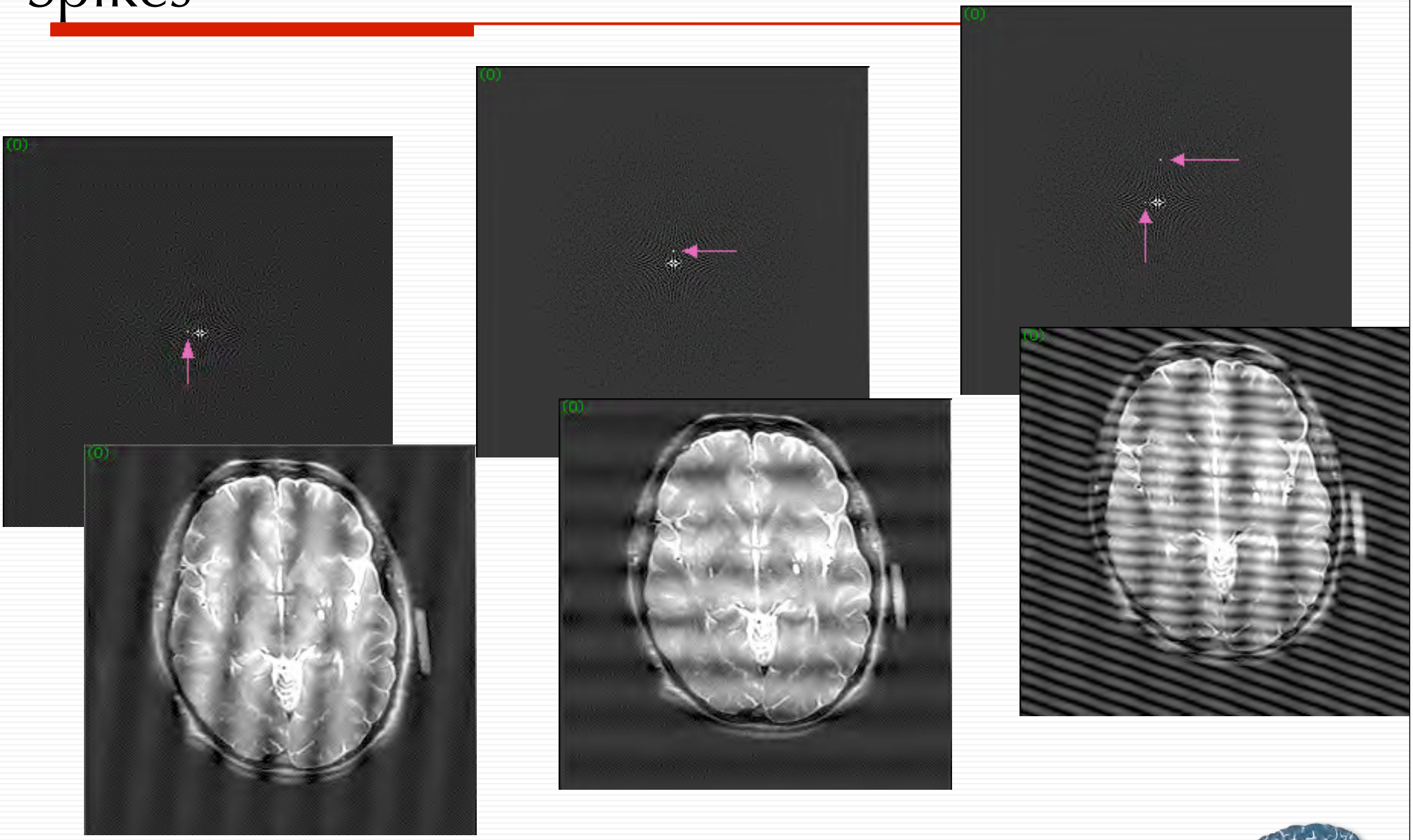
Spikes



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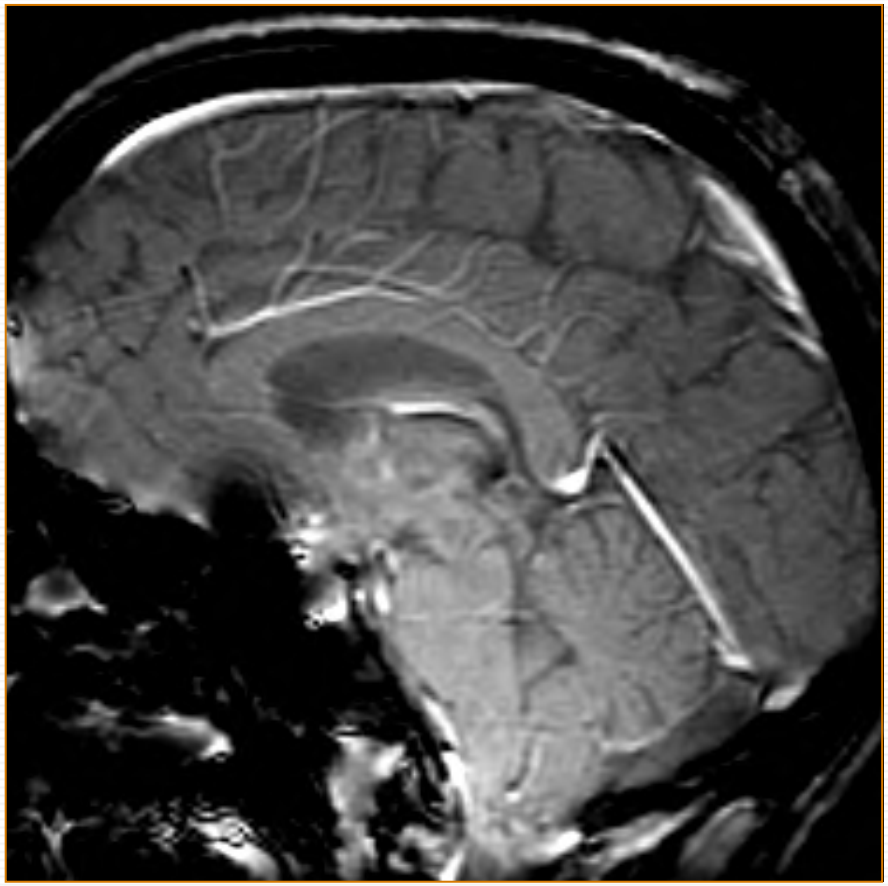
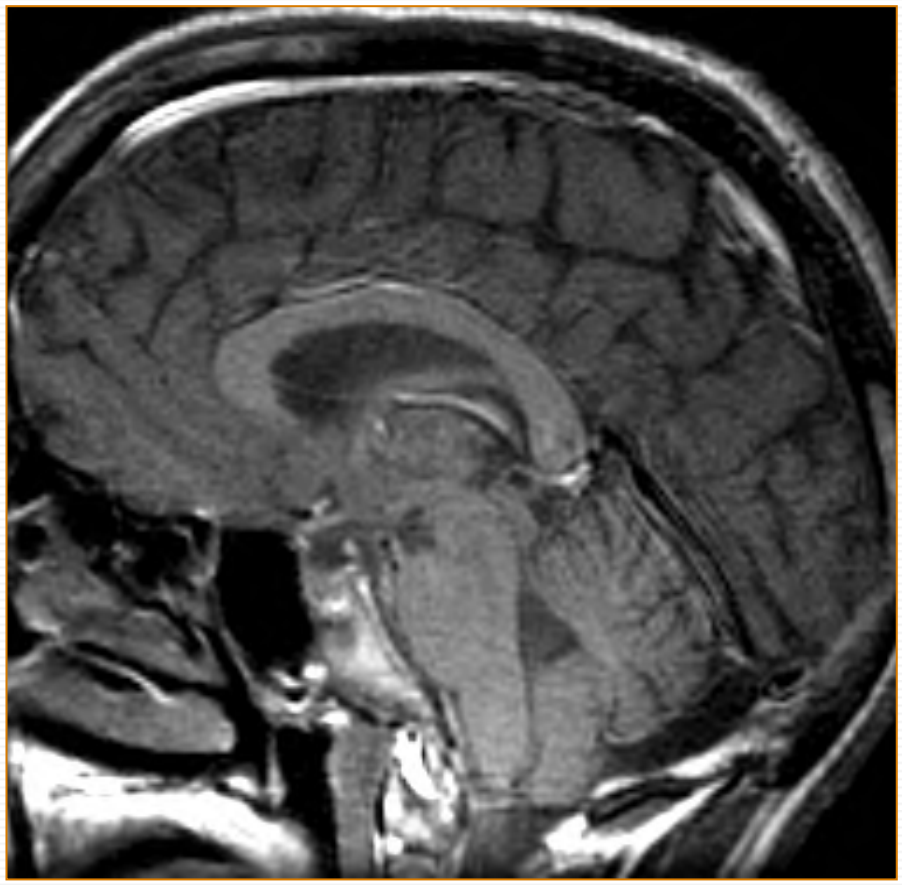
Signal Inhomogeneity



Gradient Echo

spgr, tr/te/flip
60/6/20°



Spin Echo

Spin echo, tr/te
500/11

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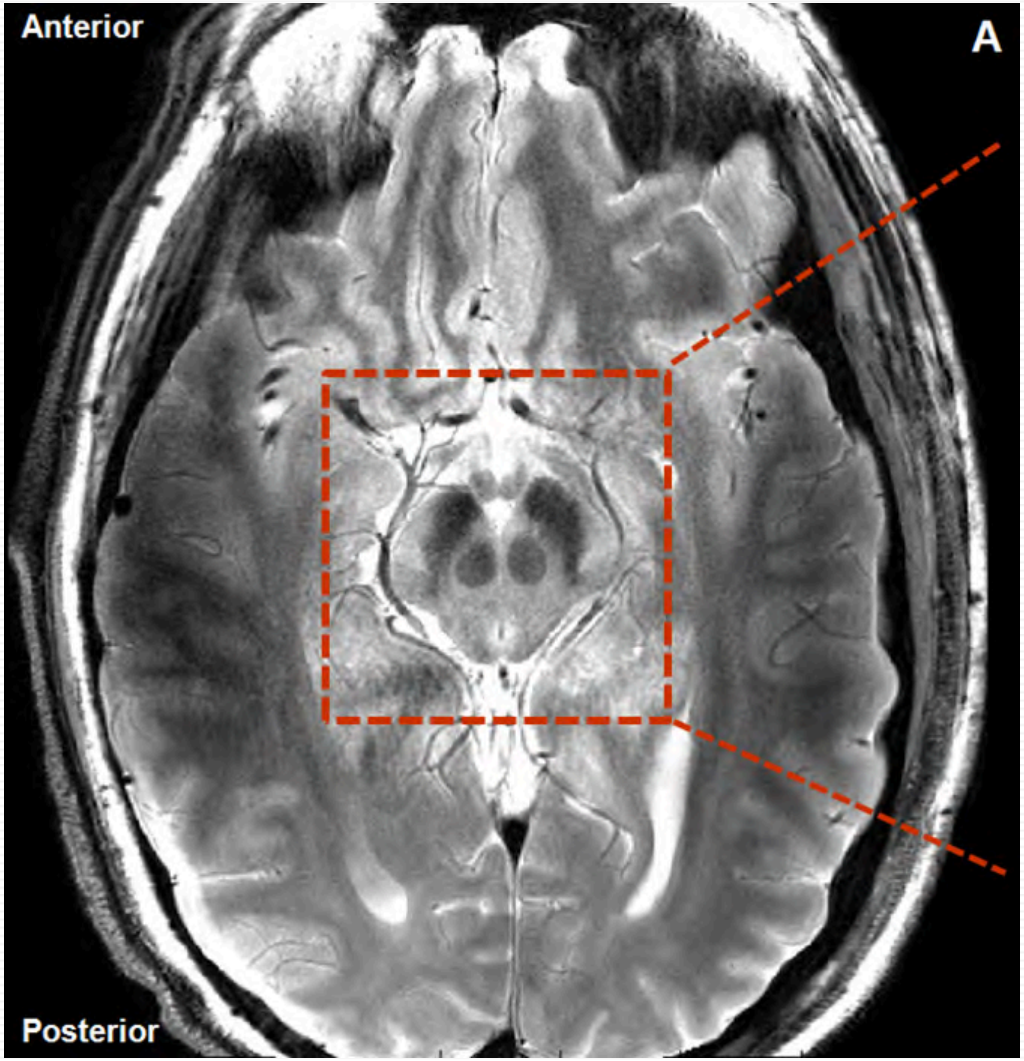
7 Tesla



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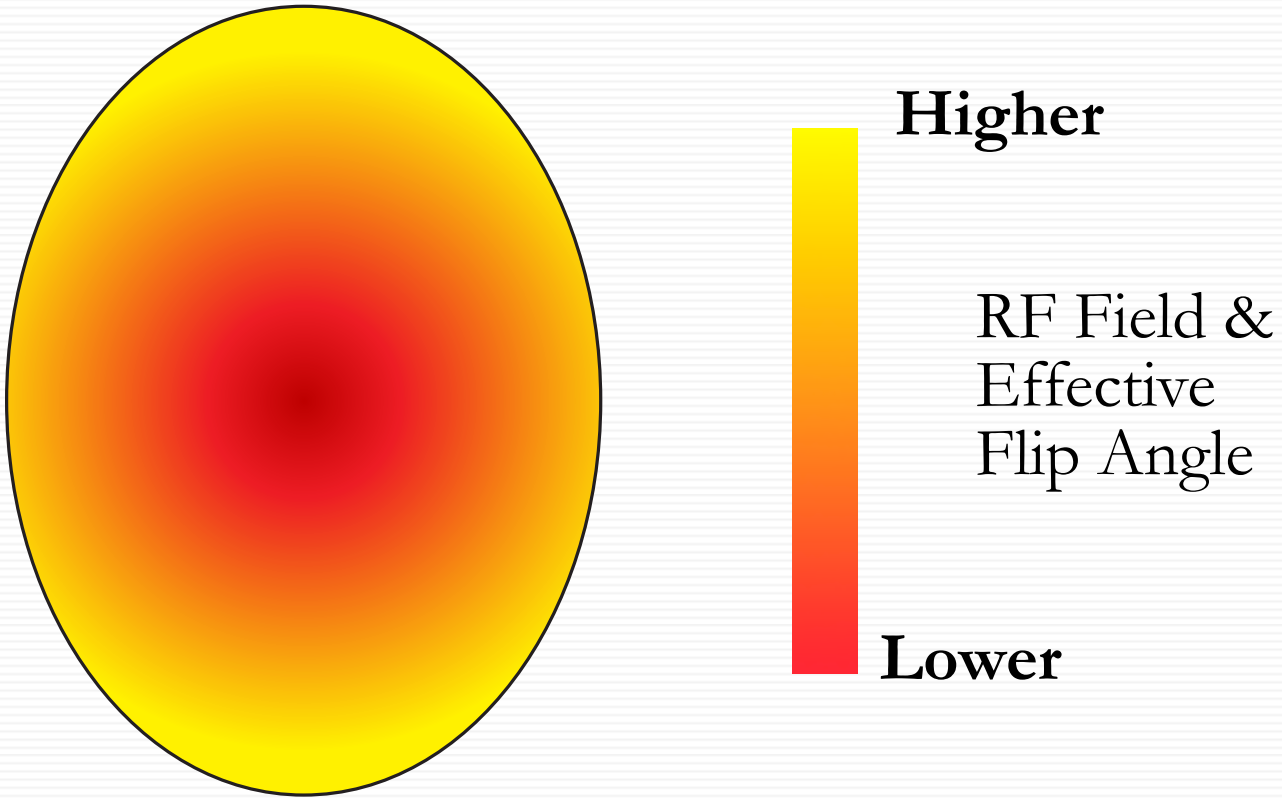
RF Penetration



The well-known "skin effect" results in greater current density (and flip angle) on the surface of conducting objects than at their center

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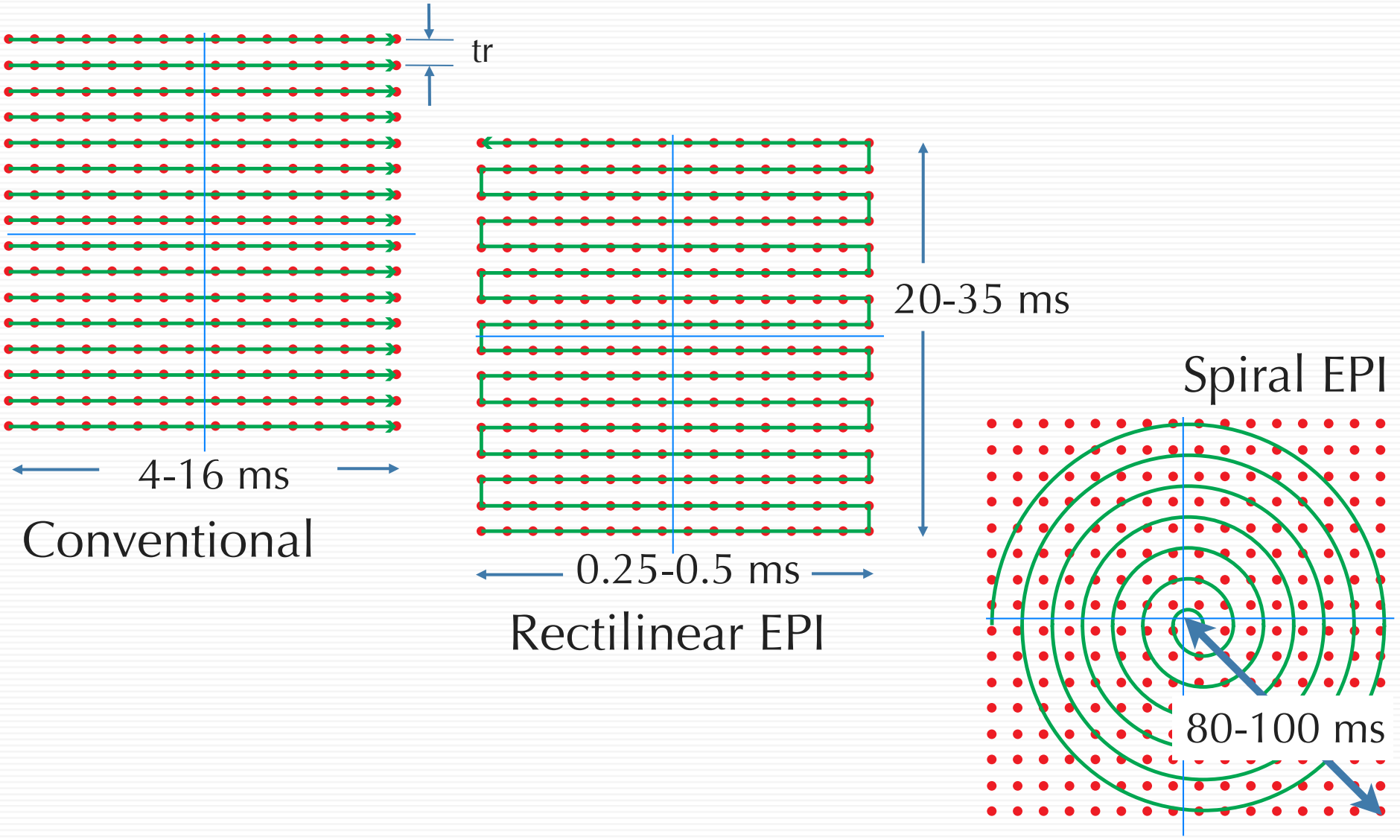
K-space traversals



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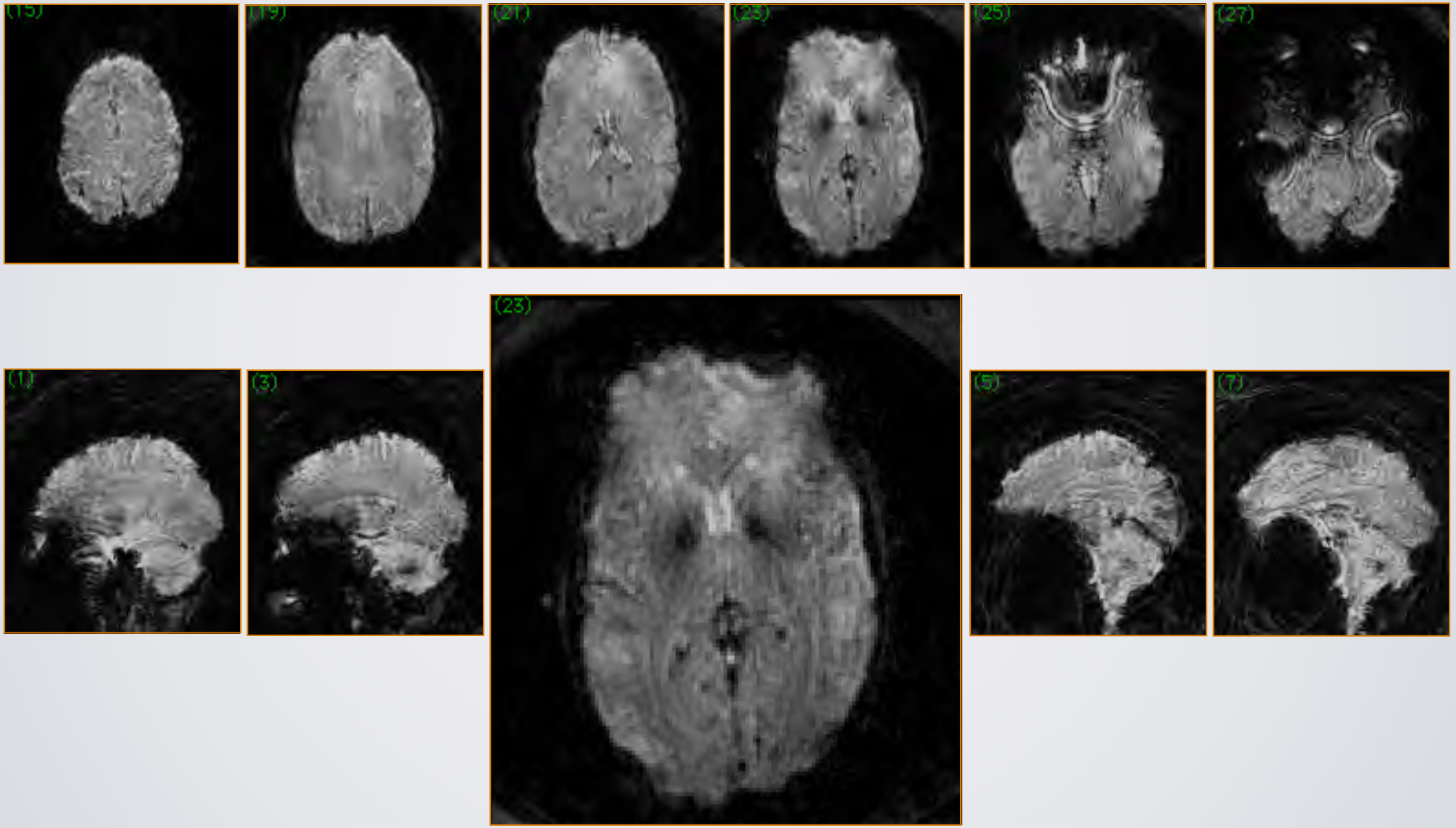
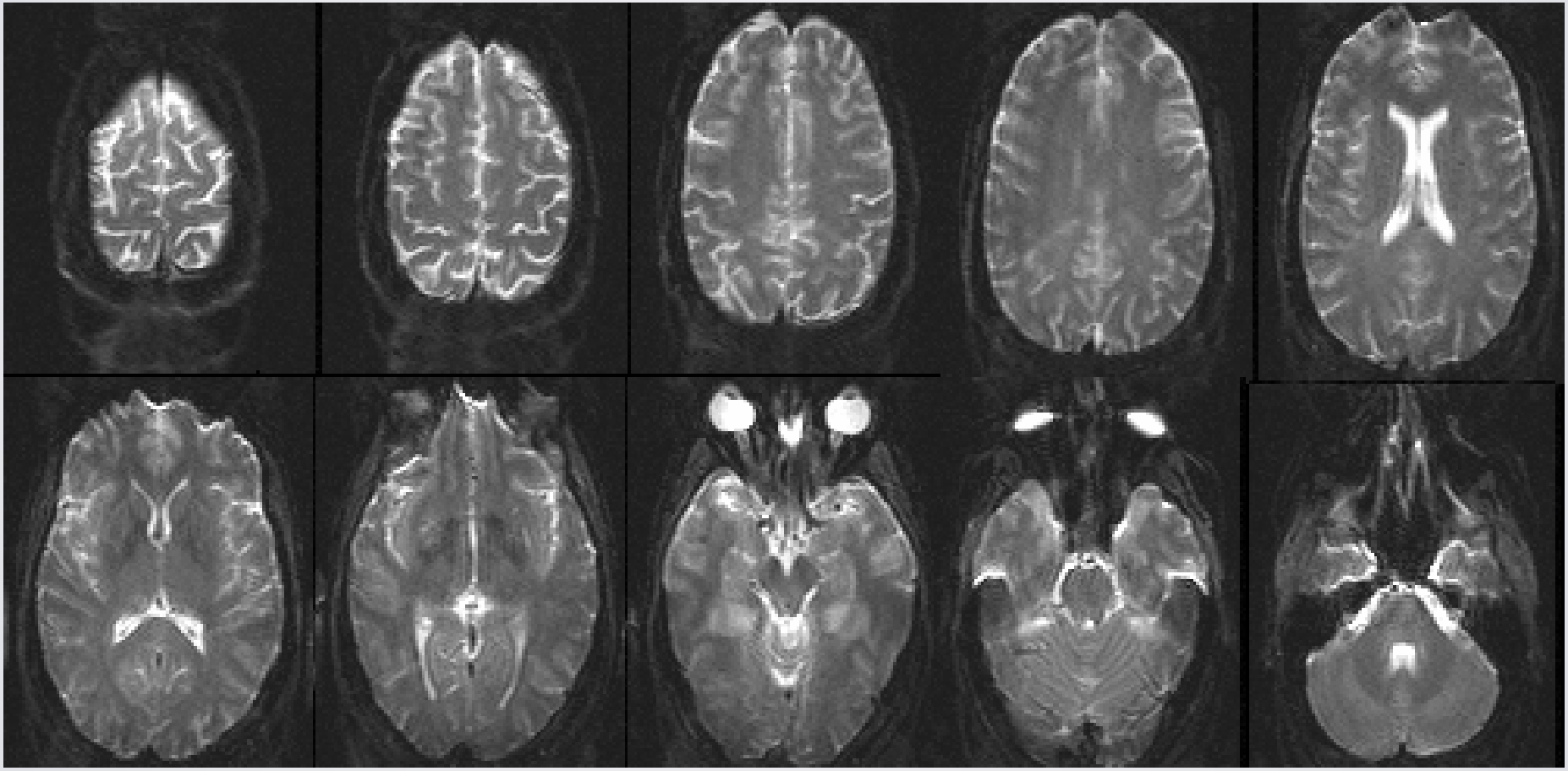
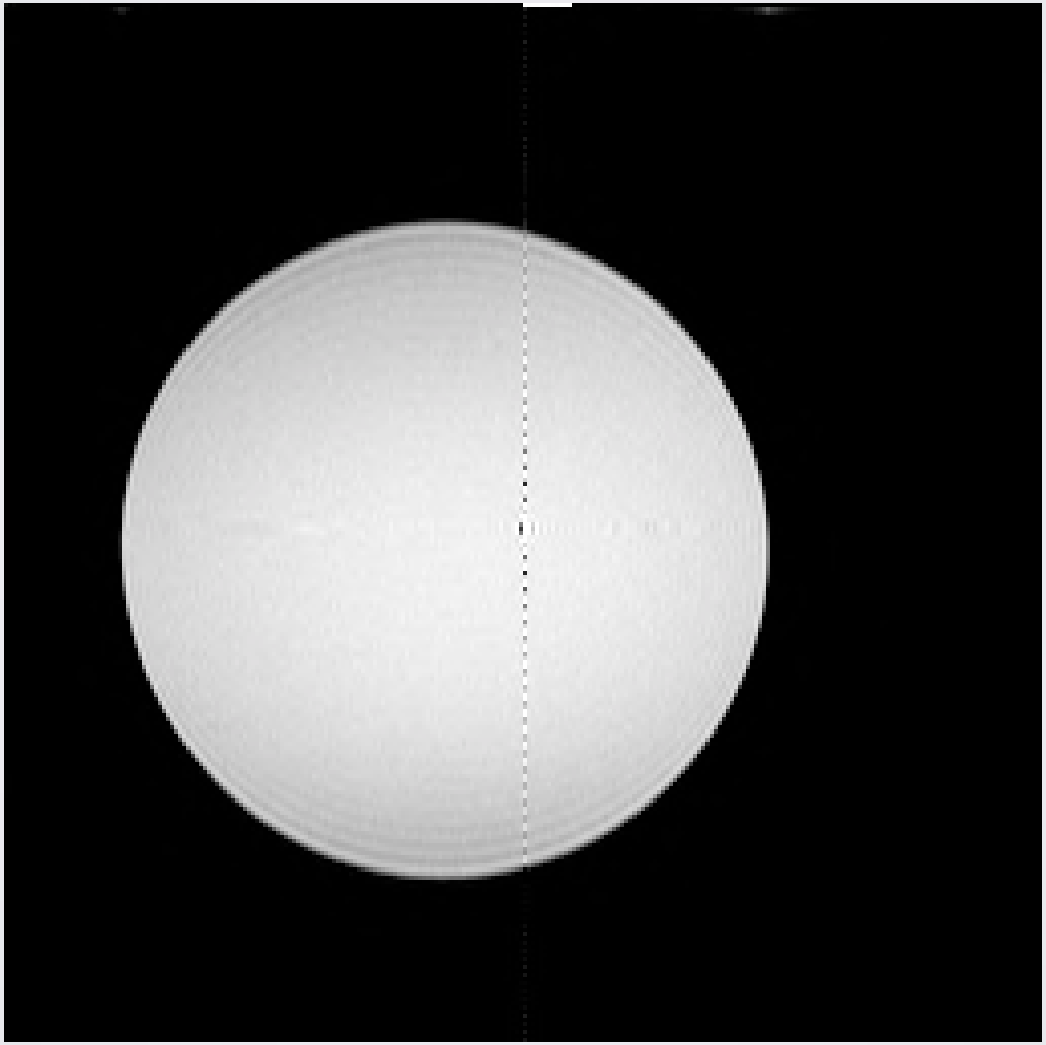
SPIRAL SCANS (128X128)



3 TESLA ECHO PLANAR IMAGES 128X256

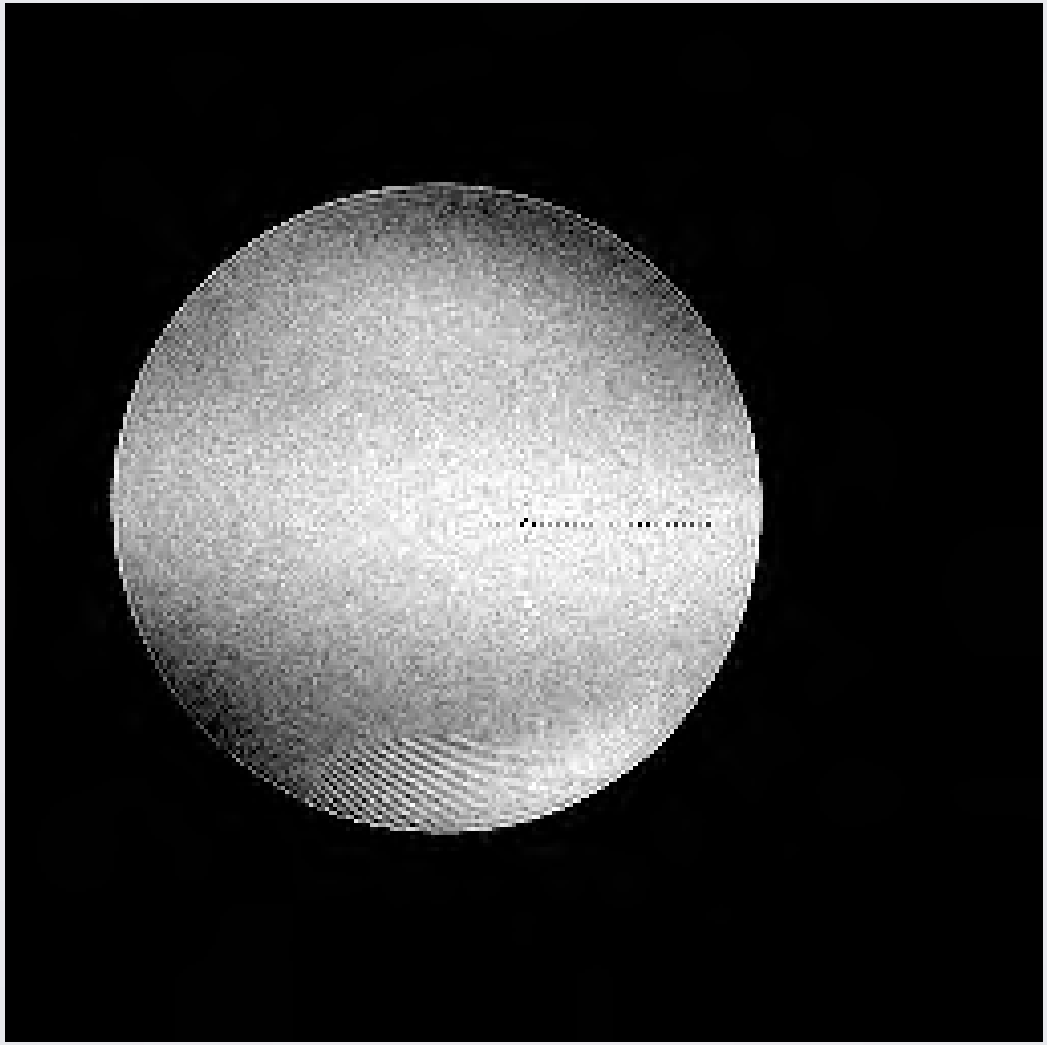


10 of 20 4 mm sections, each acquired in 78 ms.
TE = 55 msec, 1.5 mm pixels



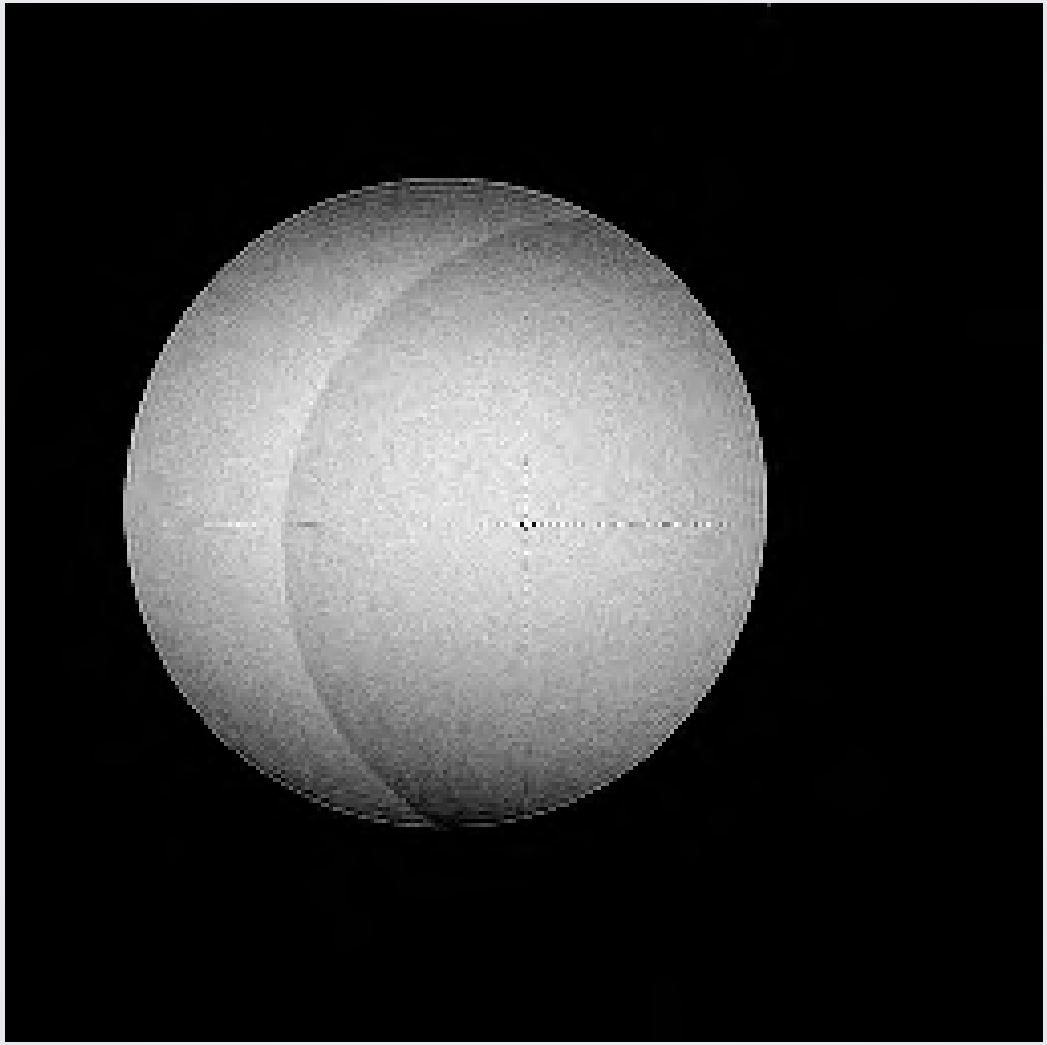
- DC Offset

http://chickscope.beckman.uiuc.edu/roosts/carl/artifacts.html



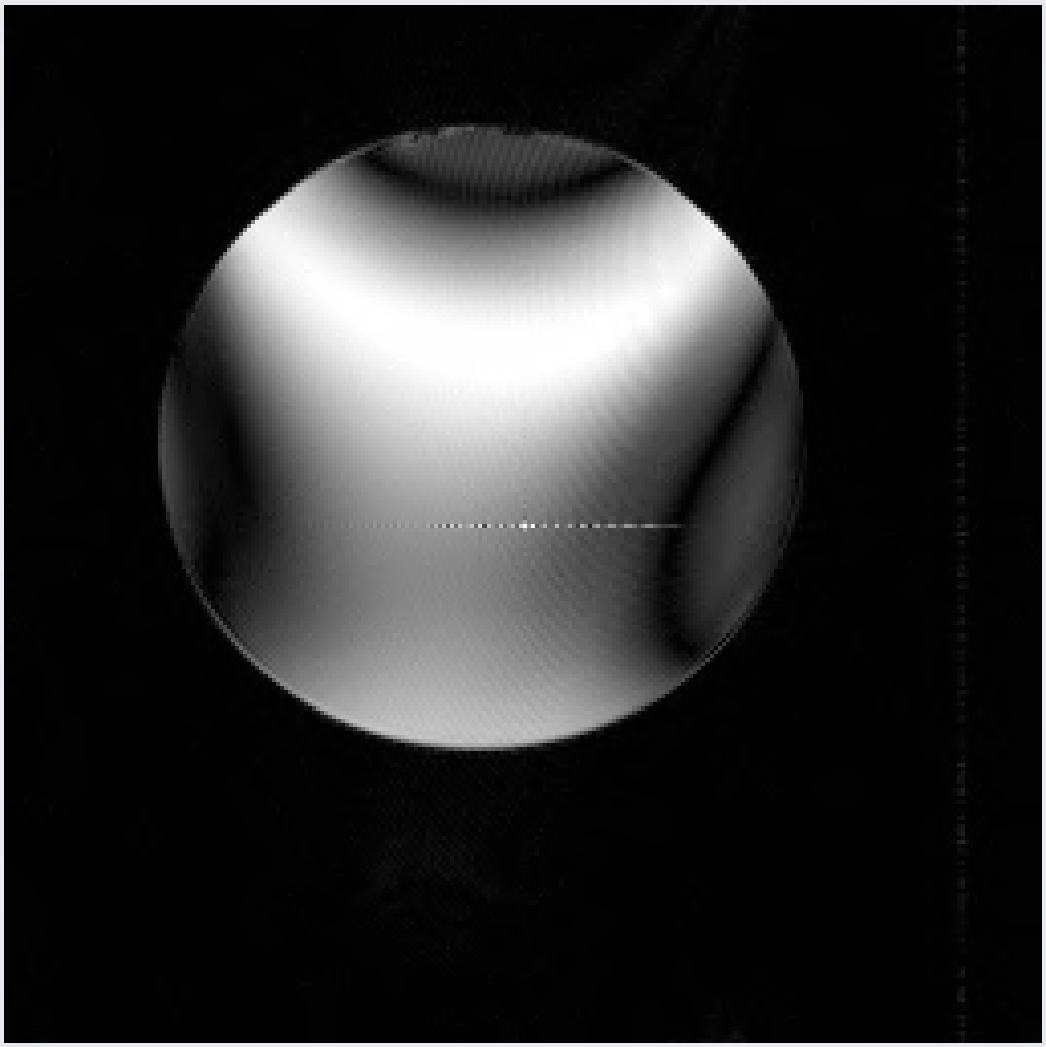
- Stimulated Echo

http://chickscope.beckman.uiuc.edu/roosts/carl/artifacts.html



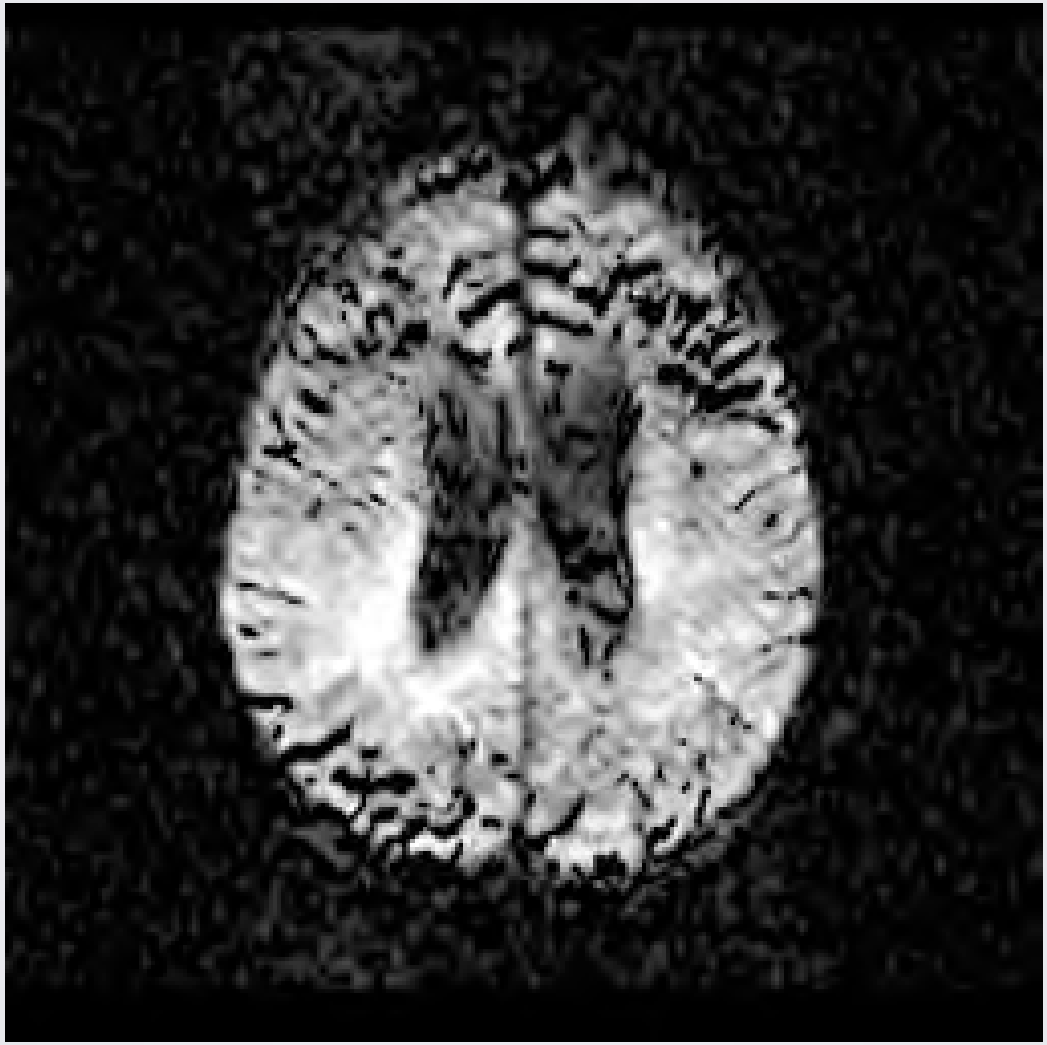
- Quadrature Ghost

http://chickscope.beckman.uiuc.edu/roosts/carl/artifacts.html



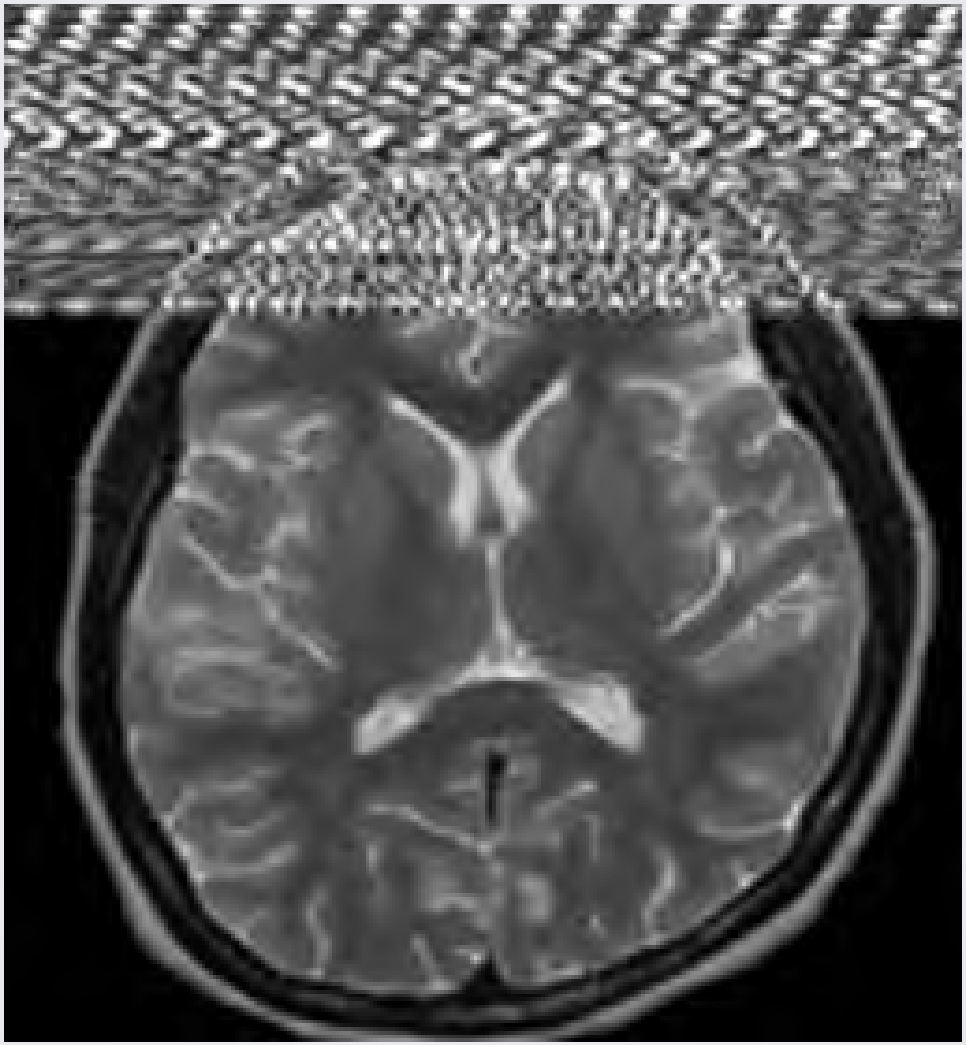
- Shimming (Gradient Echo)

http://chickscope.beckman.uiuc.edu/roosts/carl/artifacts.html

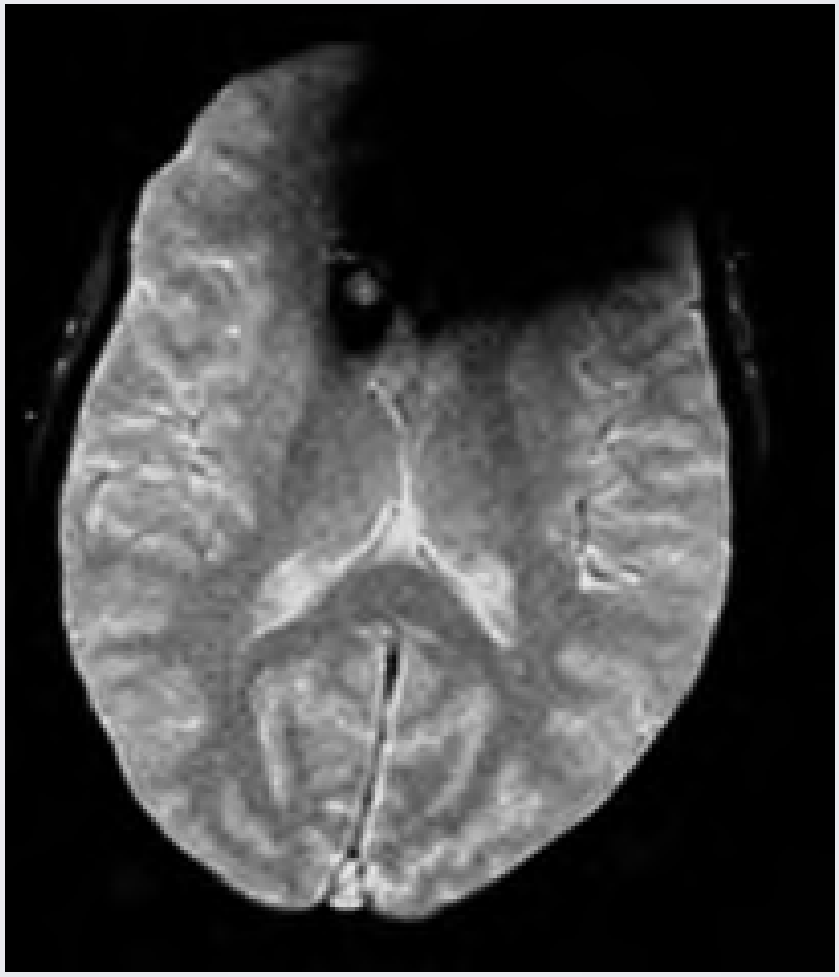


- Eddy Currents

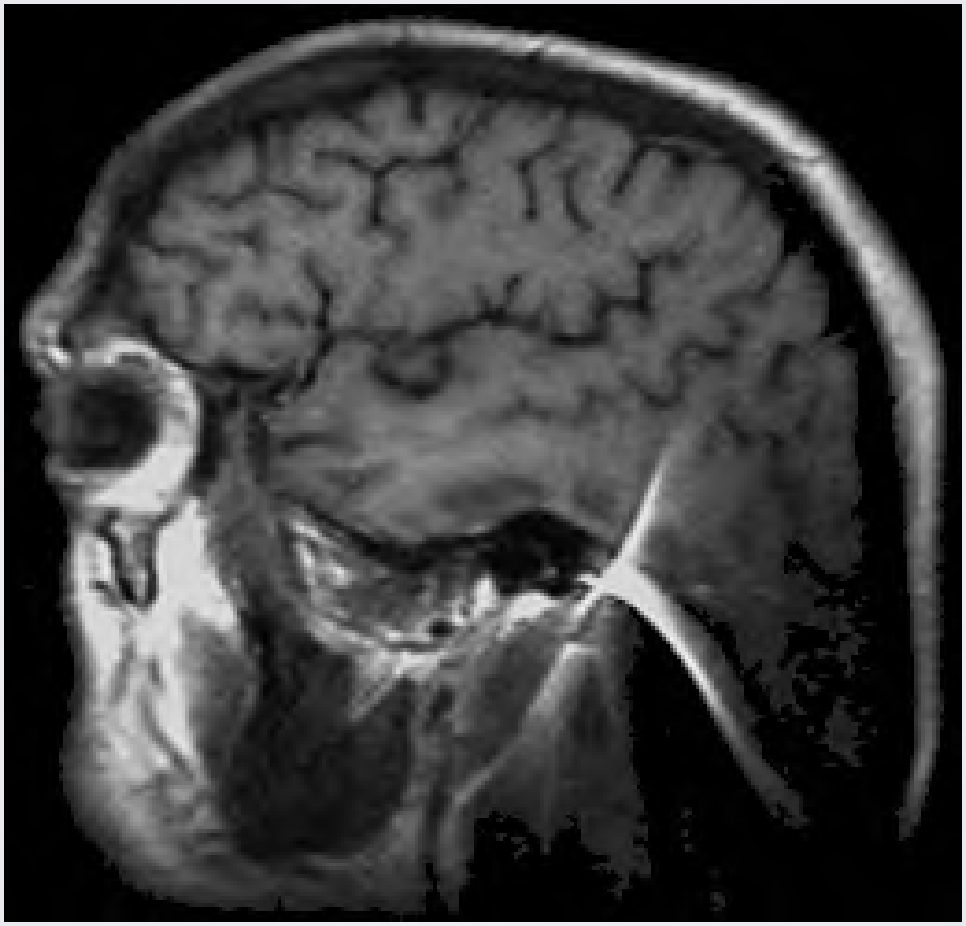
http://www.mr-tip.com



- RF noise



- Parasitic conduction

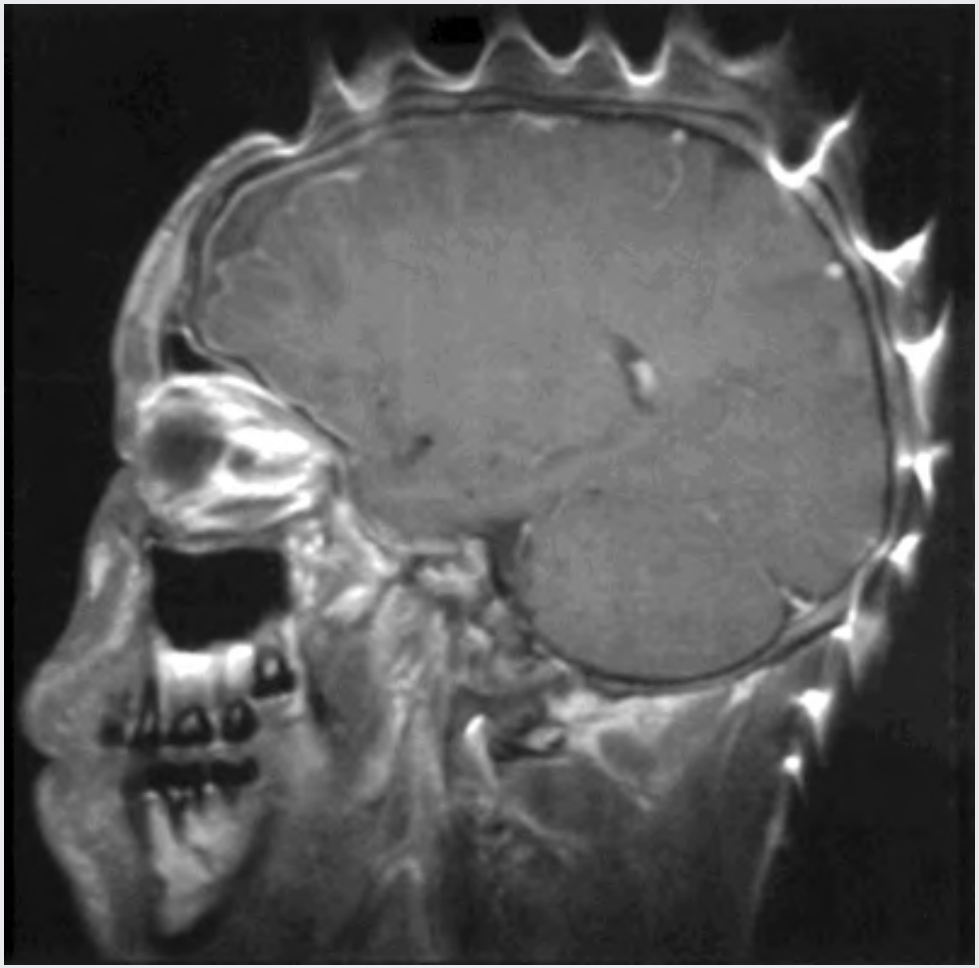


- Metal artifact

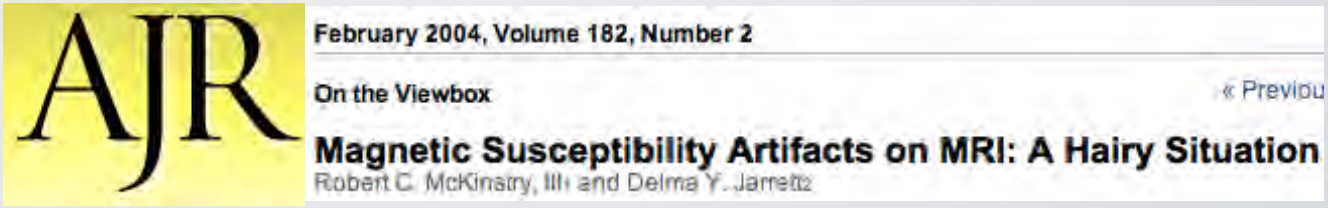
cochlear implant

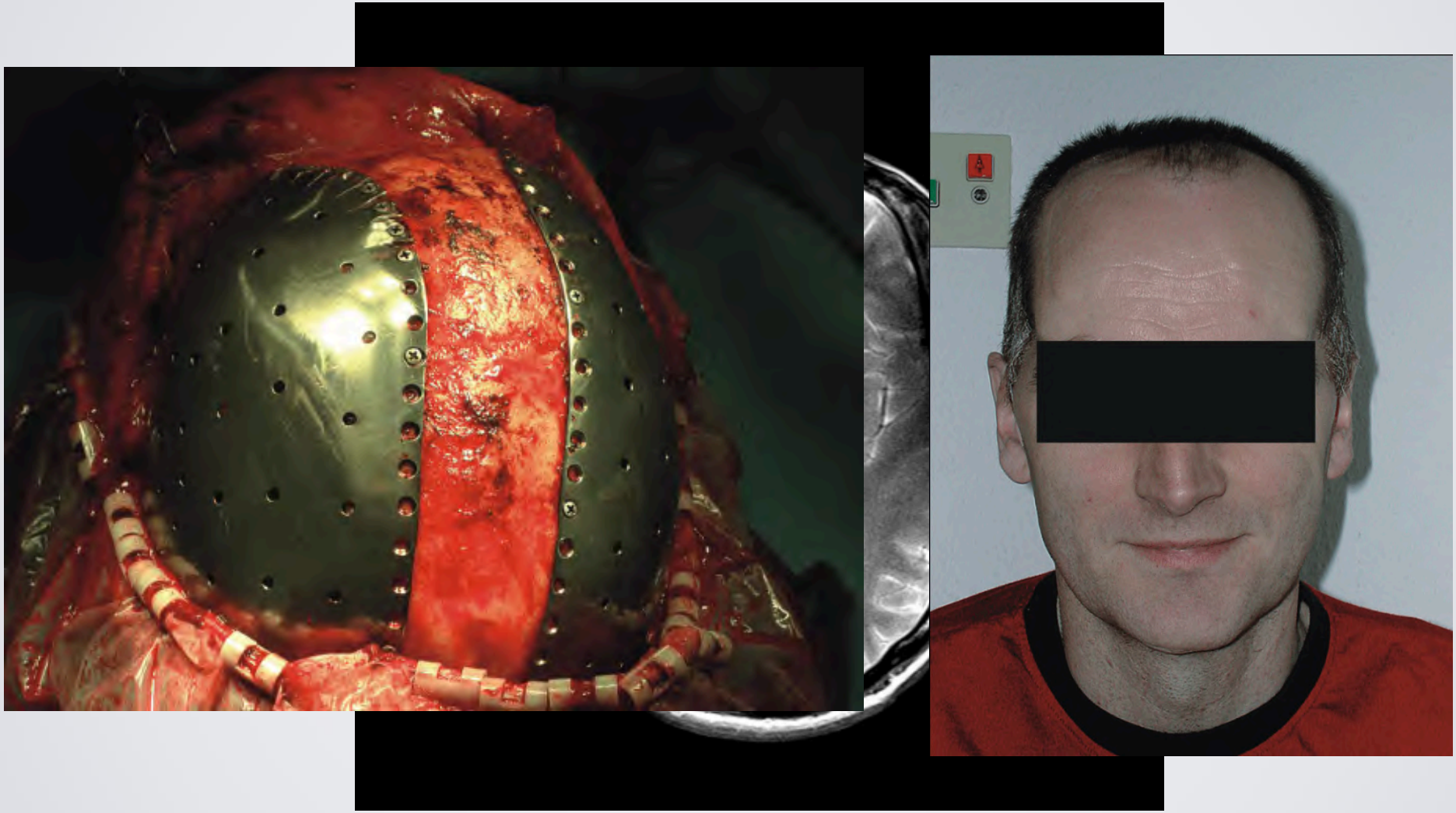
- Metal artifact

"beeswax"



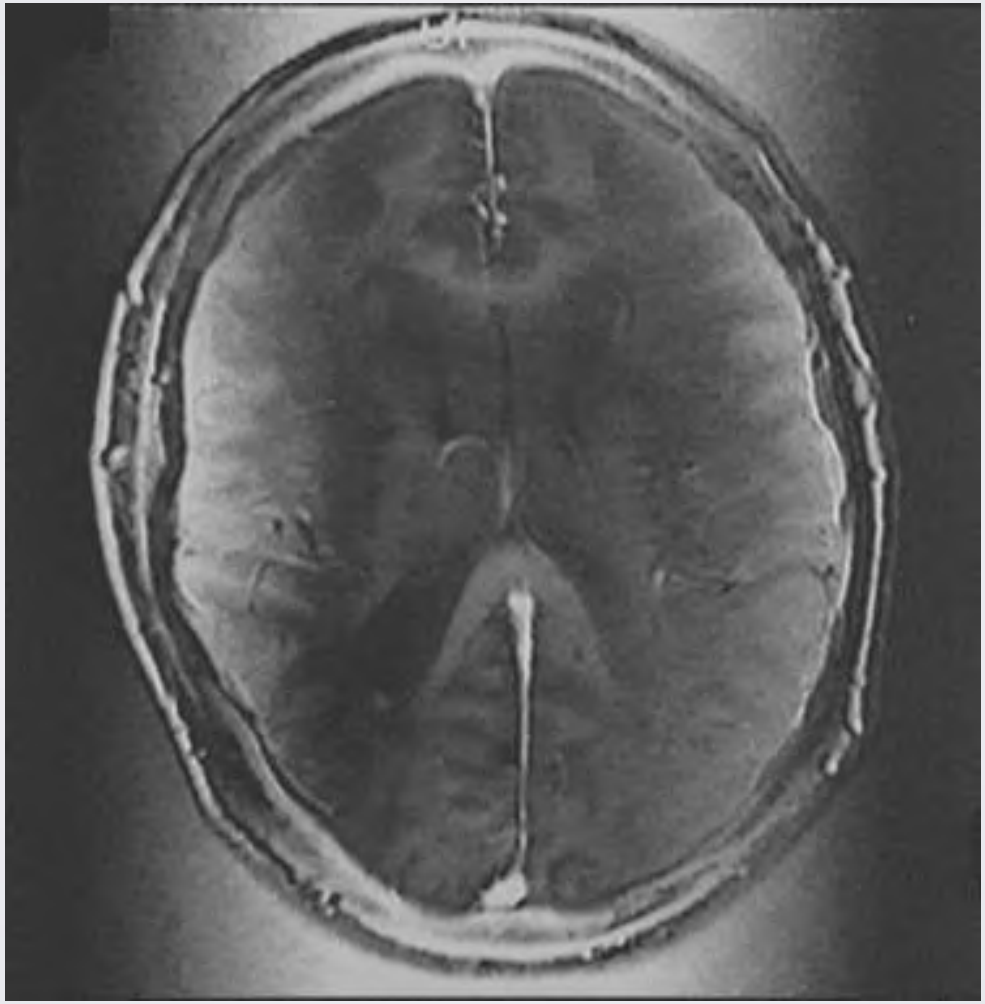
- Foreign bodies

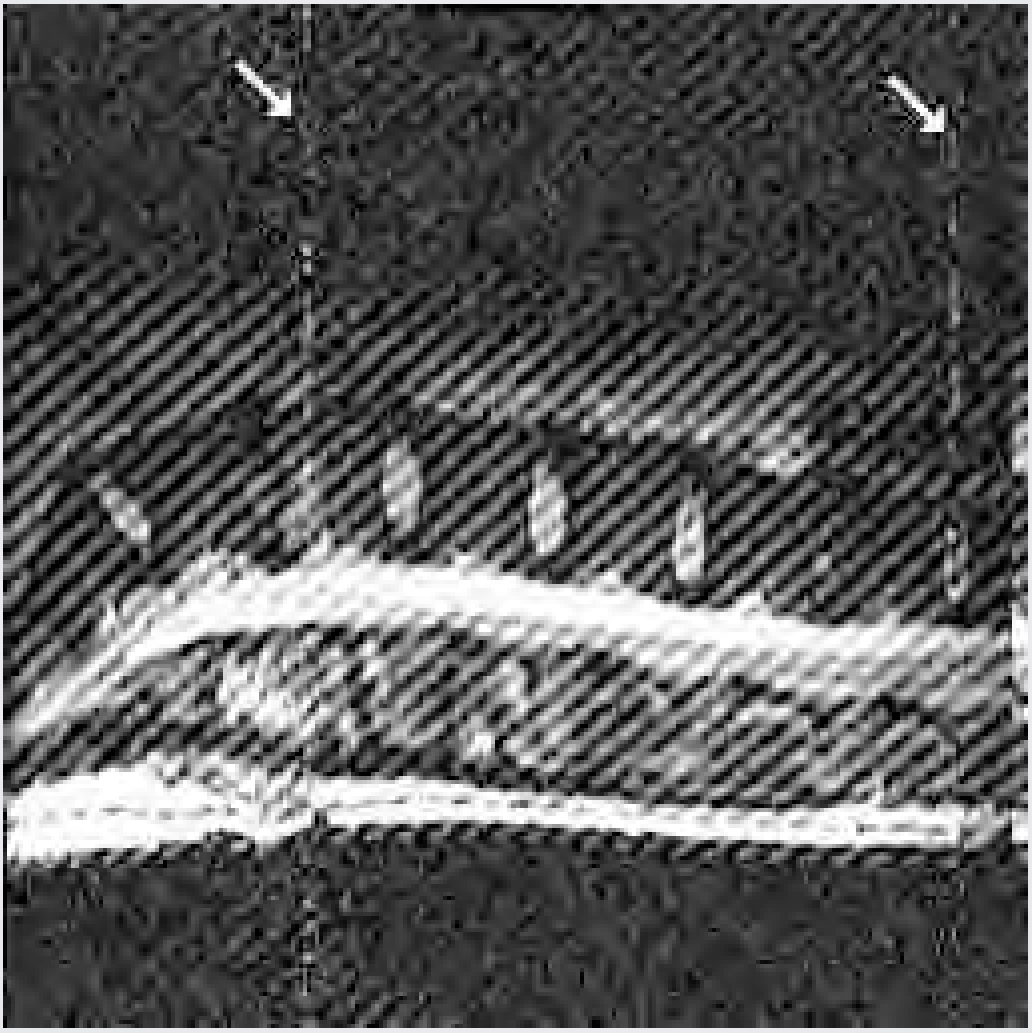


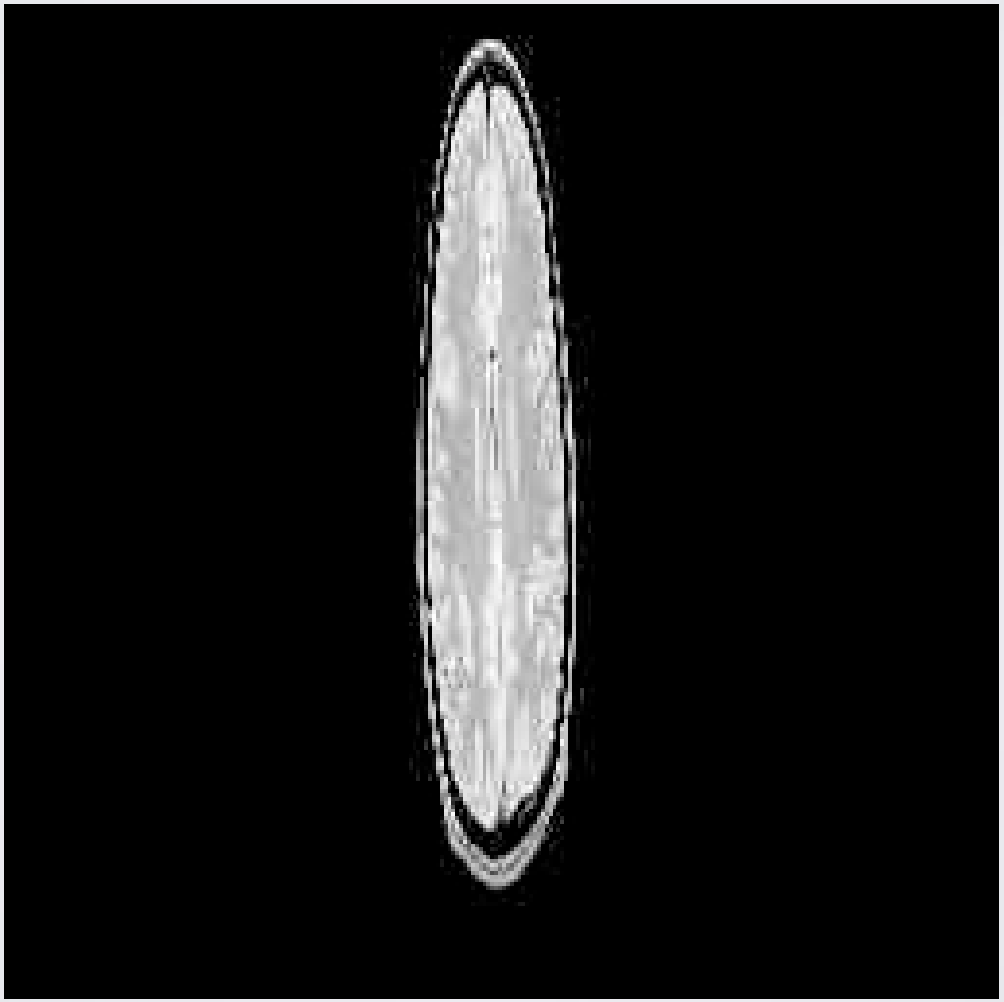


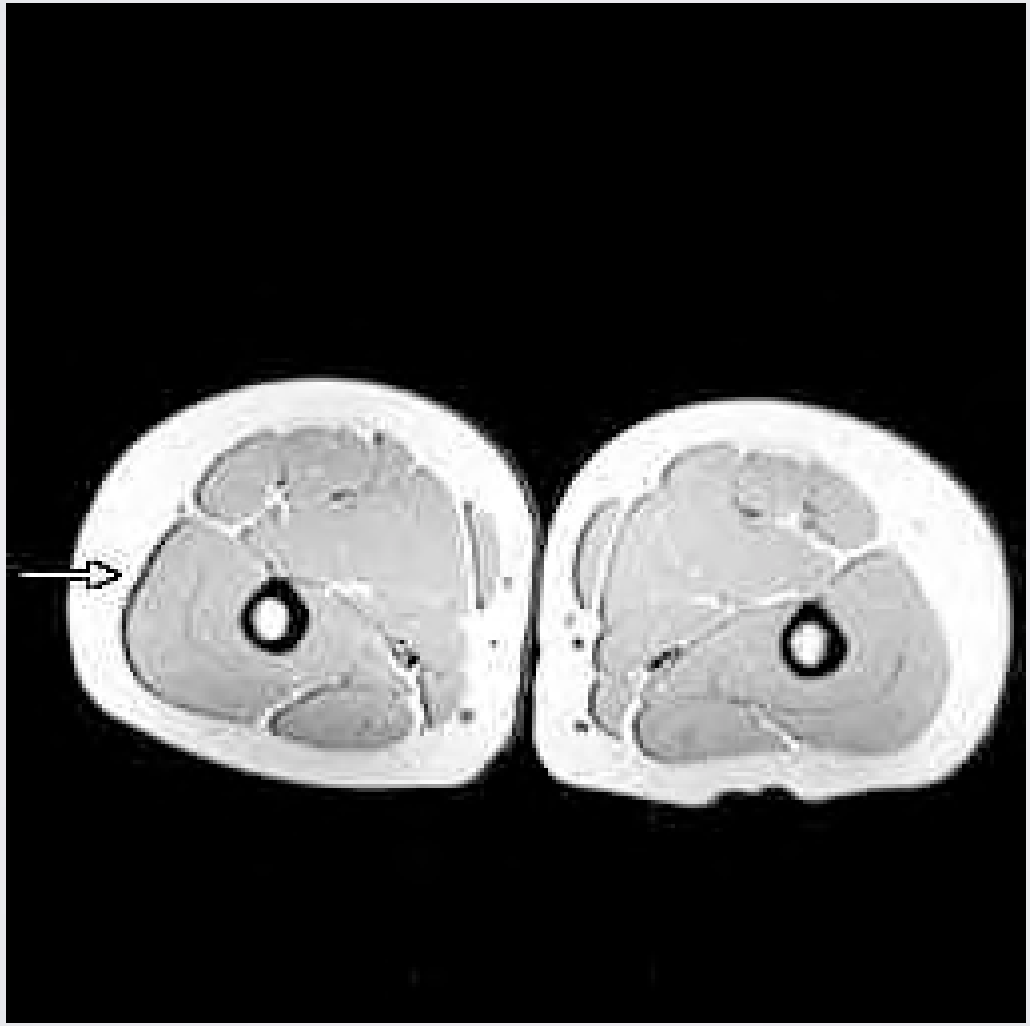
- Metal artifact

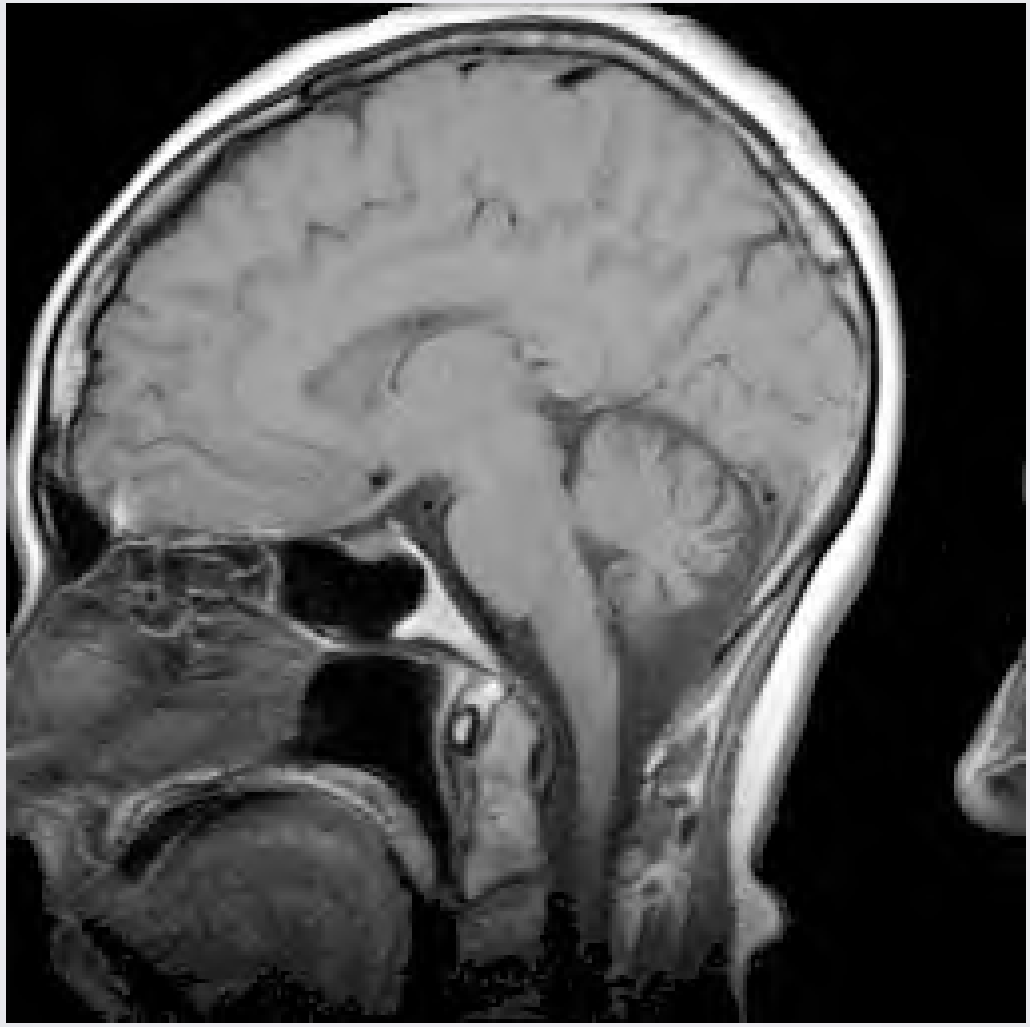
- EPI ghost

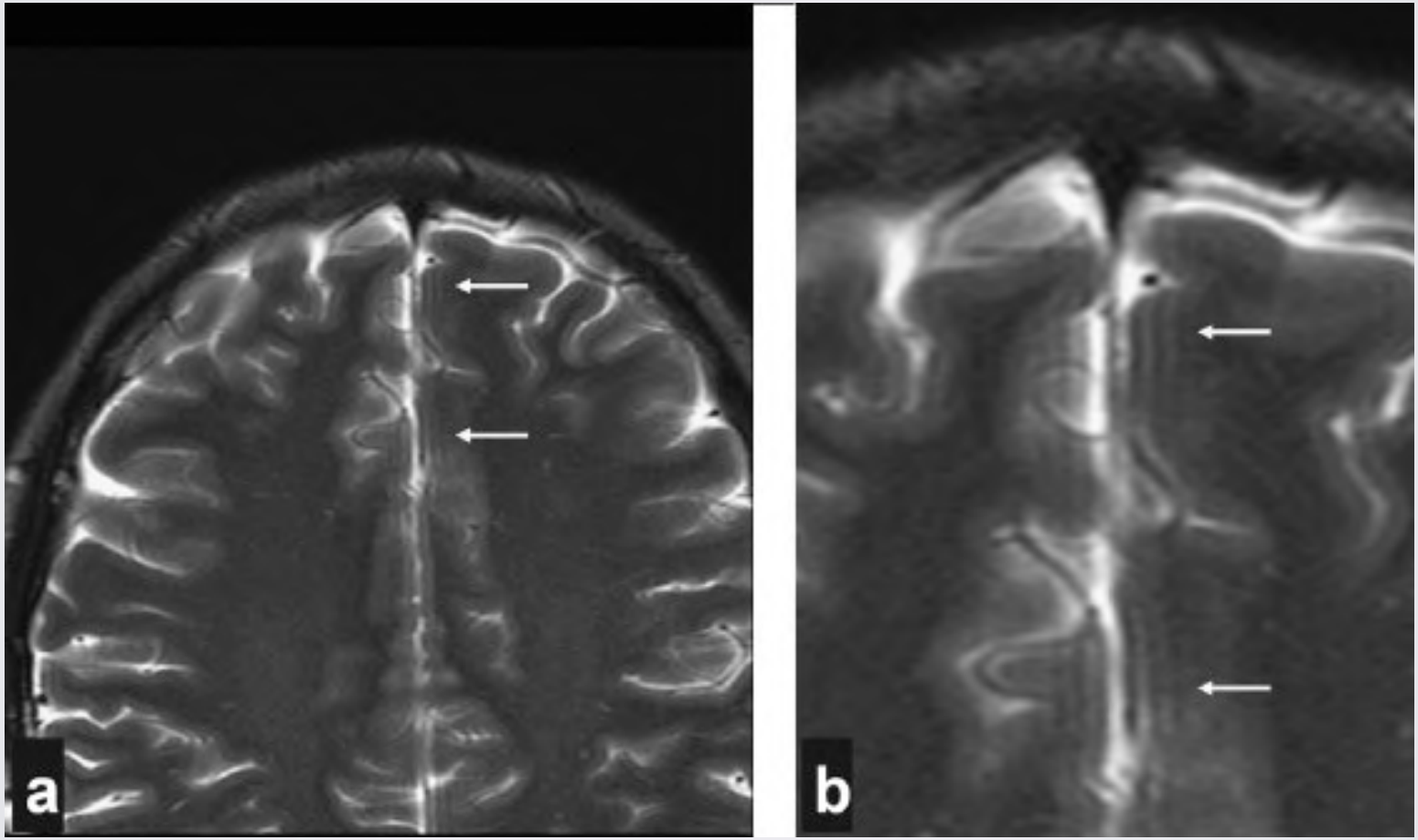


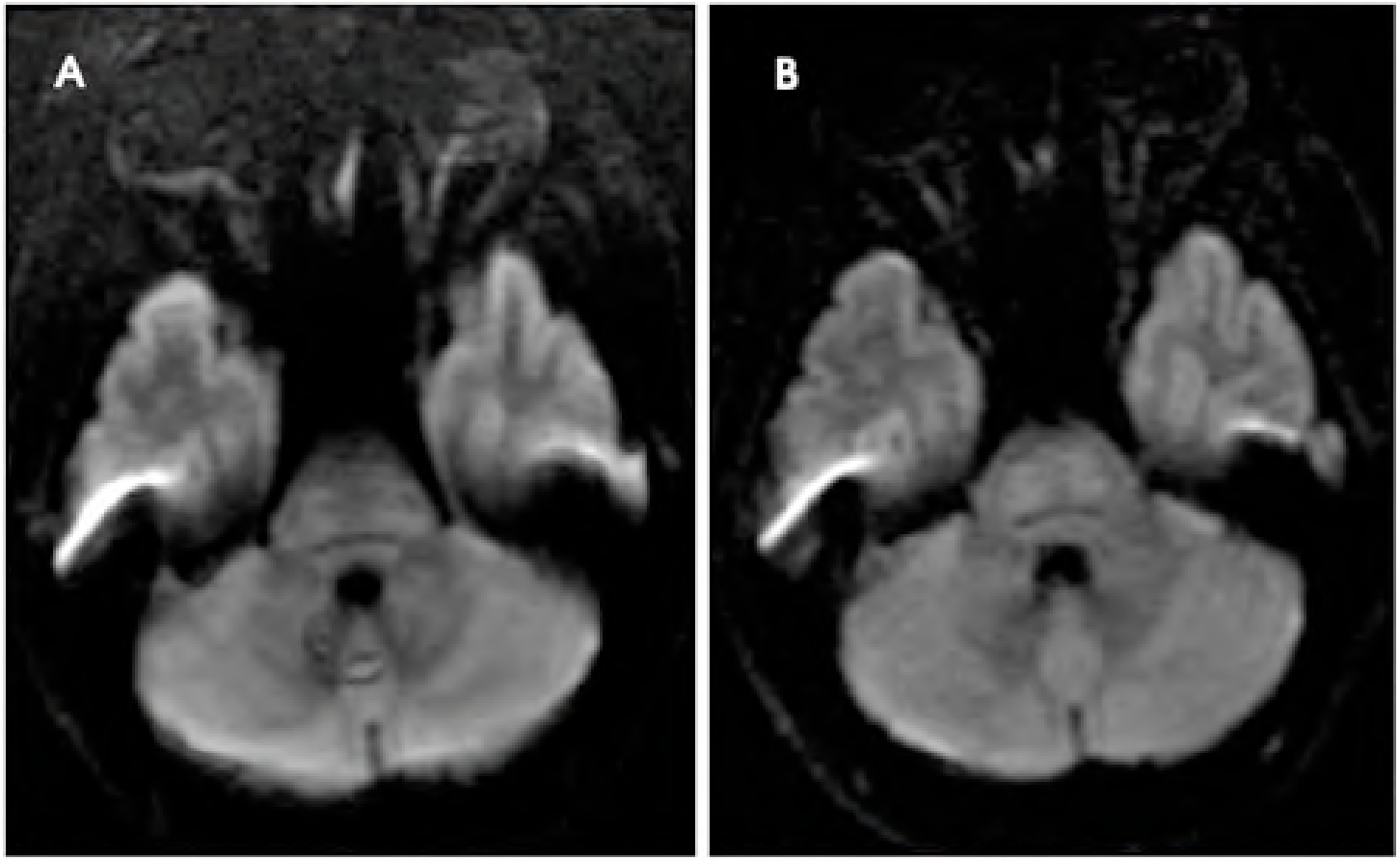




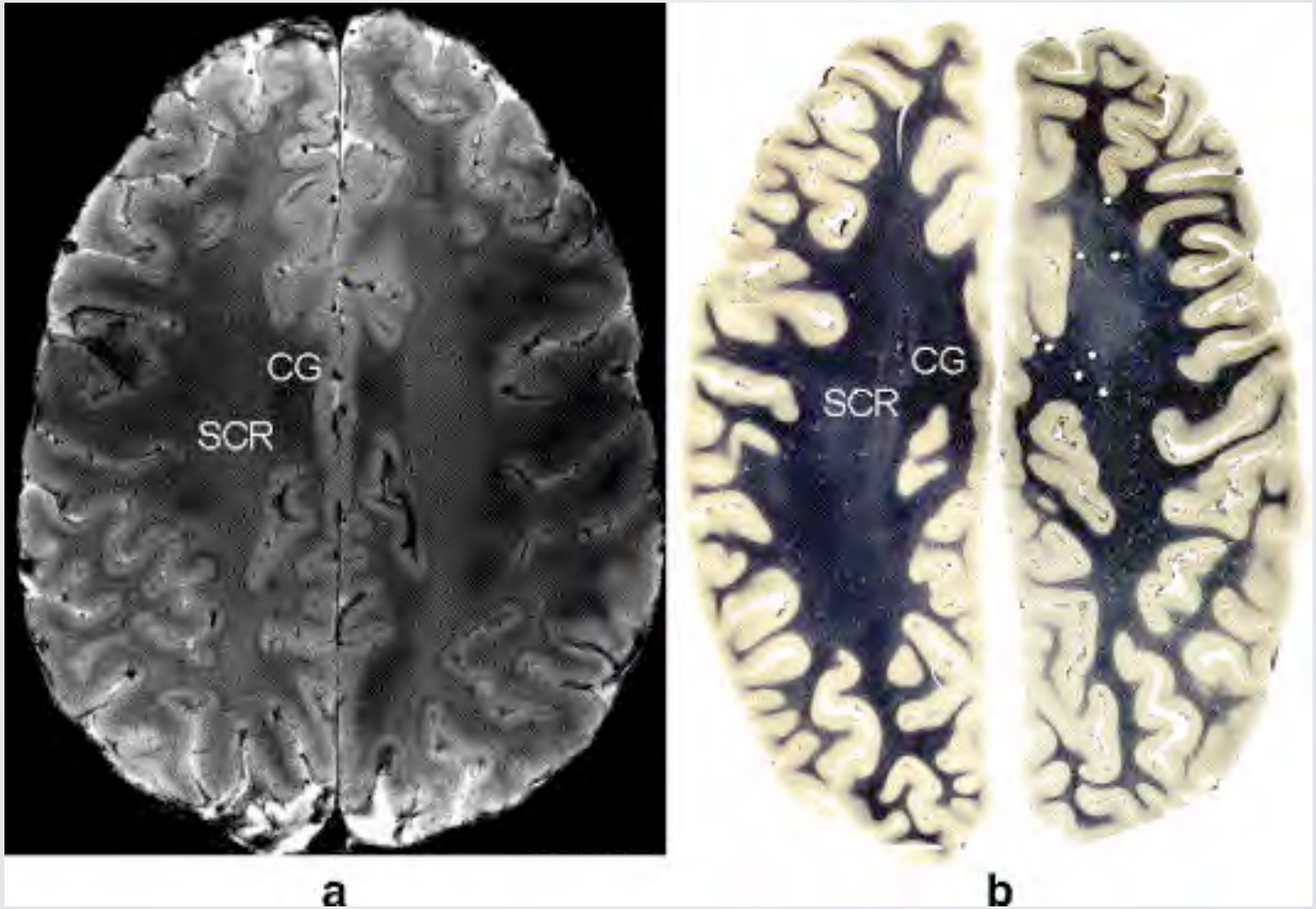





a
b

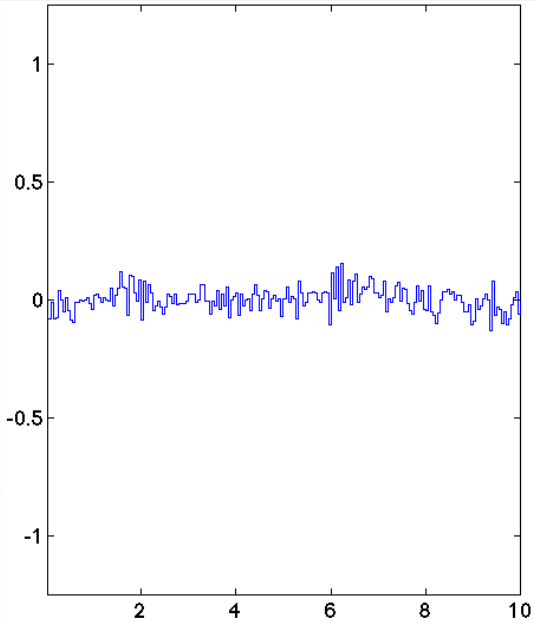


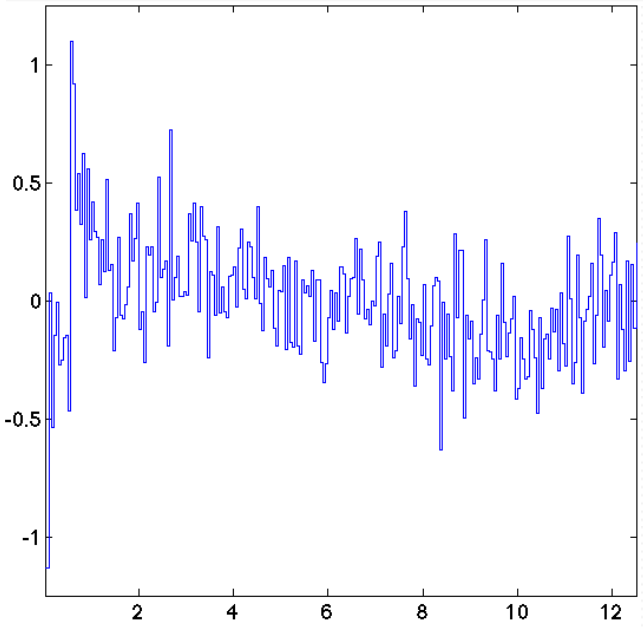
Source: Appl Radiol © 2006 Anderson Publishing, Ltd.

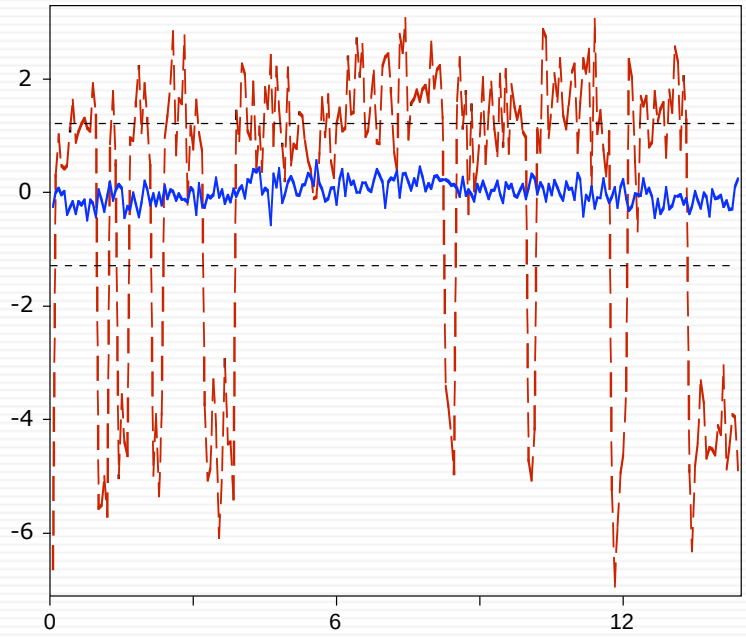

CG
SCR
CG
SCR
a
b

Instrument Variation

1. System Instability







Mean Intensity Variation

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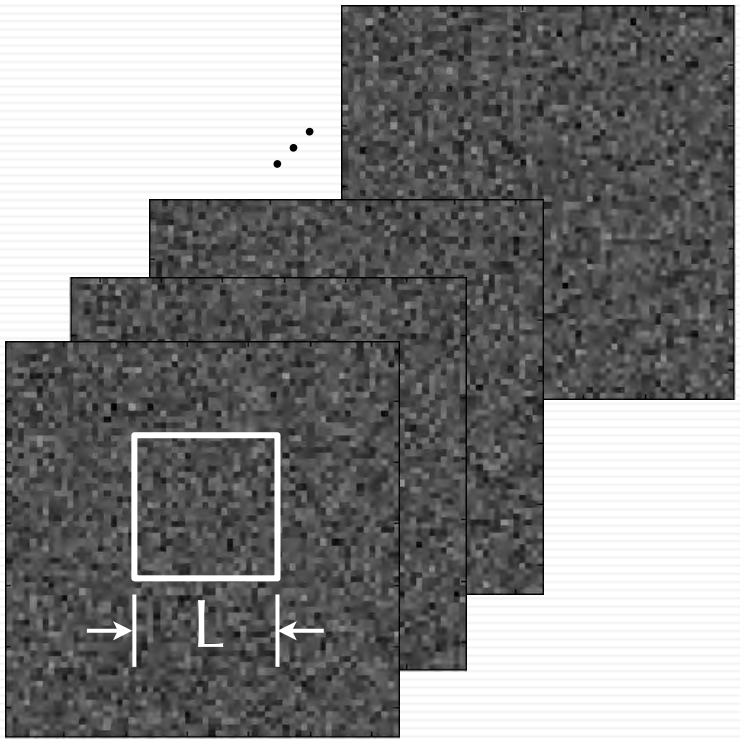
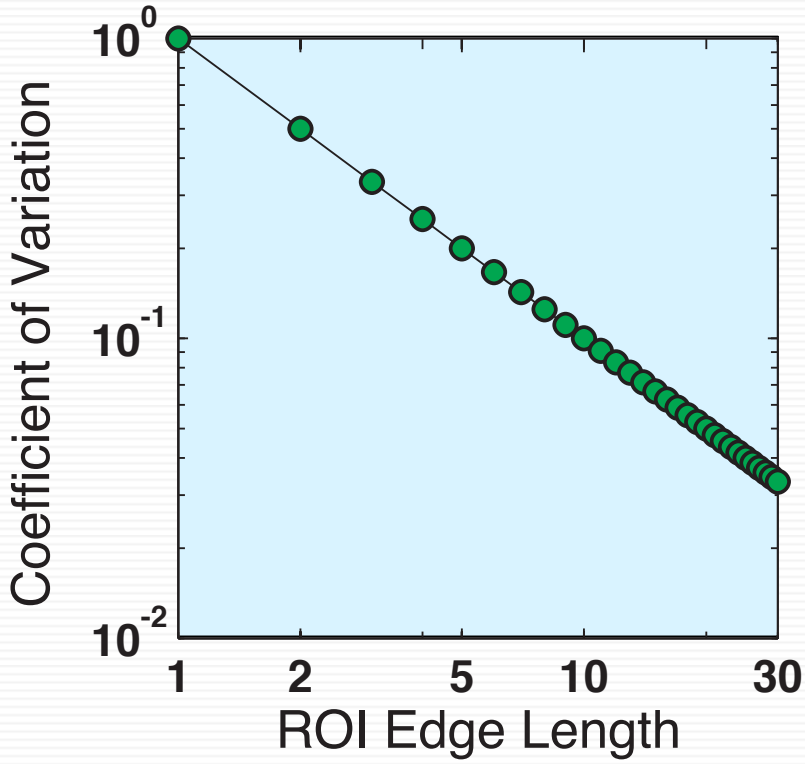
the Weisskoff Plot



The Expected Standard Deviation of the Mean Signal of a Region over Time Falls with the Square Root of the Number of Voxels.



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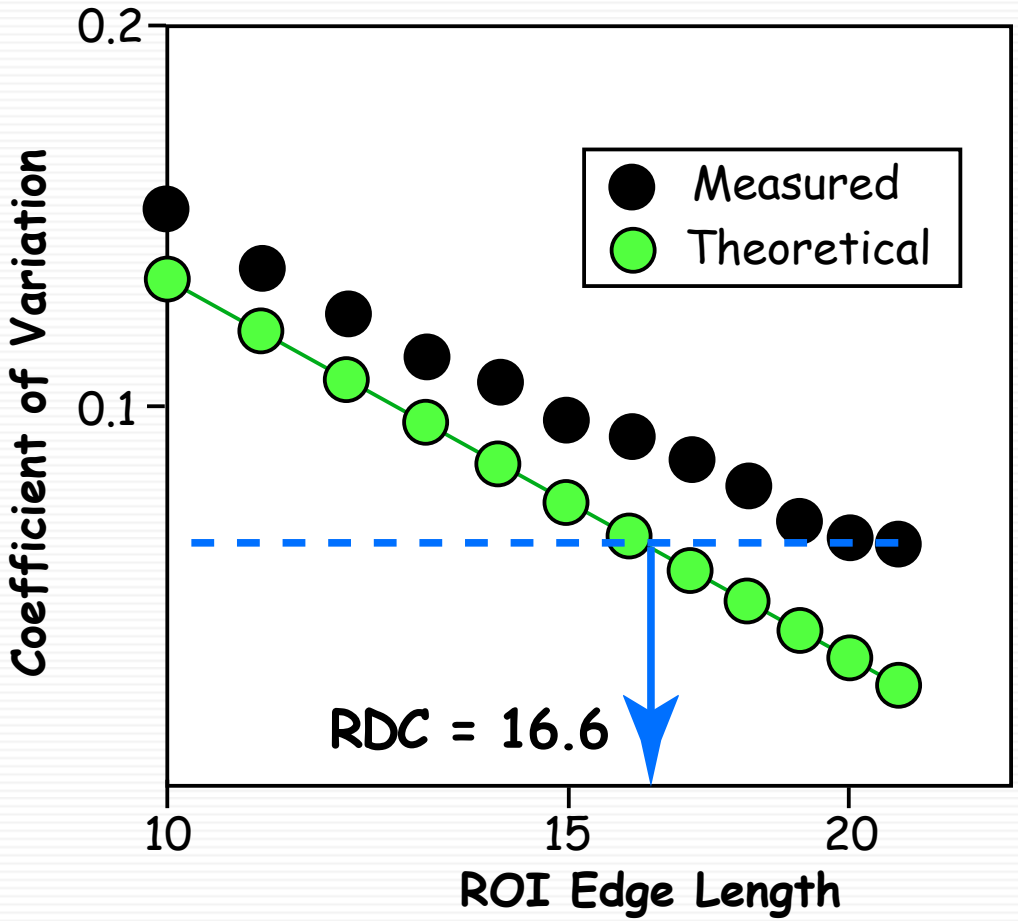
the Weisskoff Plot



Deviations from the Theoretical Curve are Evidence of Correlated Noise

RDC (*Radius of Decorrelation*) is a Single Point Quantification of the Weisskoff Plot

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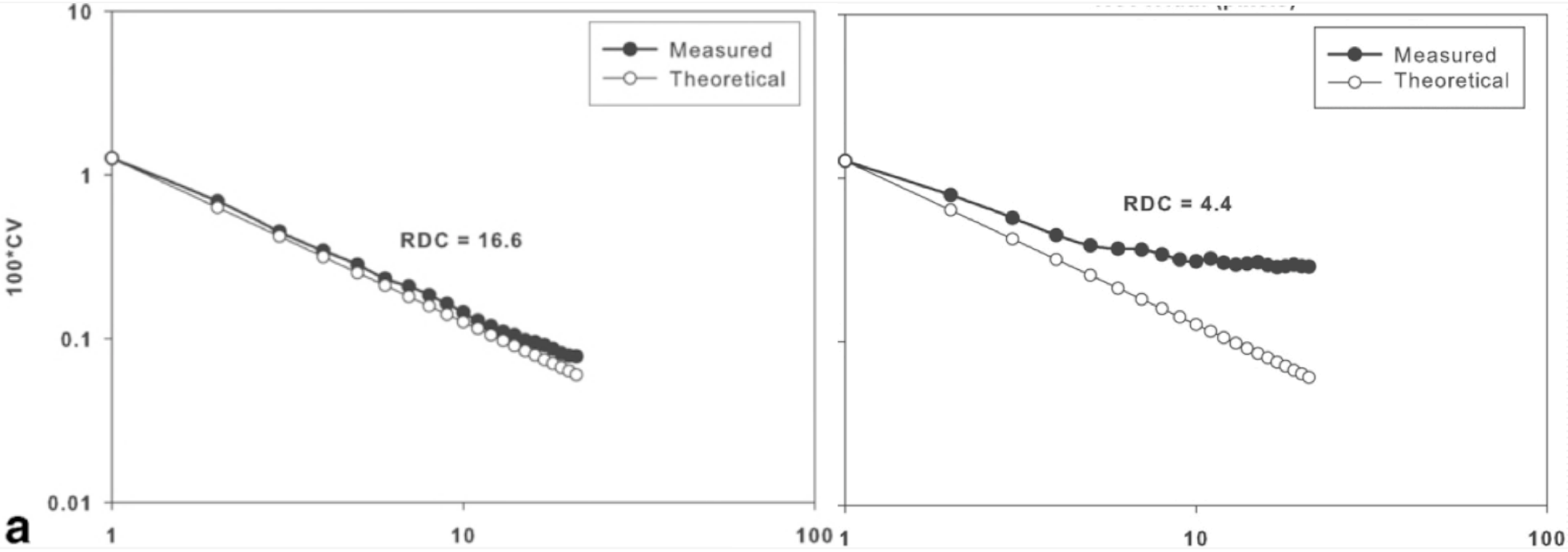
Weisskoff Plot

Weisskoff R. Magn Reson Med 36:643



ROI Length

ROI Length

Friedman and Glover, JMRI 23:827

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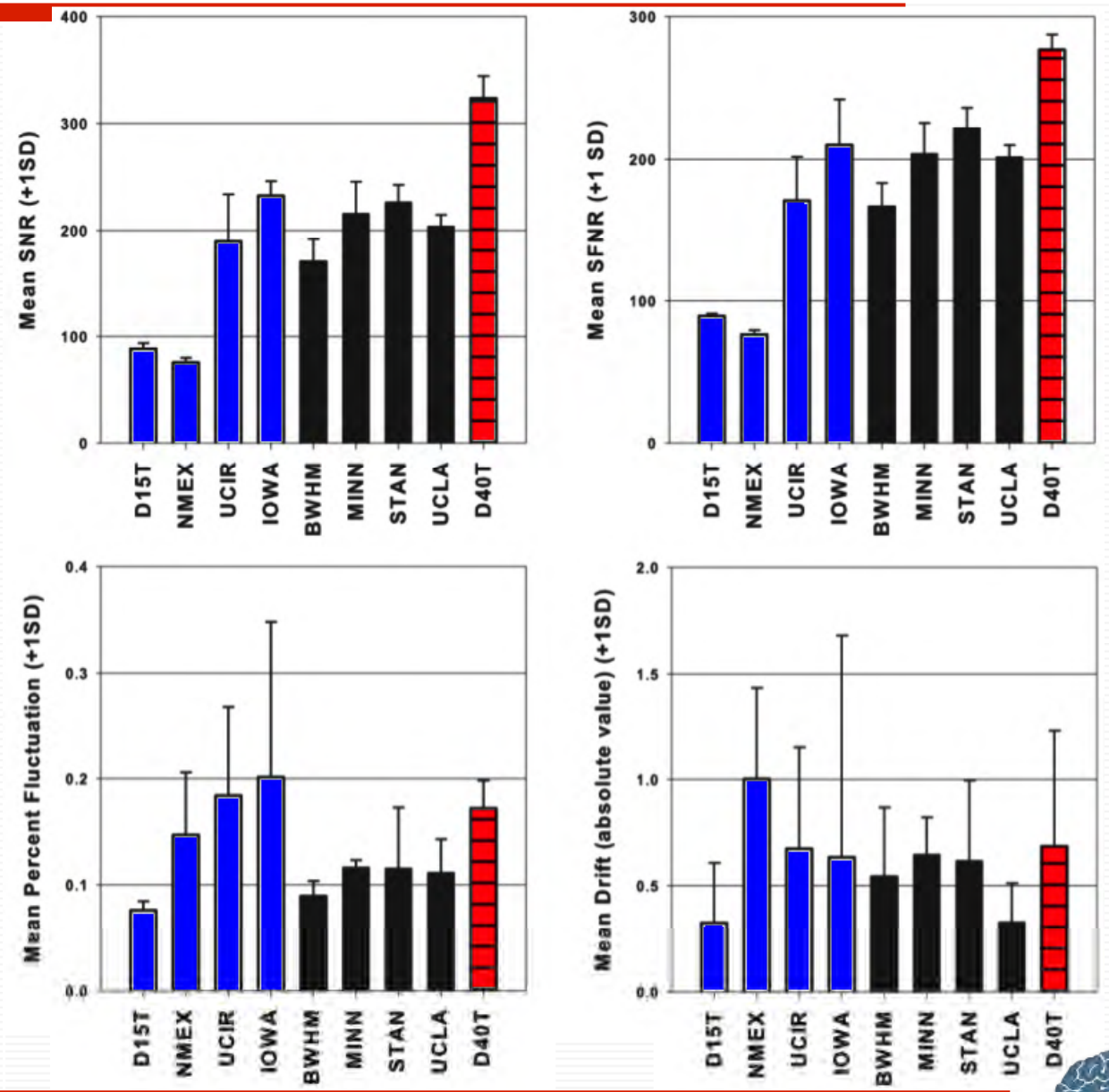
Scanner Comparisons



Friedman and Glover, JMRI 23:827

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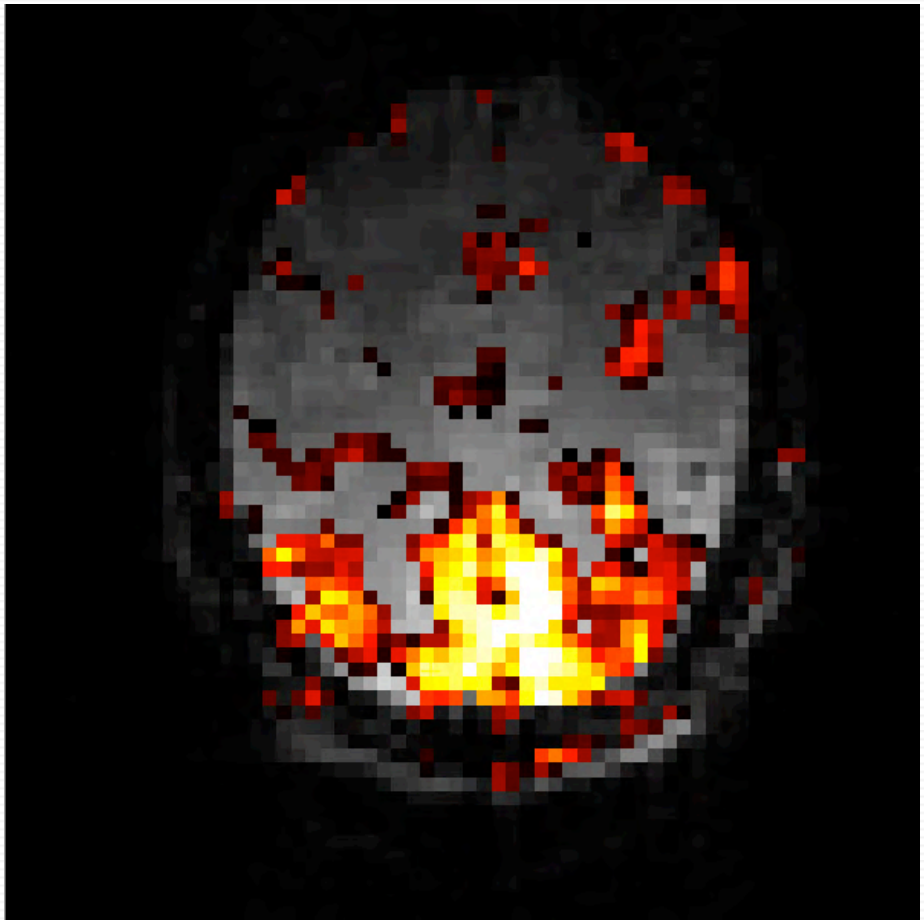
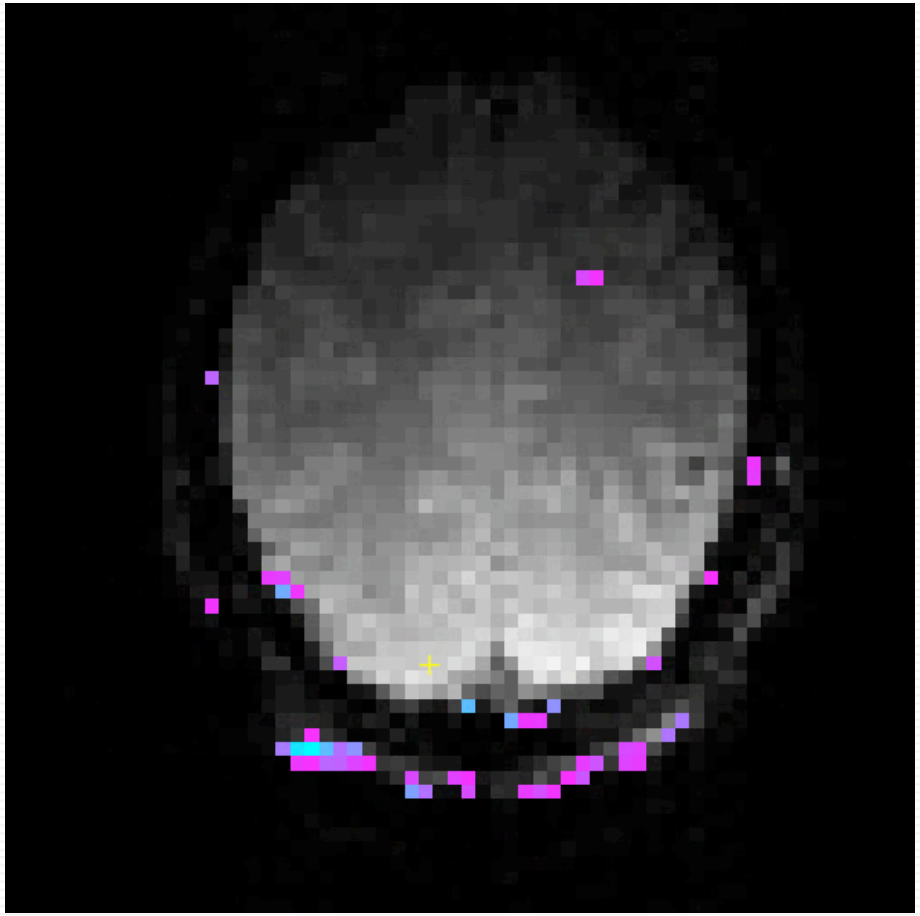
Global Mean Scaling - OFF





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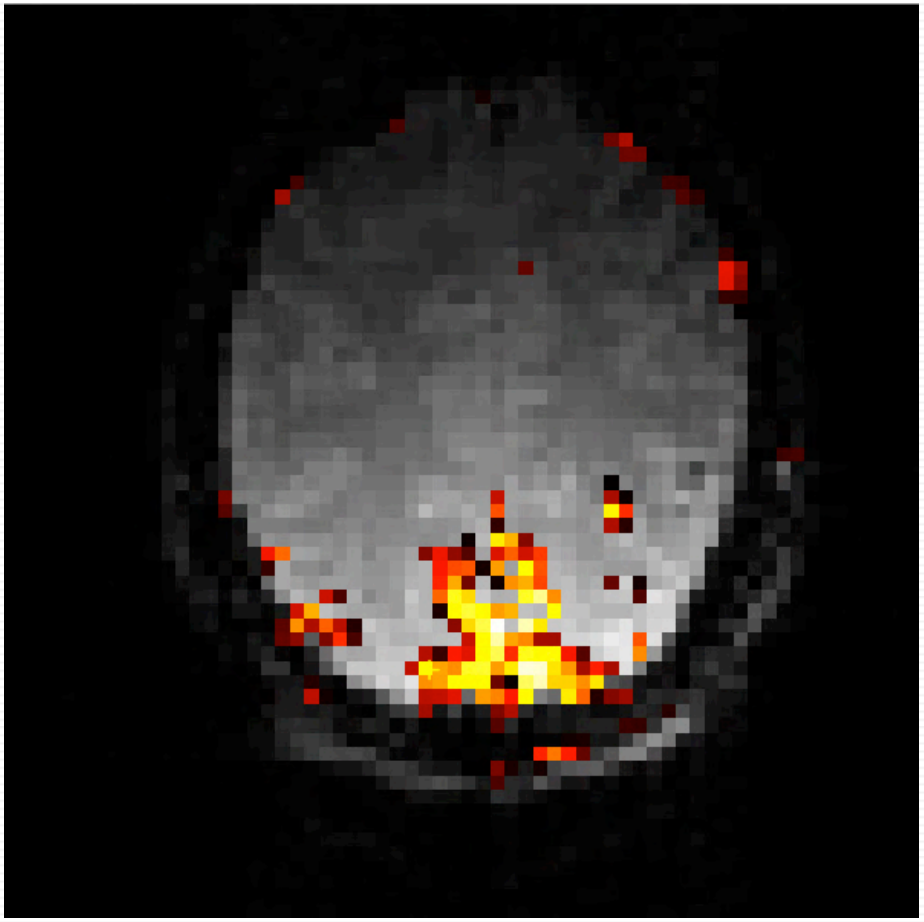
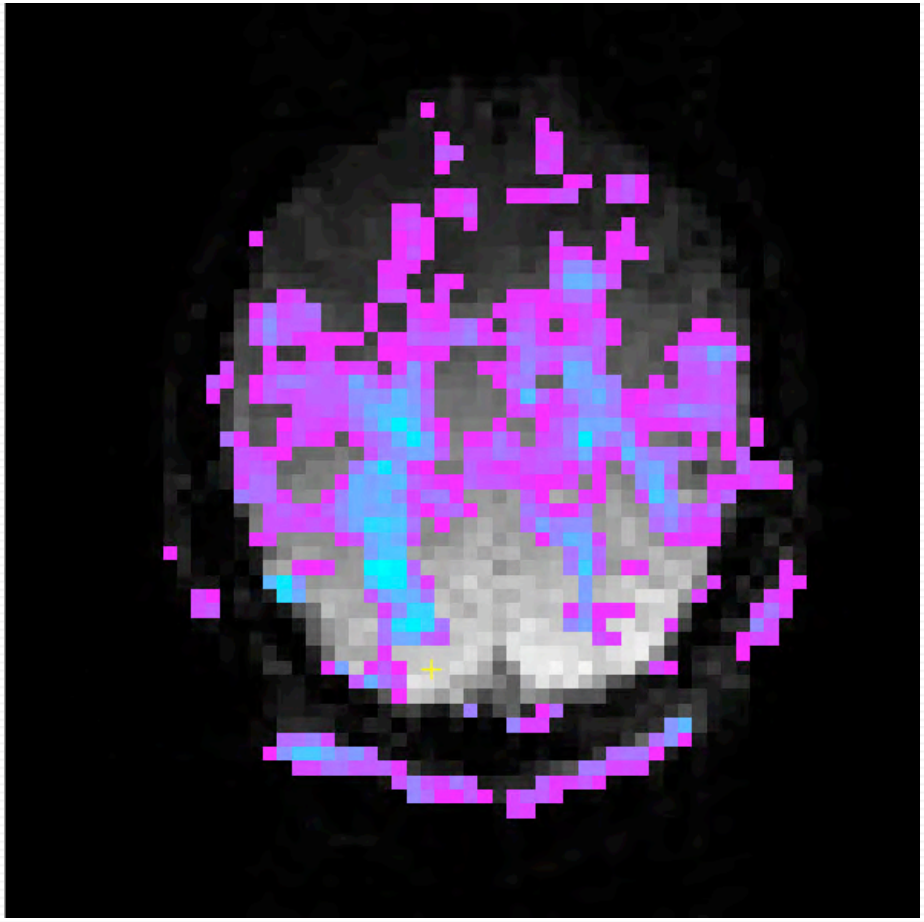
Global Mean Scaling - ON





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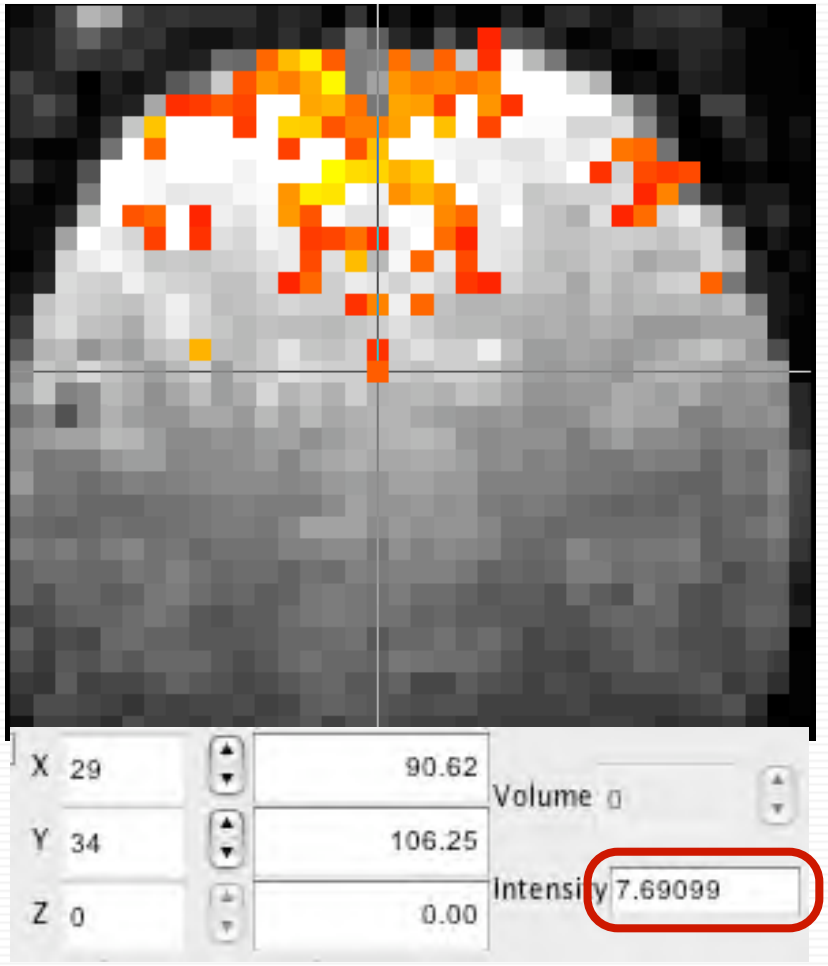
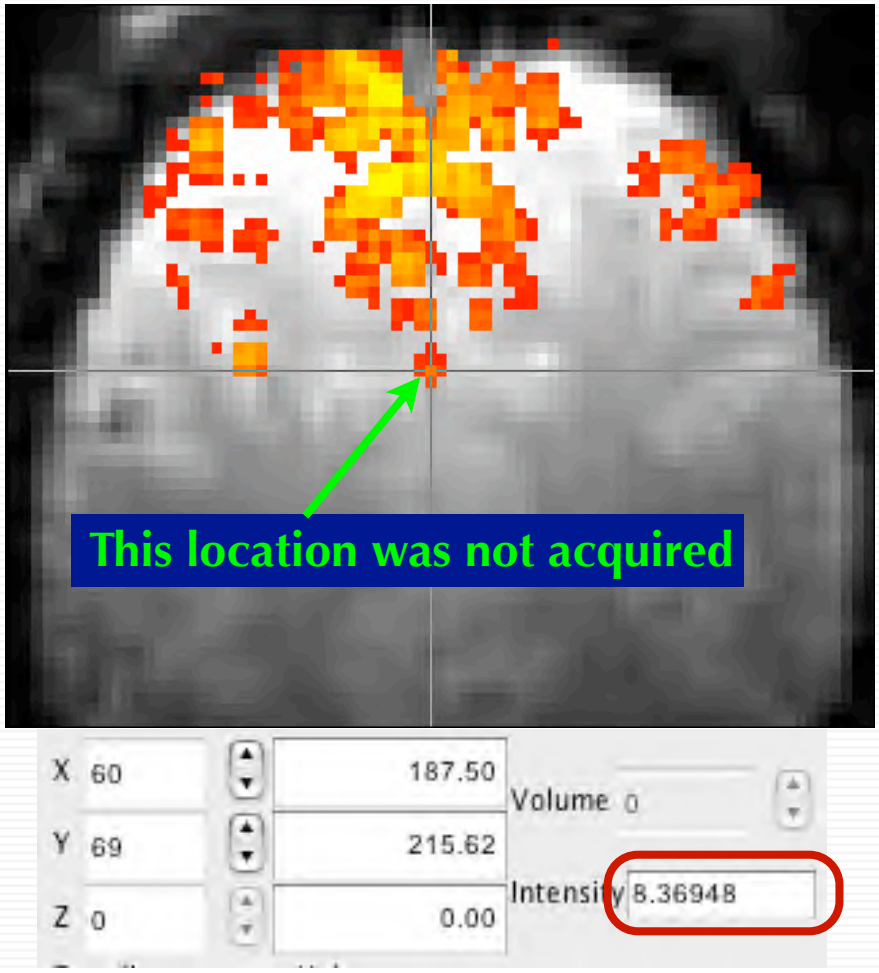
Interpolation



Native Resolution



Bilinear Interpolation

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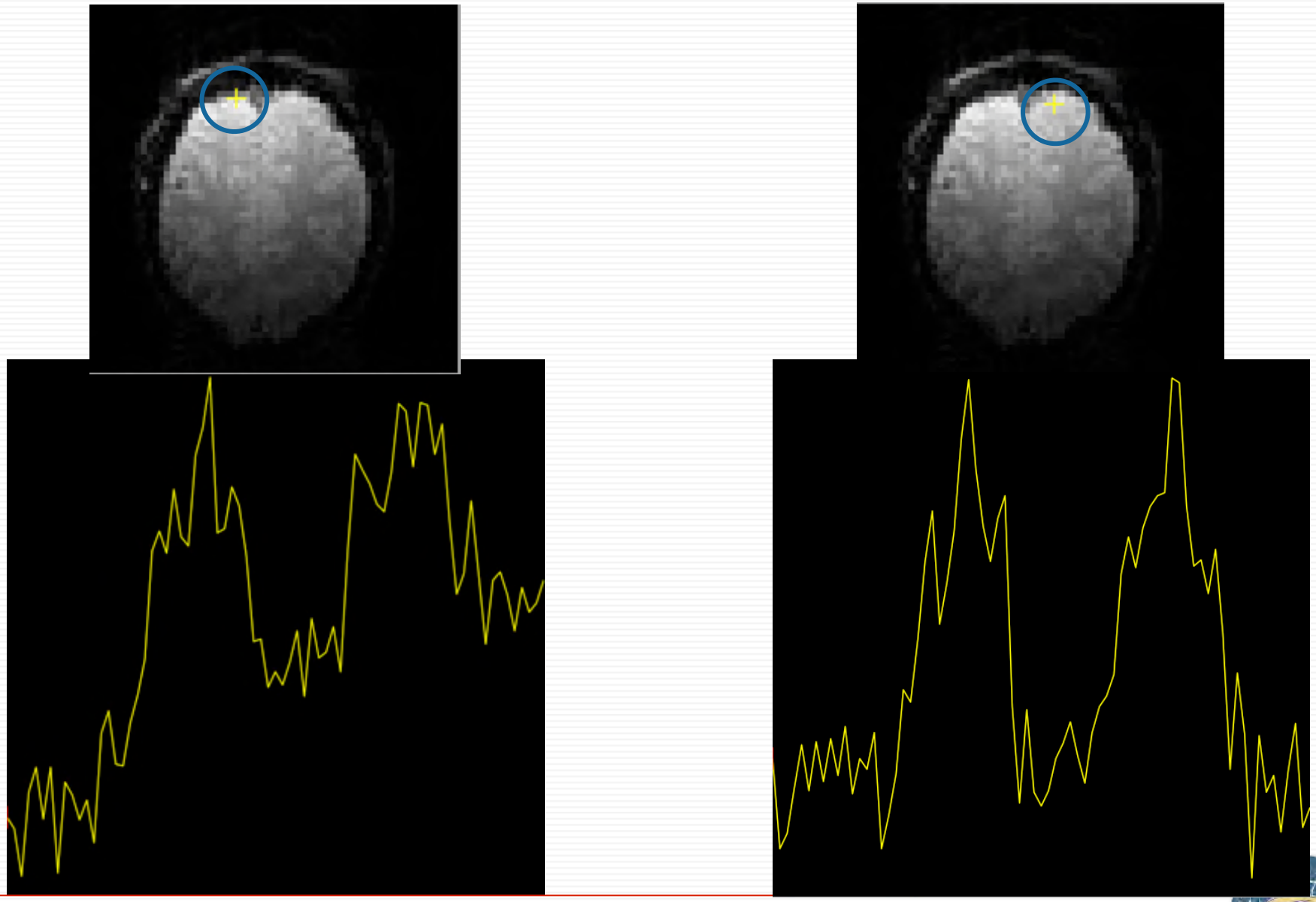
"Drift"



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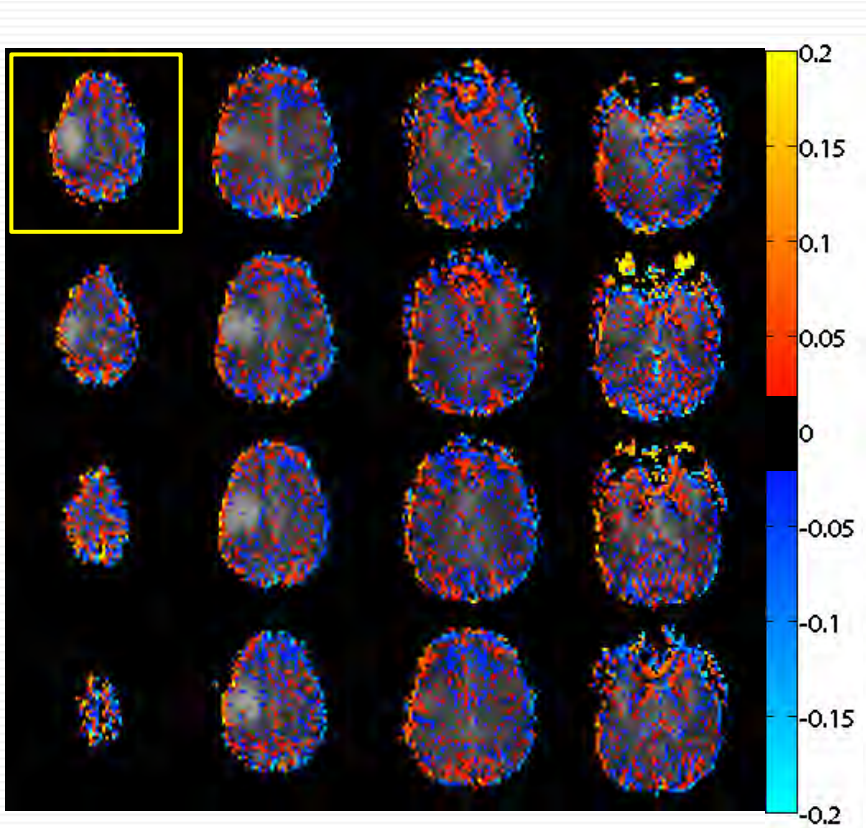
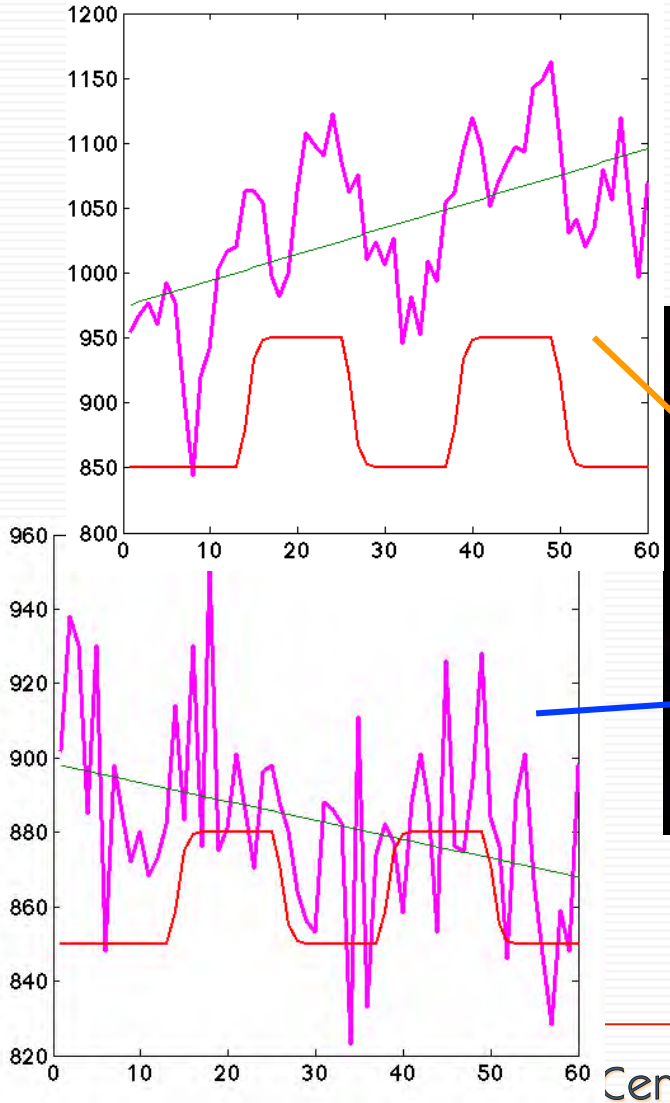
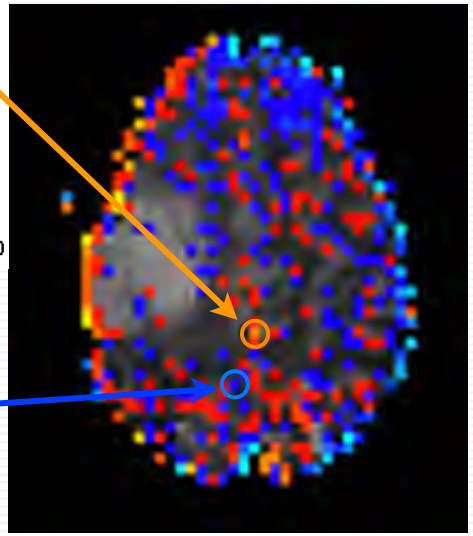
Instrument Variation

- 2. The mystery of scanner drift.







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Characterize Your Tools

- Test Statistics are Effect/Variance
- Variance includes:
  - Intrasubject (motion, attention, physiology, fatigue,…)
  - Intersubject variance (position, morphology, performance, pathology, physiology,…)
  - Experimental Variance (uncontrolled variables, stimulation variance,…)
  - Instrument Variance
  - Sitewise Variance
  - True Random Noise

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ARTIFACTS IN FMRI

Basic MRI Artifacts

- *Motion*
- *Shape and bandwidth*
- *Aliasing*
- *RF Penetration/Uniformity*
- *Signal Voids*
- *Data Spikes*
- *Apodization*
- *Chemical Shift*
- *K-Space errors (spiral)*

Time Series Artifacts

- *Signal Drifts*
- *Field Changes*

Data Analysis

- *Global Normalization*
- *Motion*
- *Smoothing*

False Positives and False Negatives

- *Excess variance*
- *Motion*
- *Cardiac Pulsation*
- *Respiration*
- *Timing Error*
- *Over-aggressive Smoothing*
- *Ratty Image Quality*
- *Wrong Statistical Test*