

Contrast in MRI

Mike Tyszka, Ph.D.

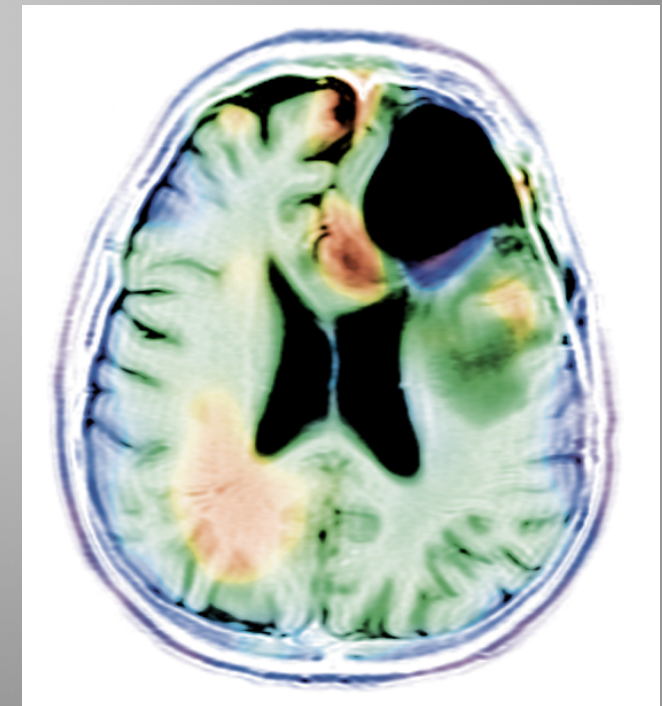
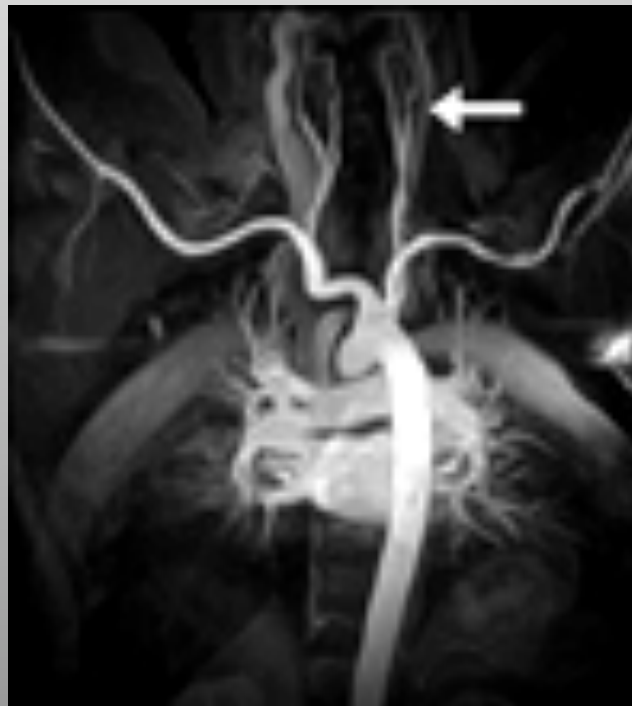
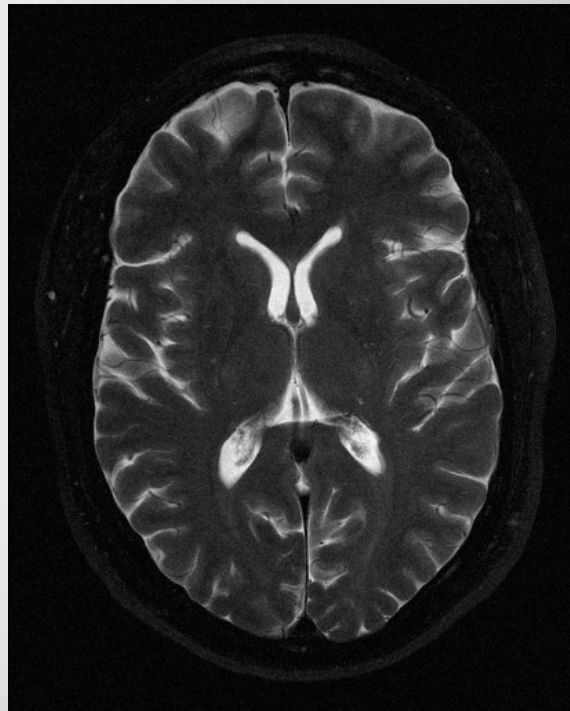
Magnetic Resonance Theory Course 2004

Caltech Brain Imaging Center

California Institute of Technology



MR Image Contrasts



MRI Contrast Sources

- Image contrast is the difference in signal between different tissues or materials.
- Contrast-to-noise ratio is more important generally than signal-to-noise ratio in MRI.
- MRI can draw on many material properties to create image contrast.

MRI Imaging Contrast Parameters

- Intrinsic

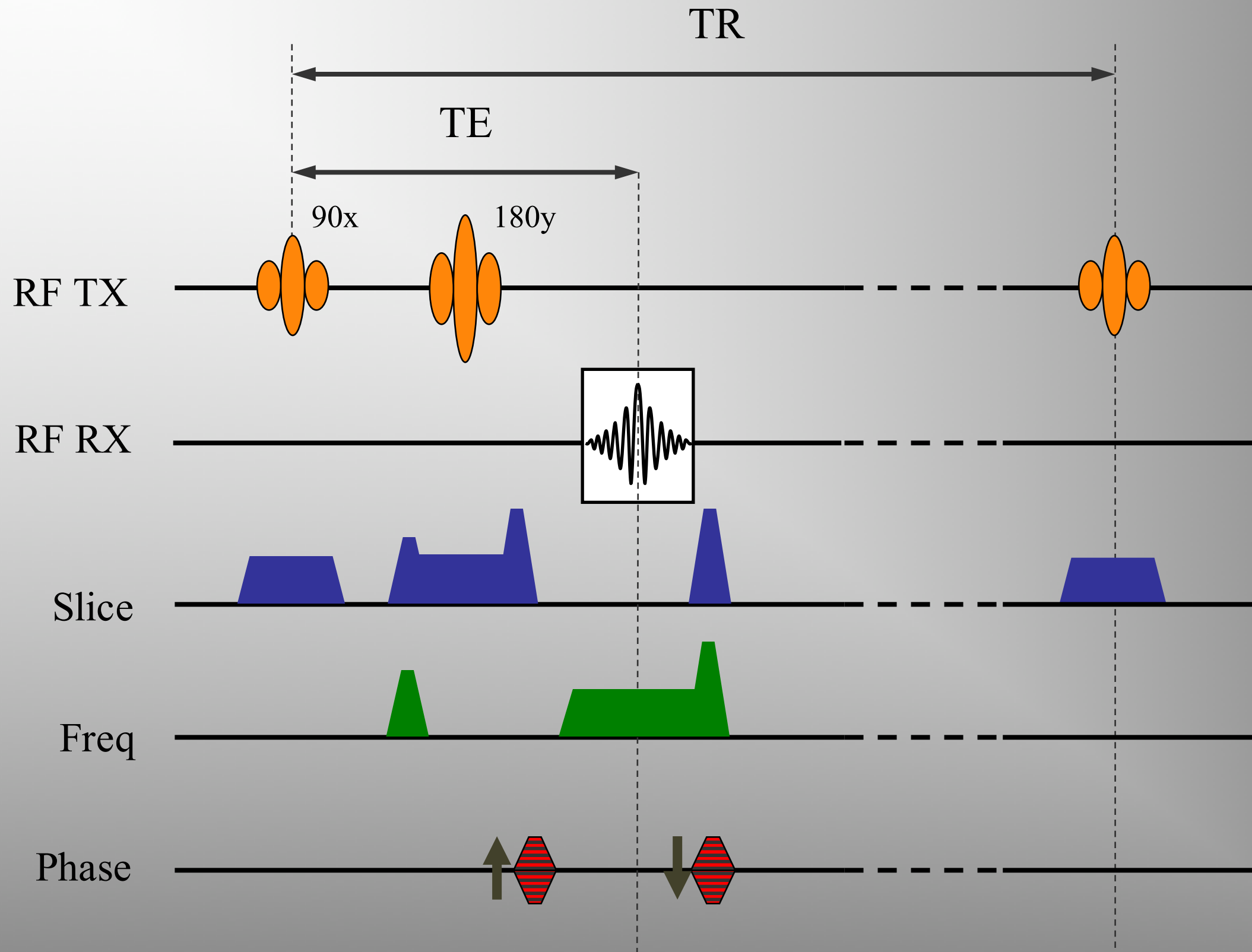
- Proton Density
- T1
- T2
- T2*
- Flow
- Diffusion
- ...

- Pulse Sequence

- Repetition Time (TR)
- Echo Time (TE)
- Inversion Time (TI)
- Flip Angle
- Diffusion Gradients
- Flow Encoding Gradients
- Saturation Pulses
- Spectral Editing
- ...

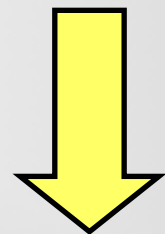
Spin Echo Contrast

Spin Echo Pulse Sequence

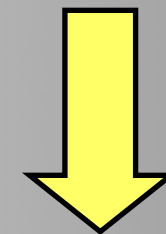


Generalized Spin Echo Contrast

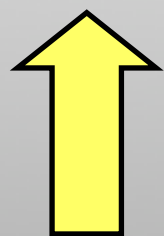
Proton Density



T₂ Weighting



$$S(TR, TE) = S(0) \cdot \left(1 - e^{-TR/T_1}\right) \cdot e^{-TE/T_2}$$



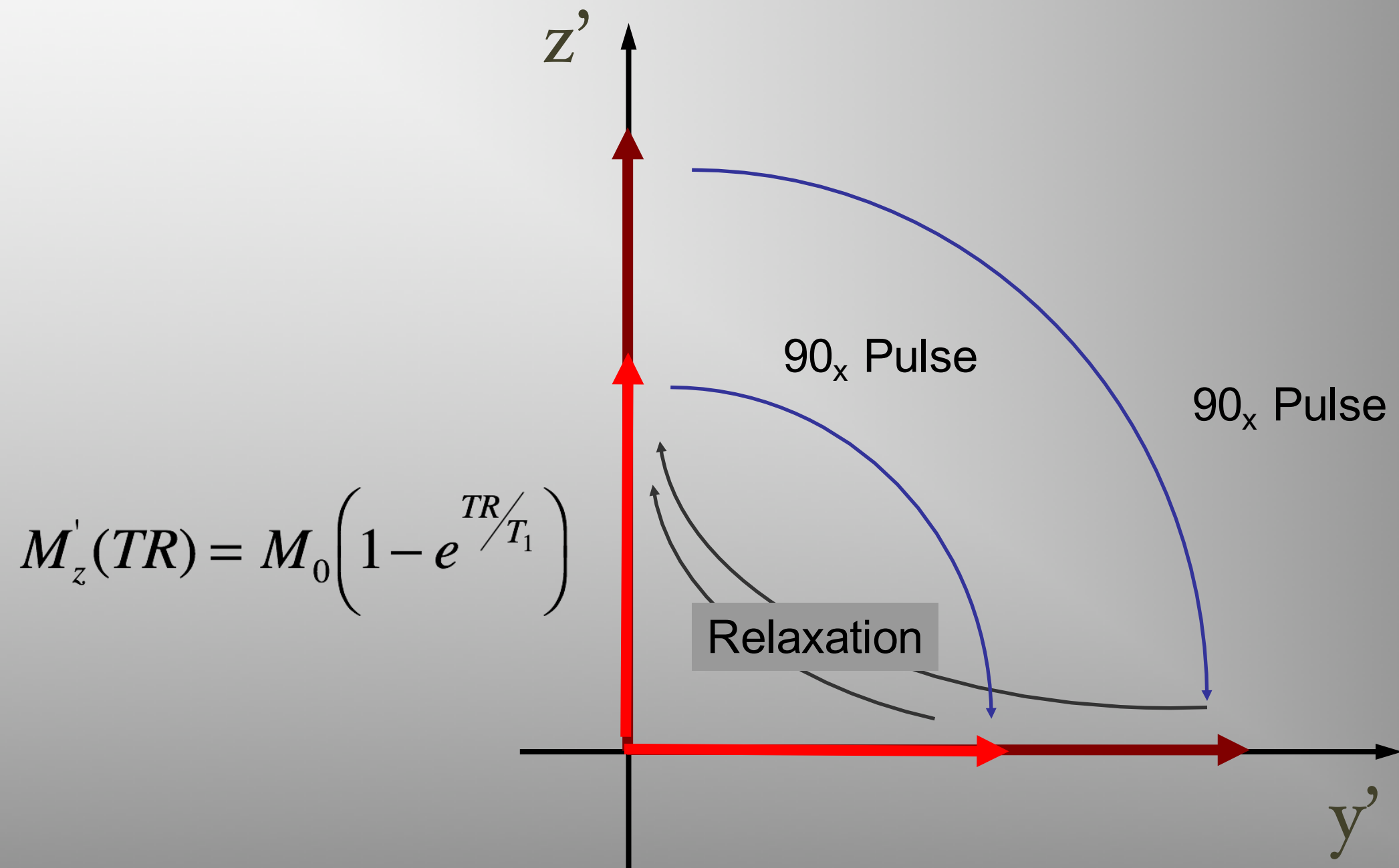
Signal Magnitude



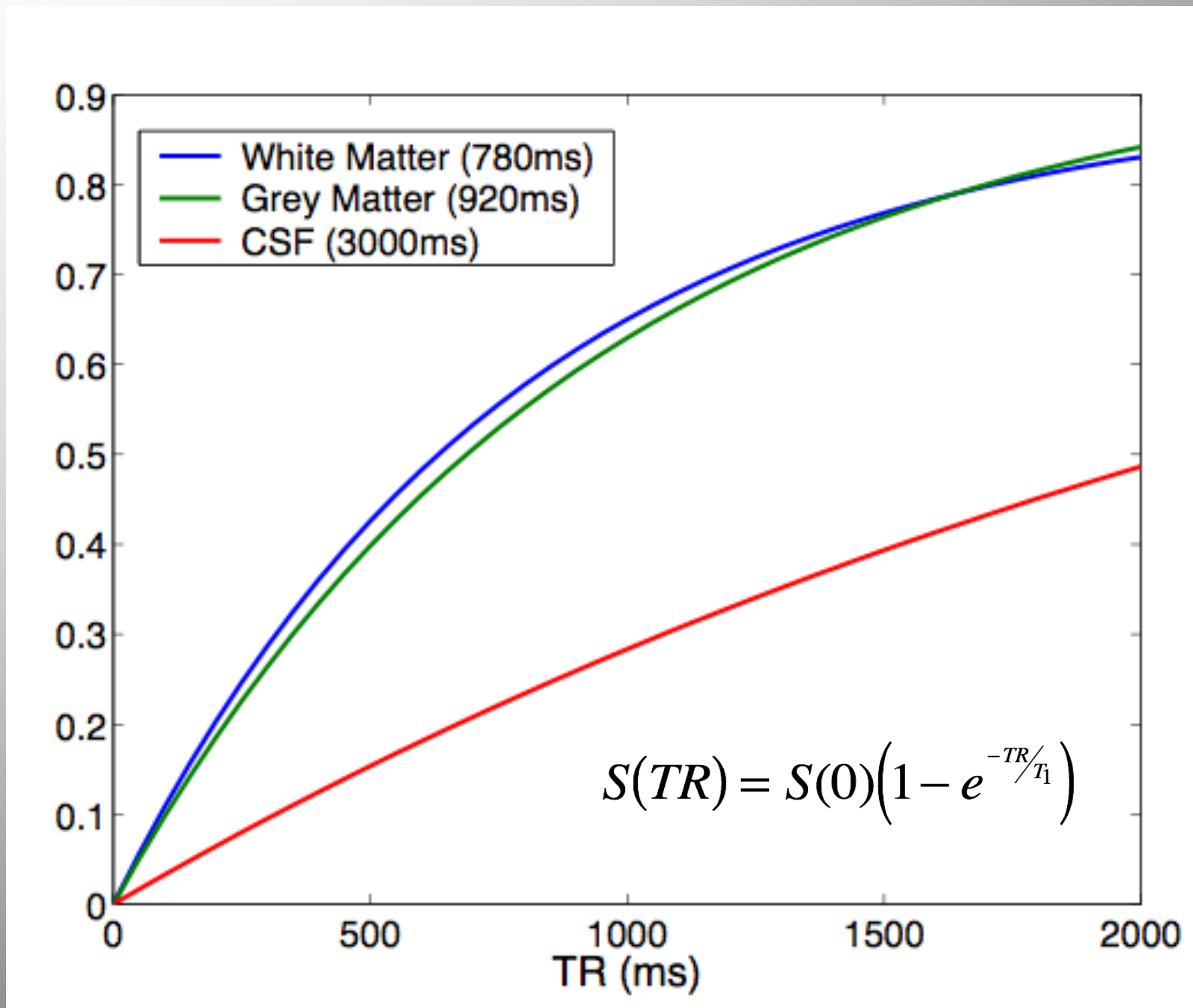
T₁ Weighting

Magnetization Saturation

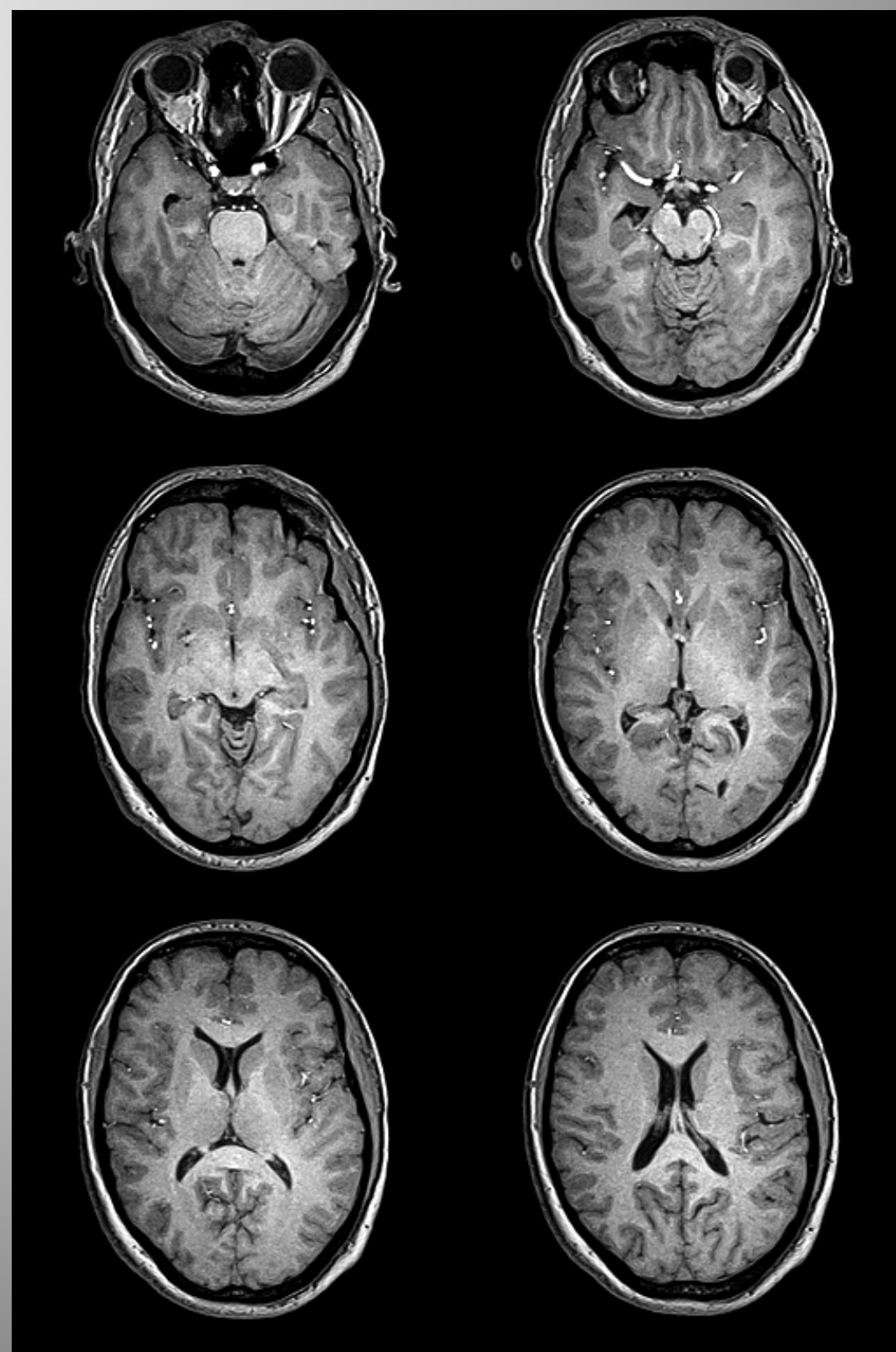
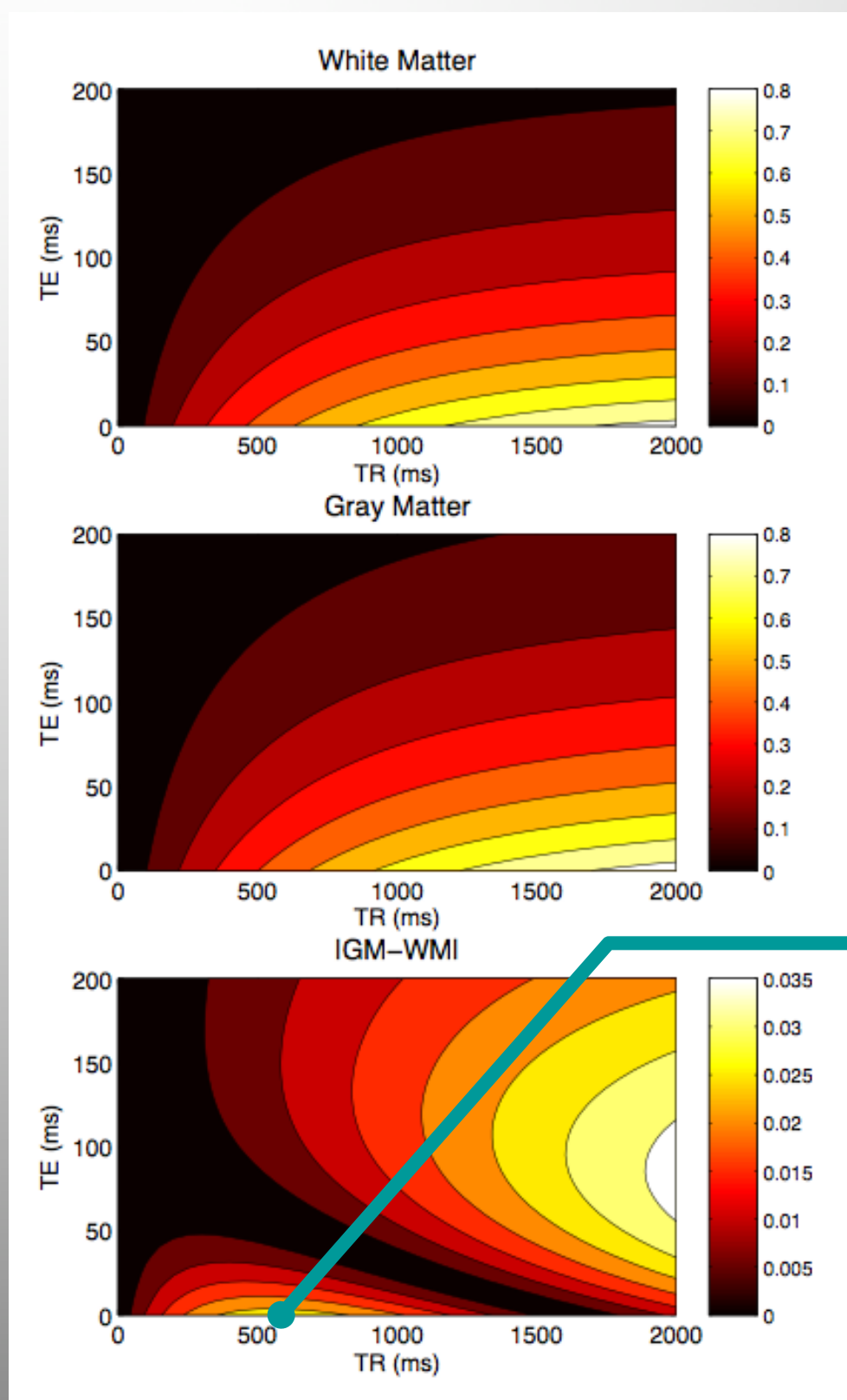
- Saturation is most pronounced when TR is short compared to T_1



Saturation Recovery



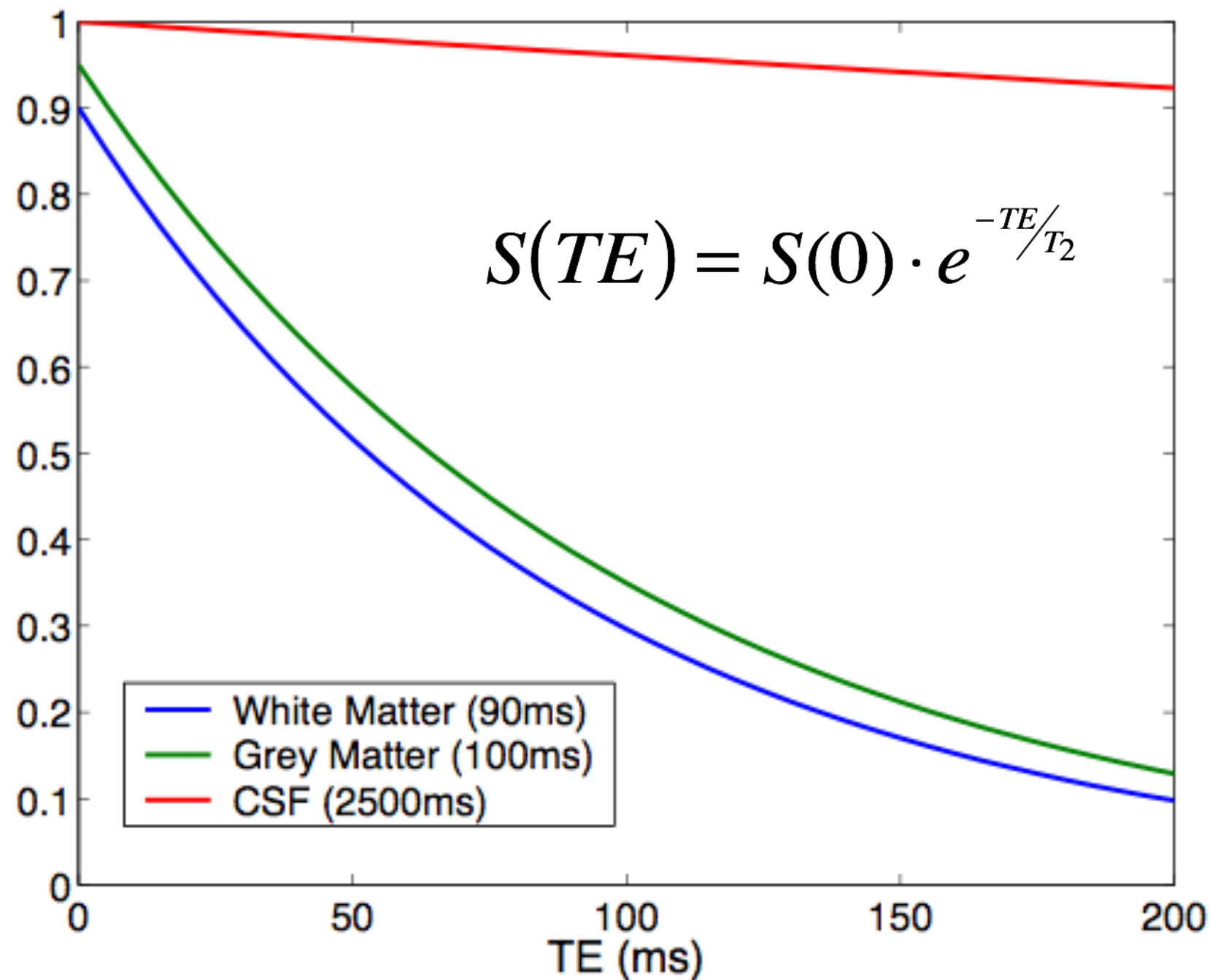
Saturation Recovery Contrast (T_1 -weighted)



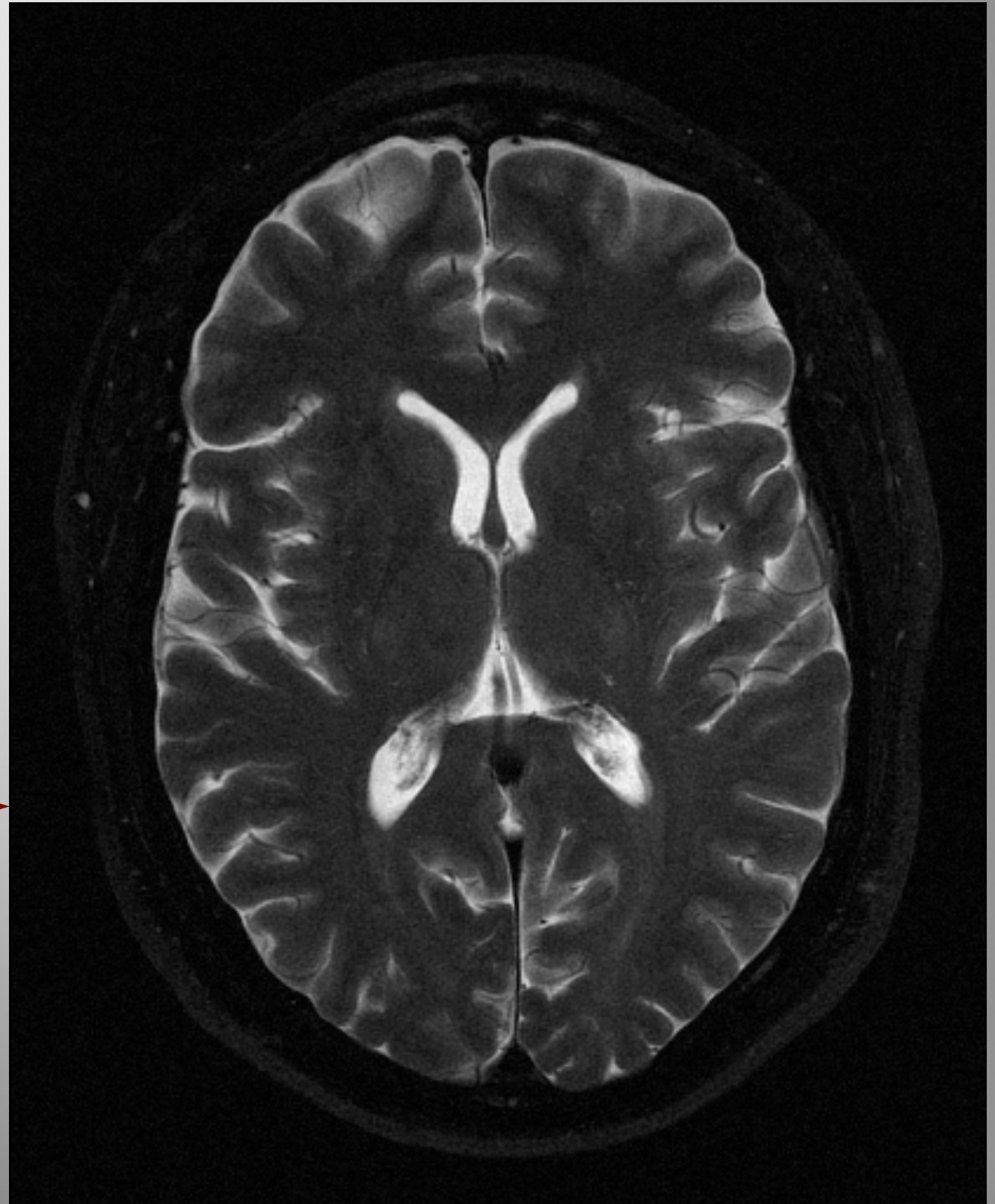
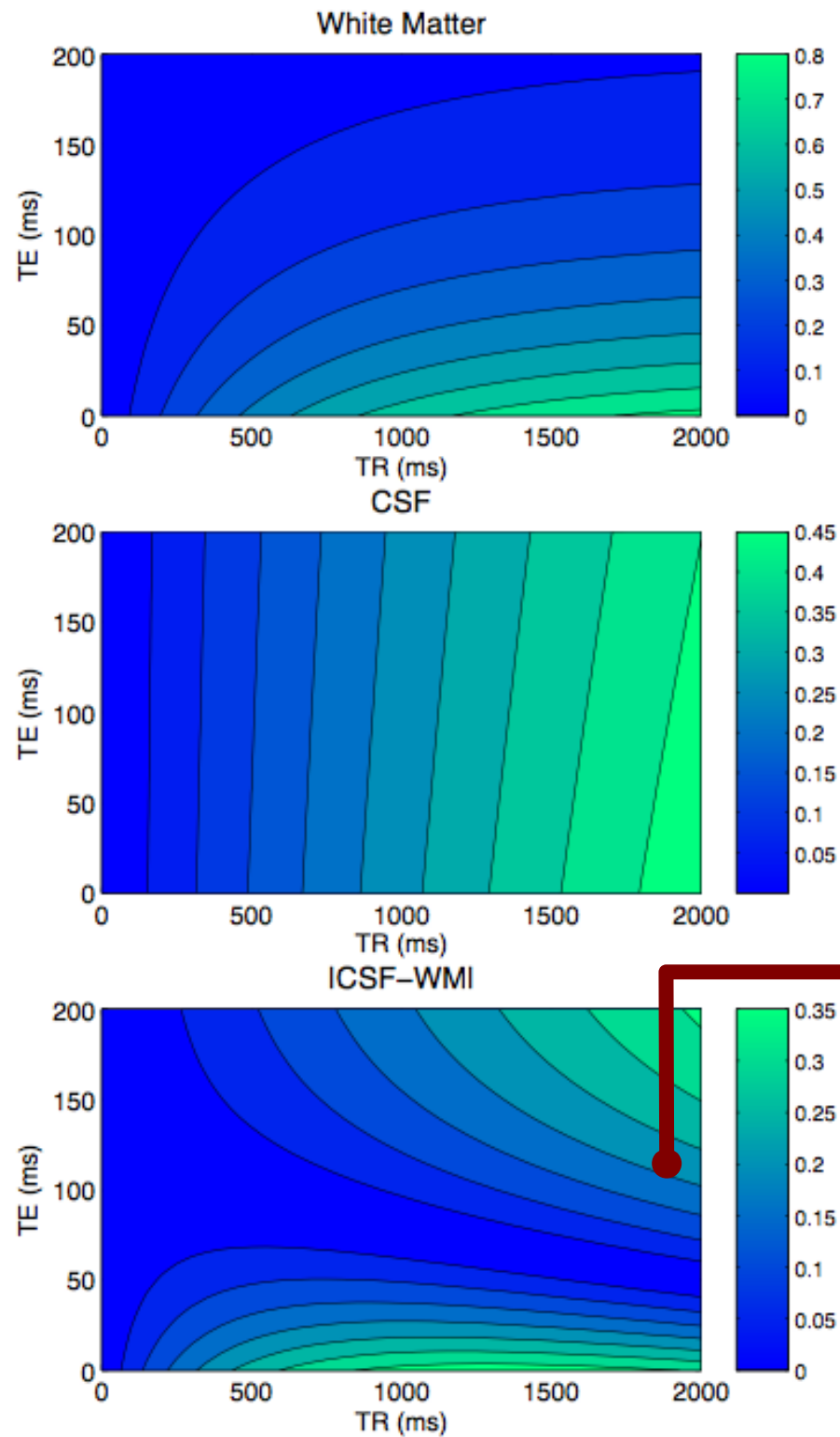
Spin Echo

- Key Parameters
 - TR : Typically moderate to long (100ms to 10s)
 - TE : Short to long (5ms to 150ms)
- Primary Applications
 - T_1 -weighted 2D multi-slice imaging
- Artifacts
 - Some motion sensitivity
 - Insensitive to susceptibility gradients

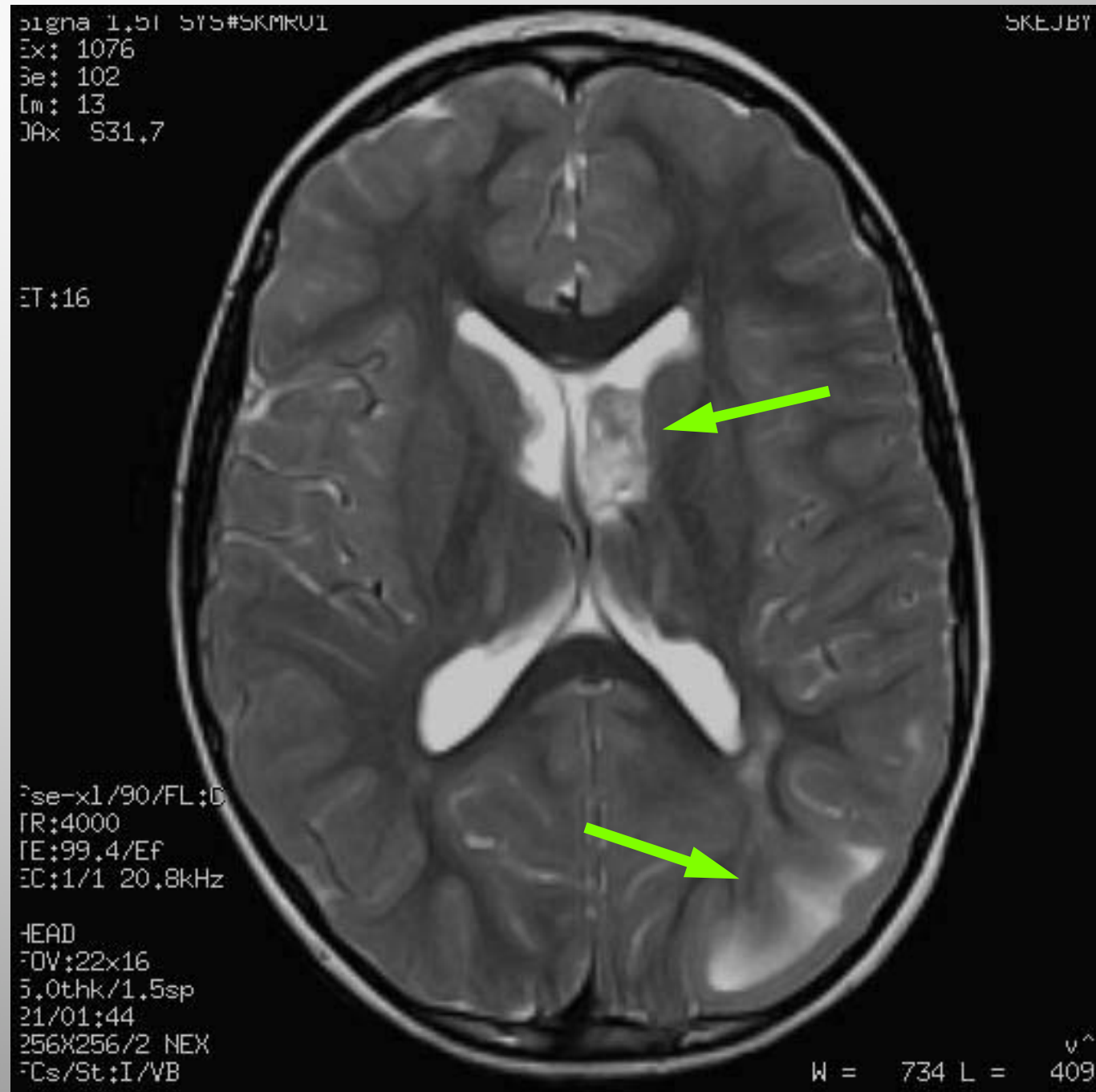
T₂ Decay: The Effect of Echo Time



T₂-weighted Contrast

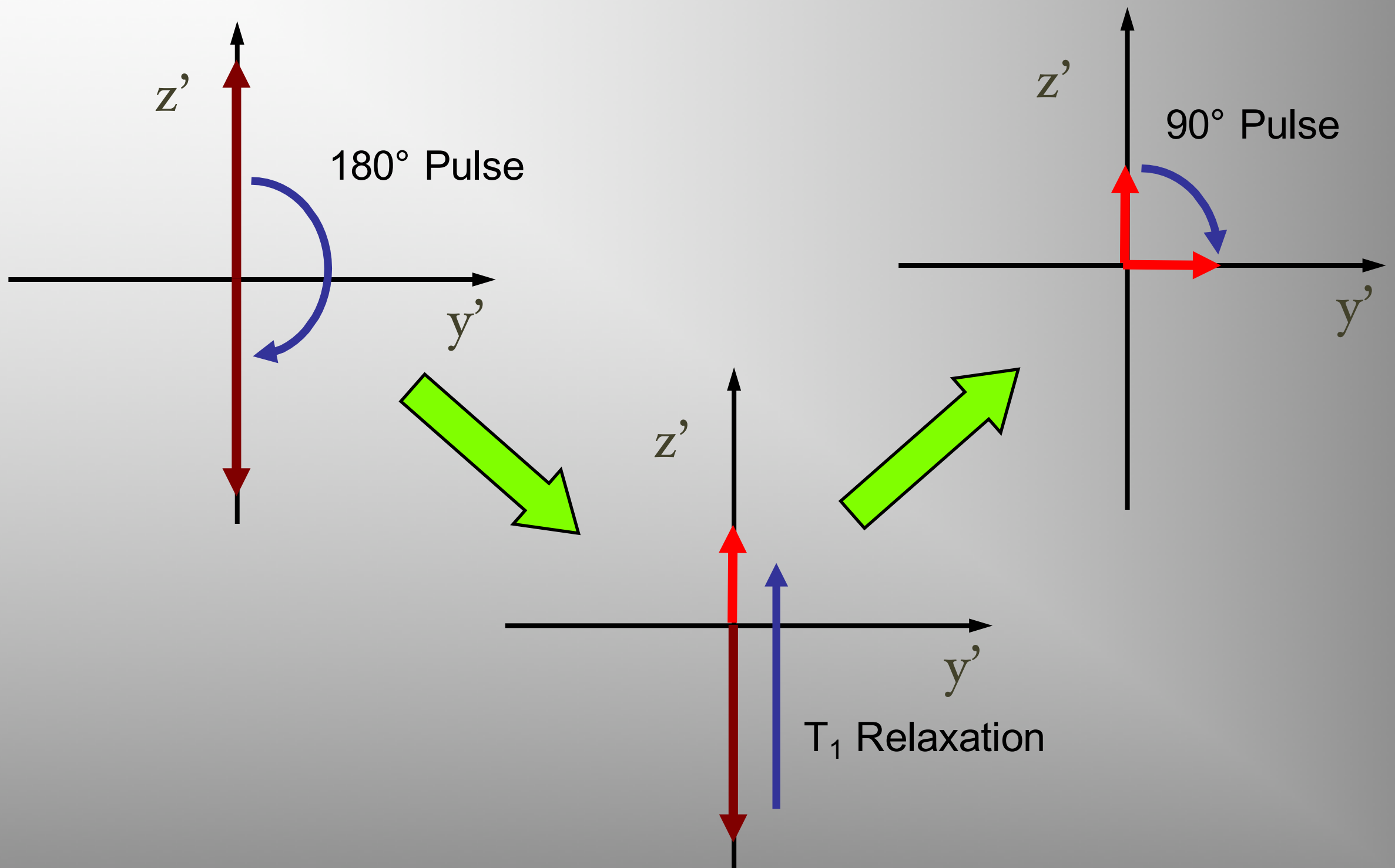


T₂-weighted MRI in Diagnostic Imaging

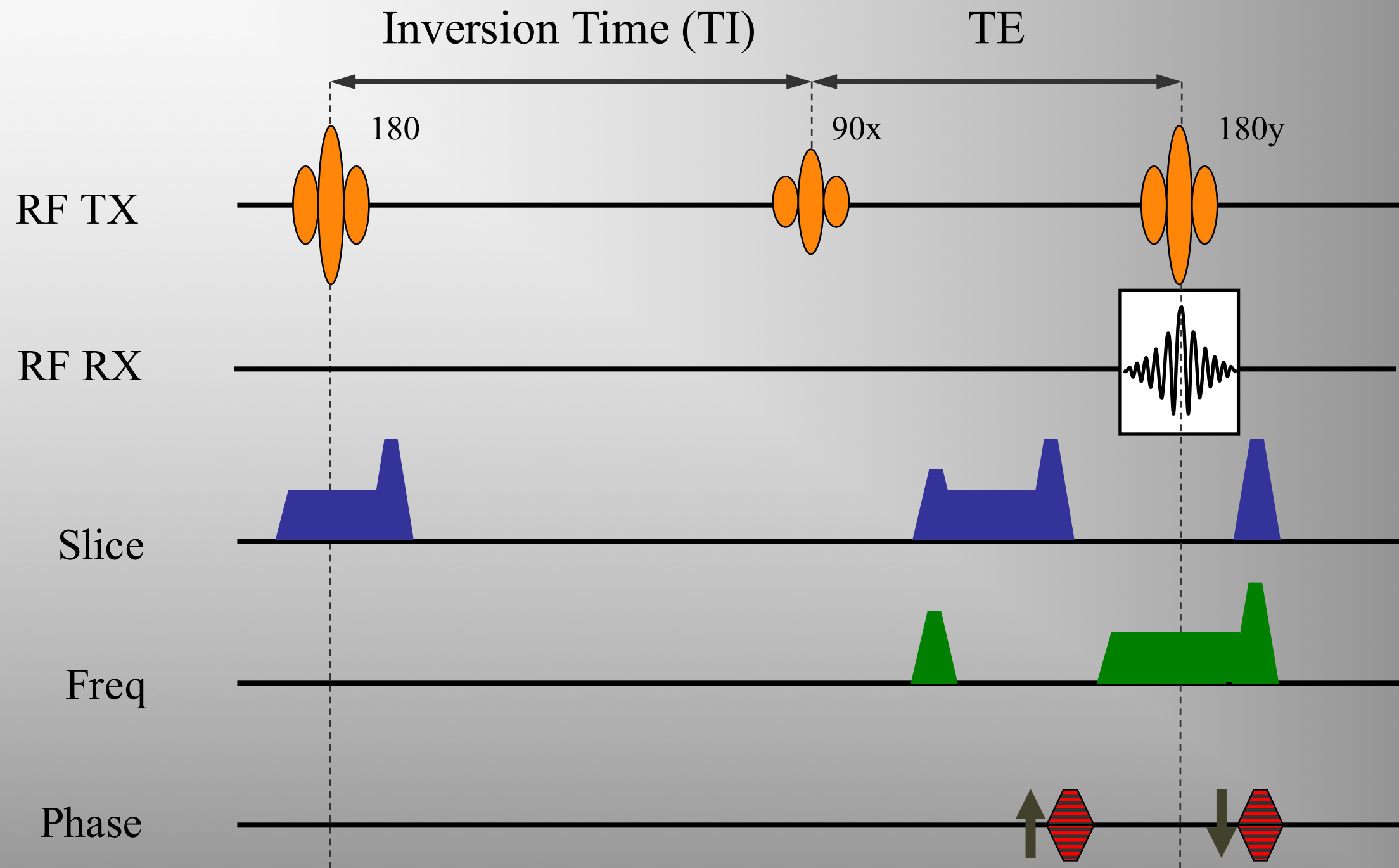


http://www.gemedicalsystems.com/rad/mri/images/med/mri/neuro/I5_neuroI_OI_imageI.jpg

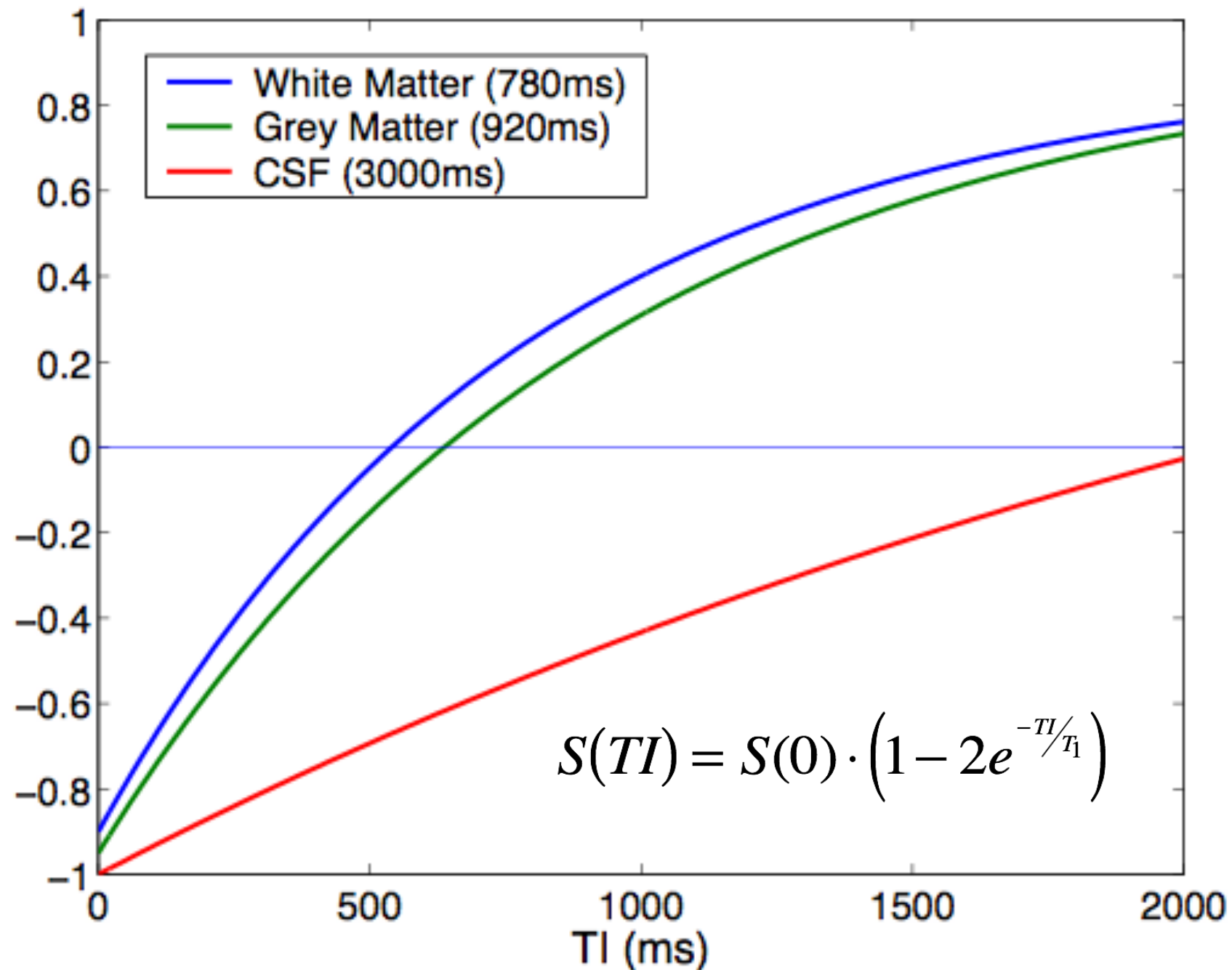
Inversion Recovery



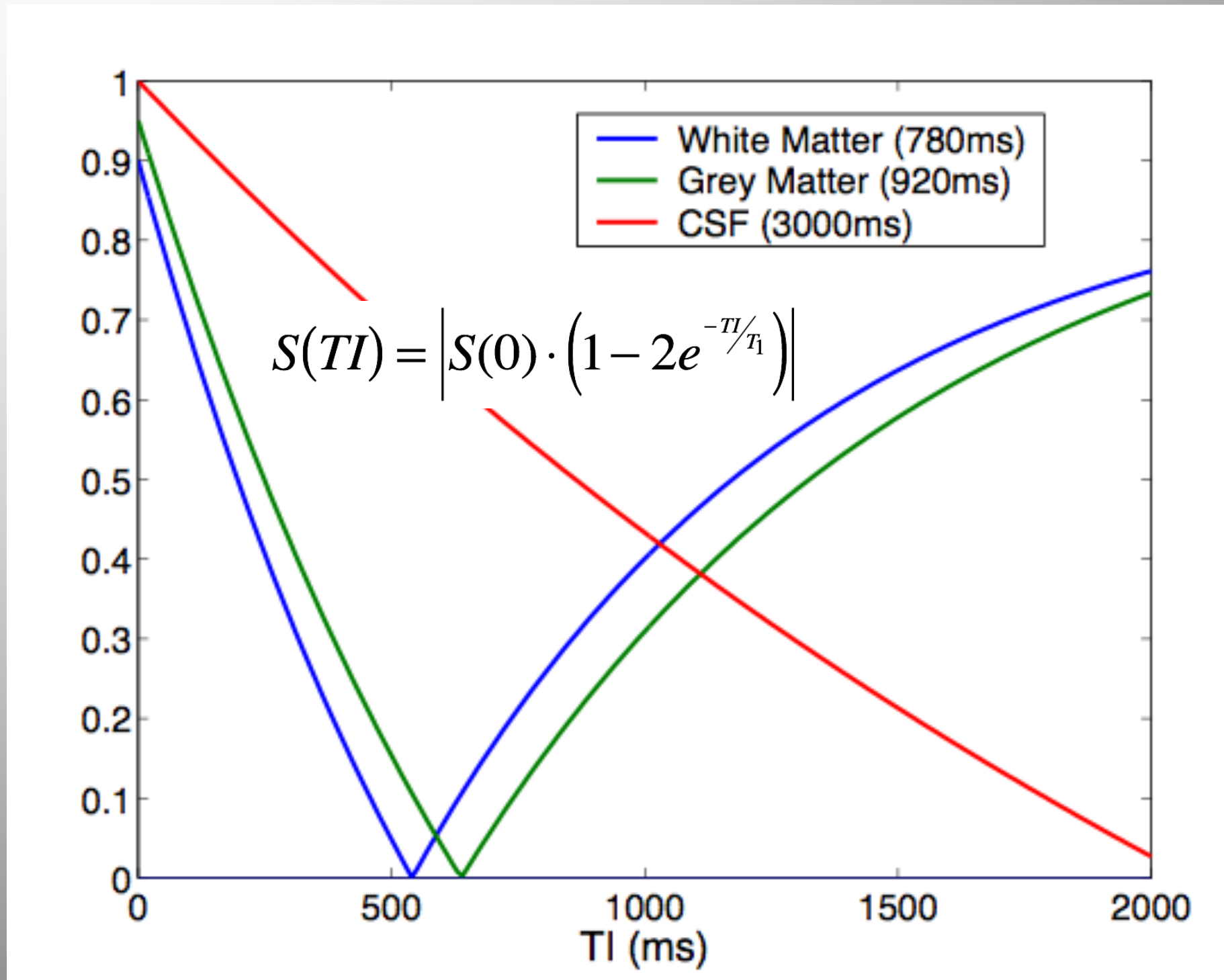
Inversion Recovery Spin Echo



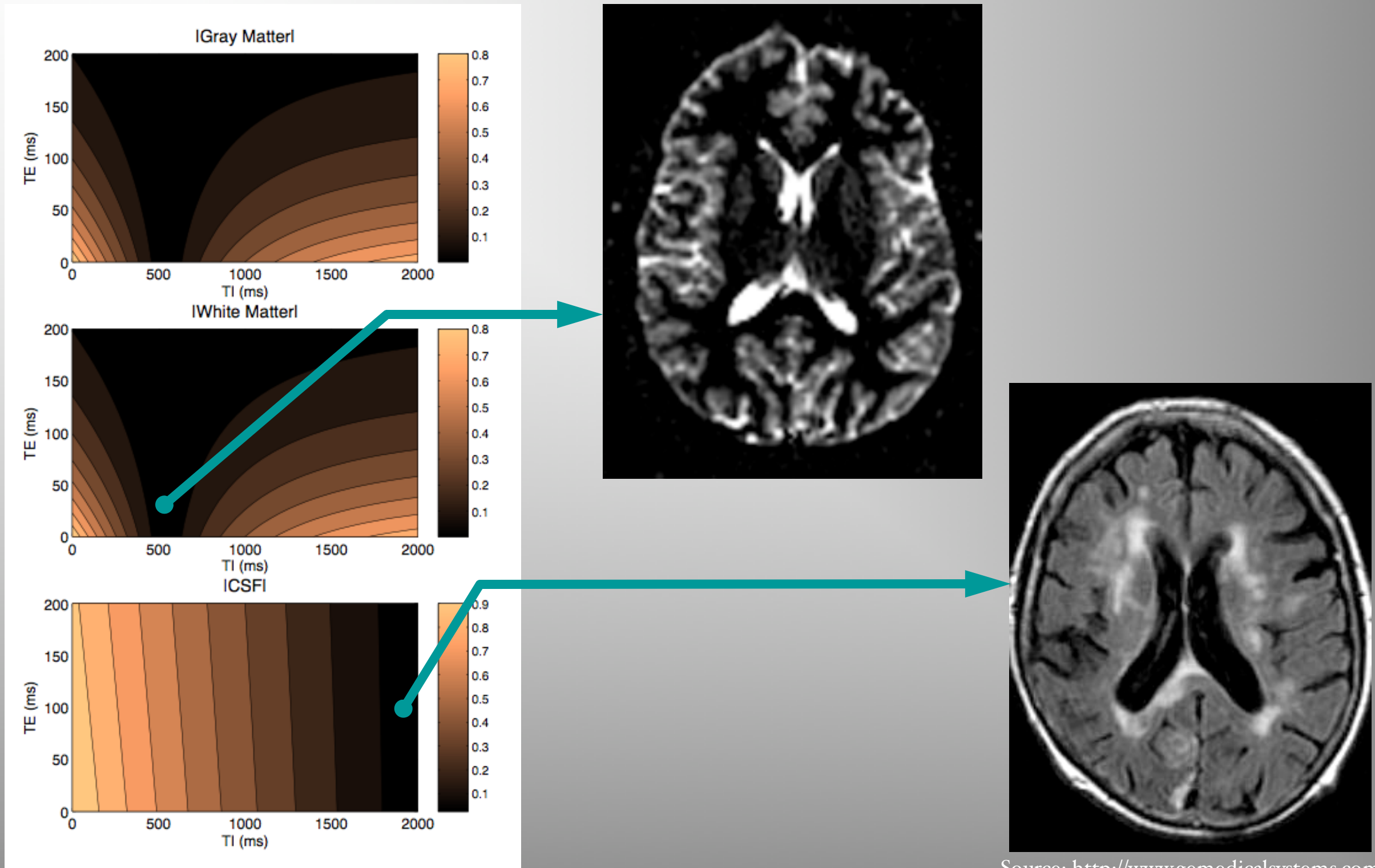
Inversion Recovery Weighting



Magnitude Inversion Recovery Weighting



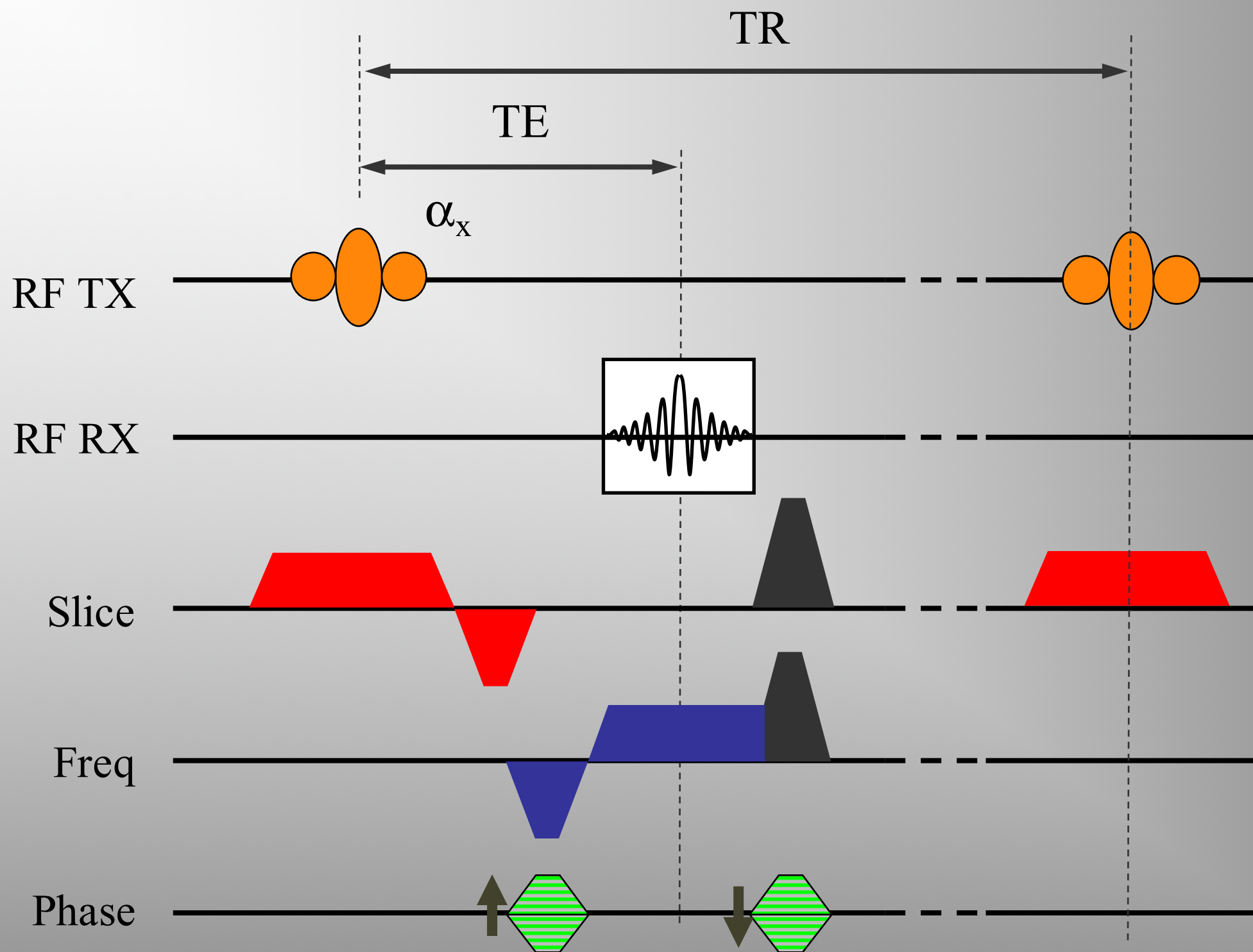
Inversion Recovery Contrast



Source: <http://www.gemedicalsystems.com/>

Gradient Echo Pulse Sequences

Gradient Echo Pulse Sequence

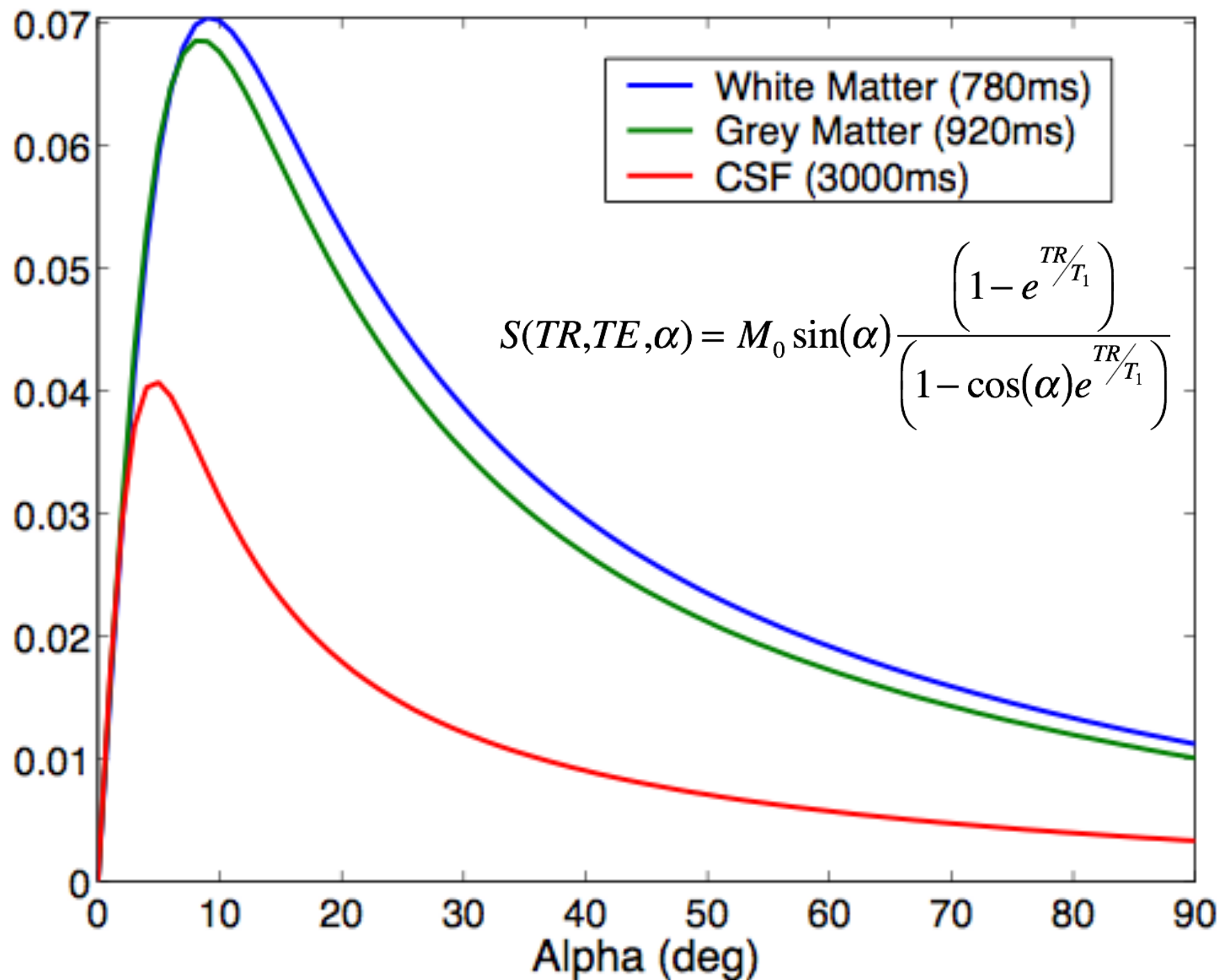


Contrast of Gradient Echo Pulse Sequences

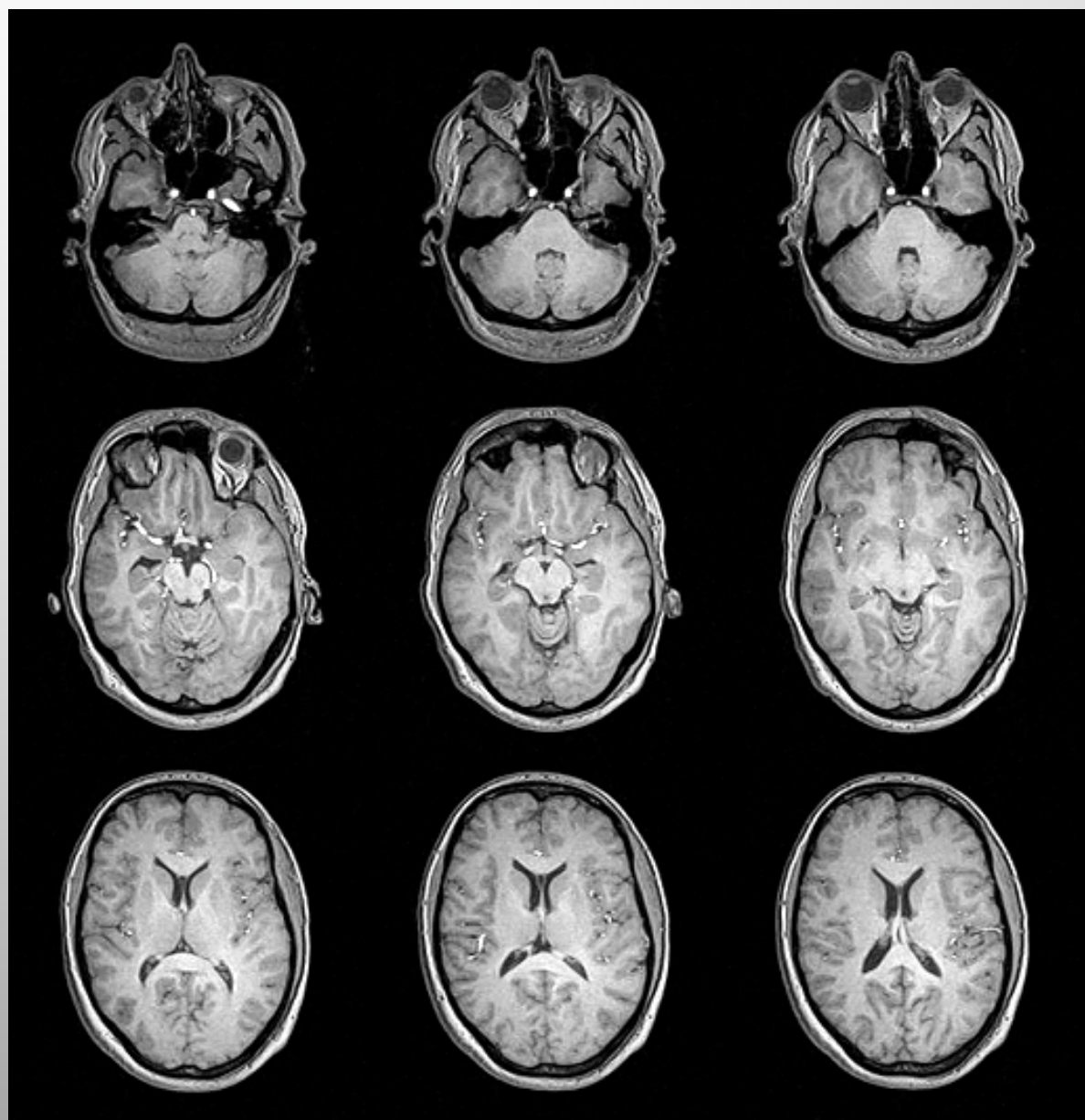
- TR invariably $\ll T_1 \Rightarrow$ “Steady-state”
- TE provides T_2^* weighting
- Many variants of the basic GE pulse sequence with commercial acronyms:
 - GRE, GRASS, FLASH, FISP, FAS , RAGE
 - PSIF, CE-FAST
 - TrueFISP, SSFP, MP-SSFP
 - SPGR
- Contrast equations generally complicated with TR, TE and Flip Angle (α) dependencies.

T2* Contrast

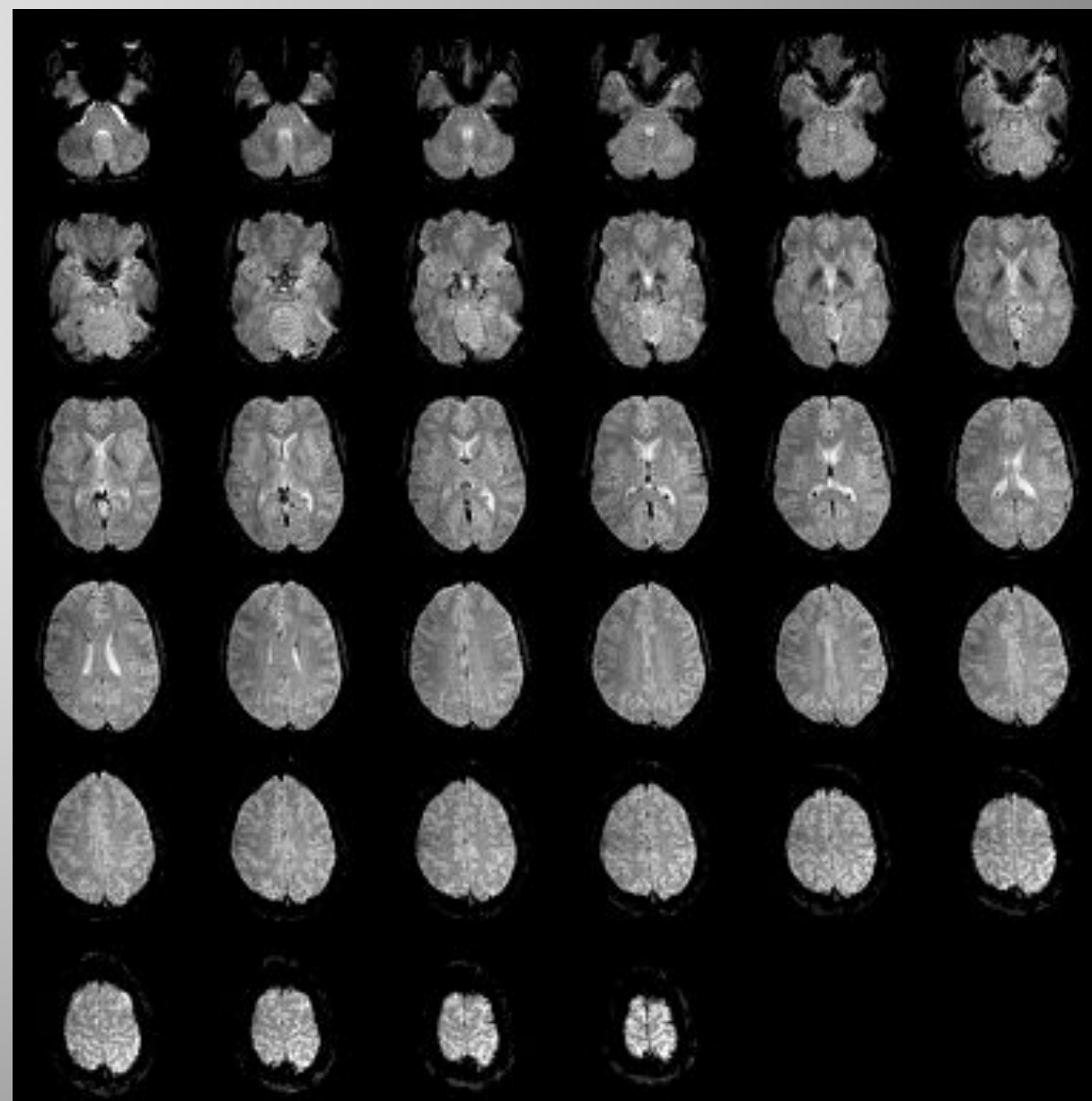
FLASH (Fast Low-angle Flip : Perfect Spoiling)



T2*-weighted GE Imaging

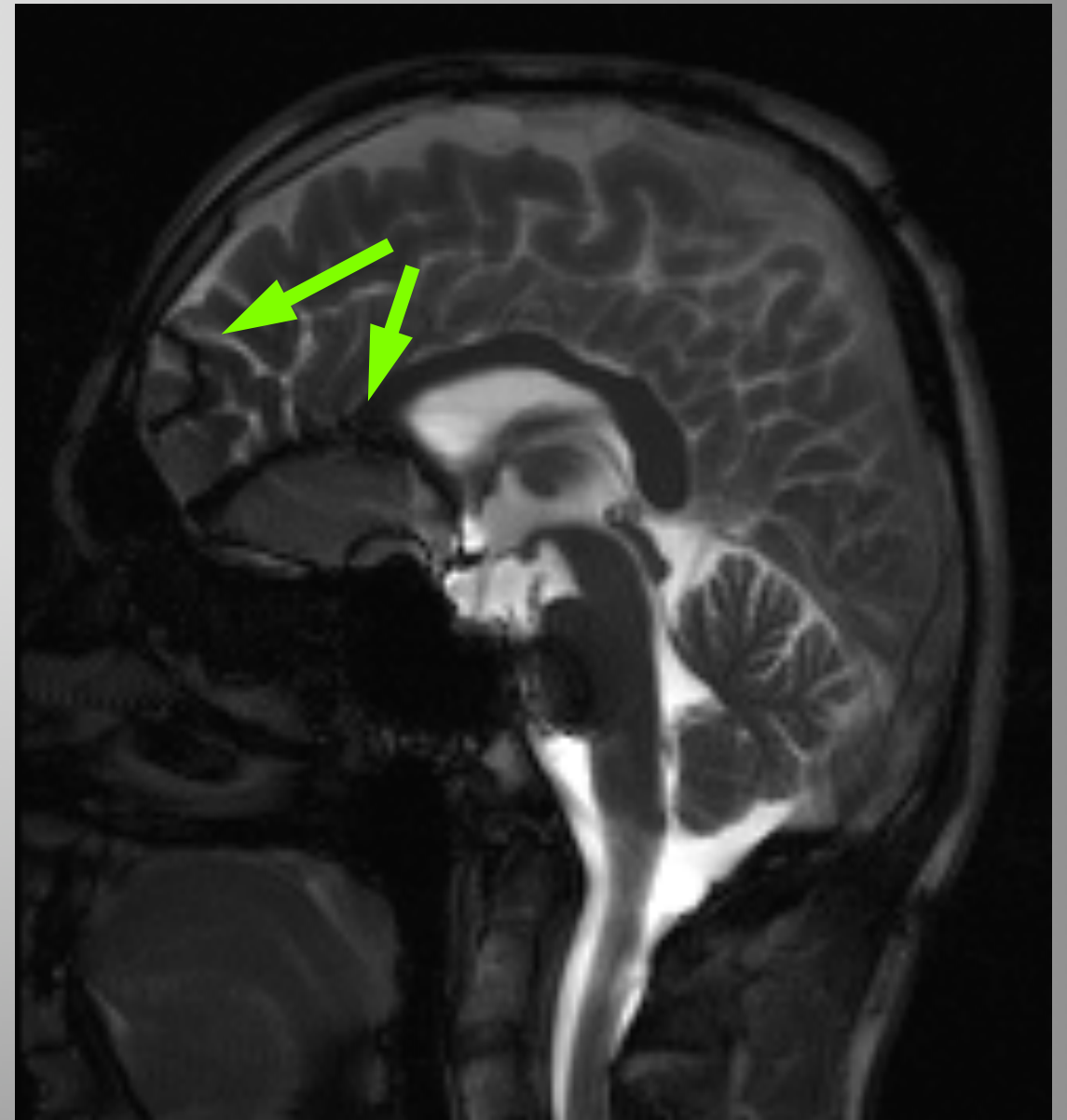
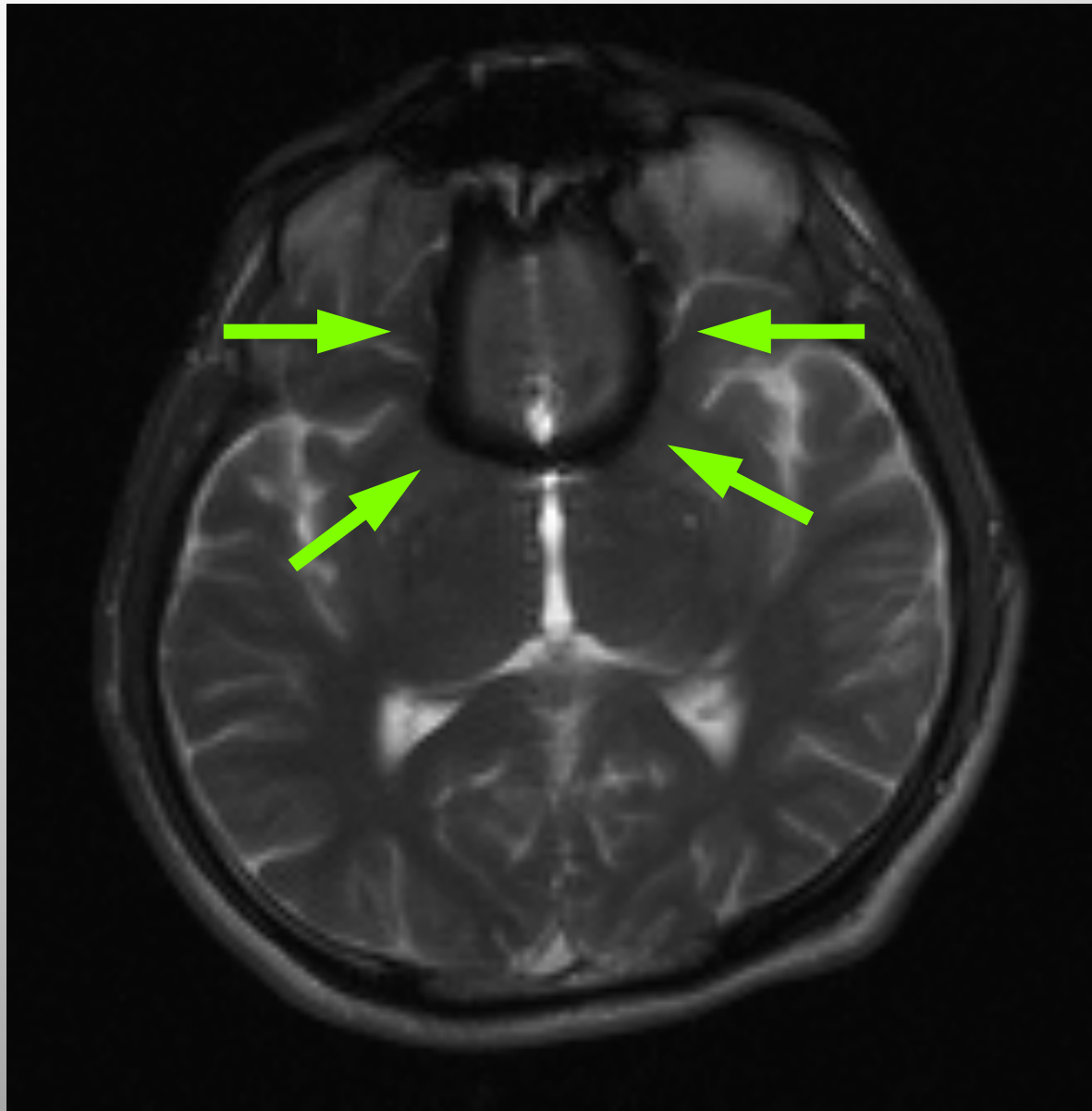


Gradient Echo (MP-RAGE)



Gradient Echo (FID) EPI

T2*-weighted TrueFISP Imaging



Gradient Echo

- Key Parameters
 - TR : Short to moderate (ms to 100s ms)
 - TE : Short
 - Flip Angle: 5° to 90°
 - Typically run in steady-state ($TR \ll T1$)
 - Complex T_1 , T_2 and Flip Angle weighting
- Primary Applications
 - Susceptibility-weighted imaging
 - Rapid volumetric imaging
- Artifacts
 - Susceptibility gradient sensitive

Other Contrasts

Exogenous Contrast Agents

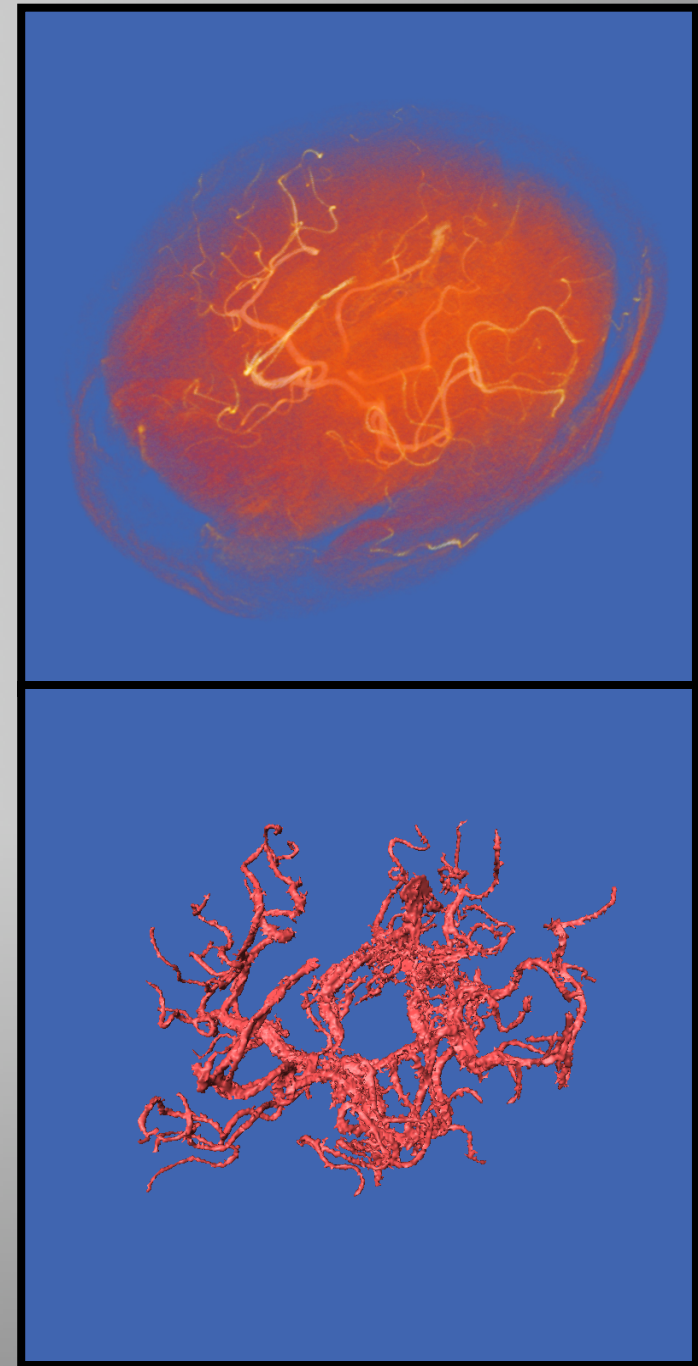
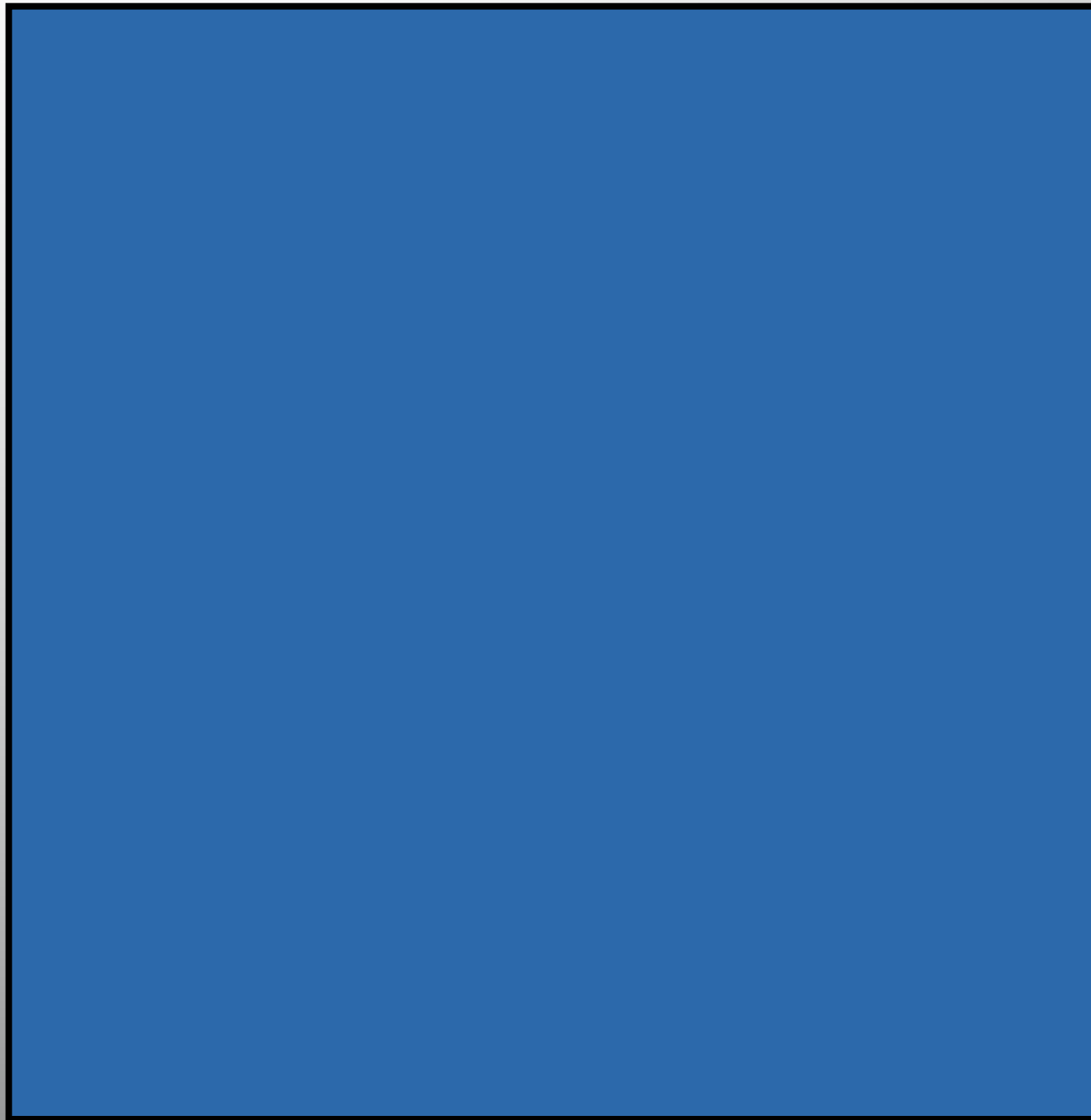


University of Zuerich, Institute for Biomedical Engineering <http://www.mr.ethz.ch/sense/>

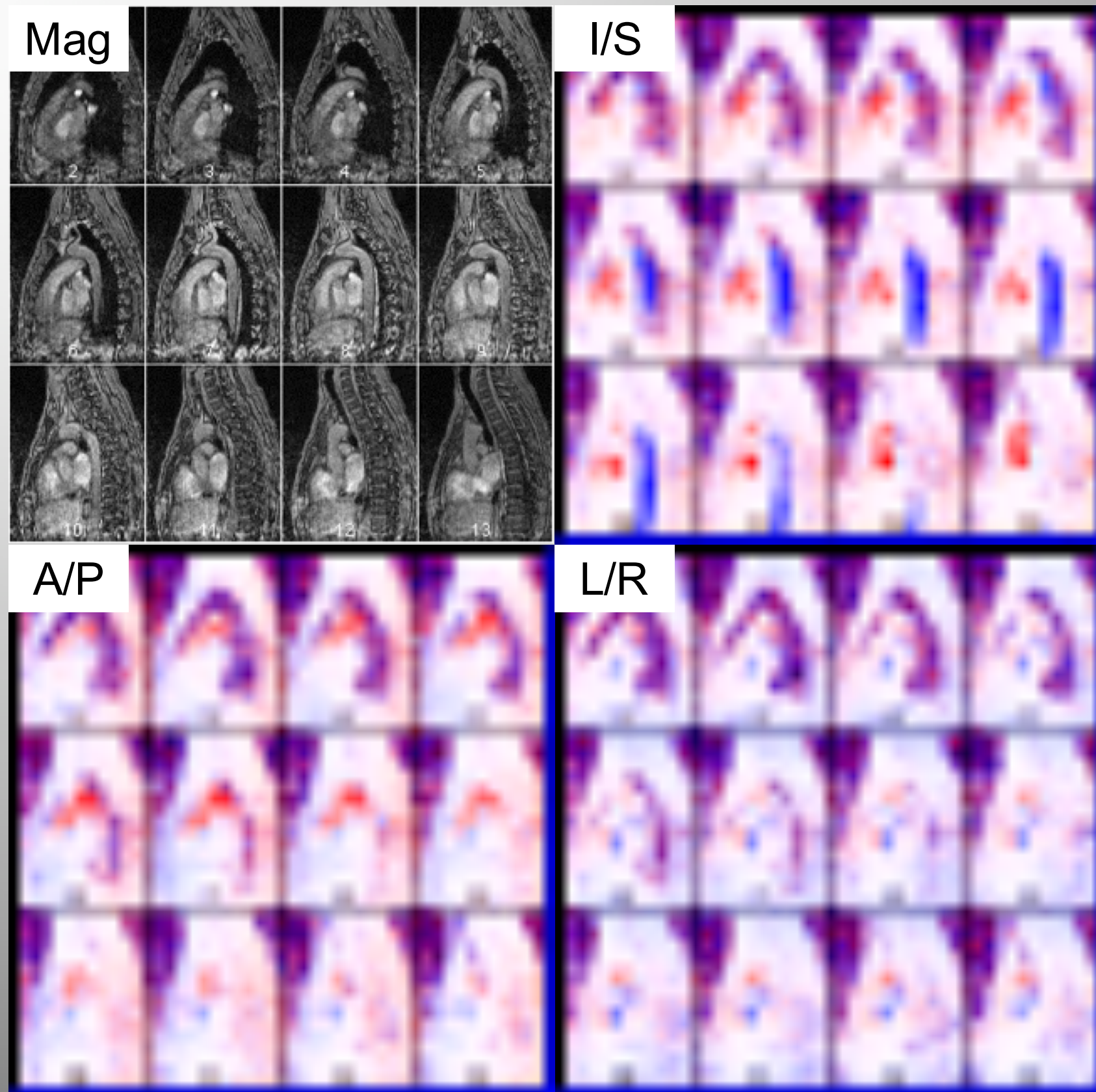
Flow and Motion

- Bulk flow
 - Inflow effect
 - Phase-contrast velocity measurement
- Water Diffusion
 - Diffusion-weighted MRI
 - Diffusion tensor MRI
 - Diffusion anisotropy MRI

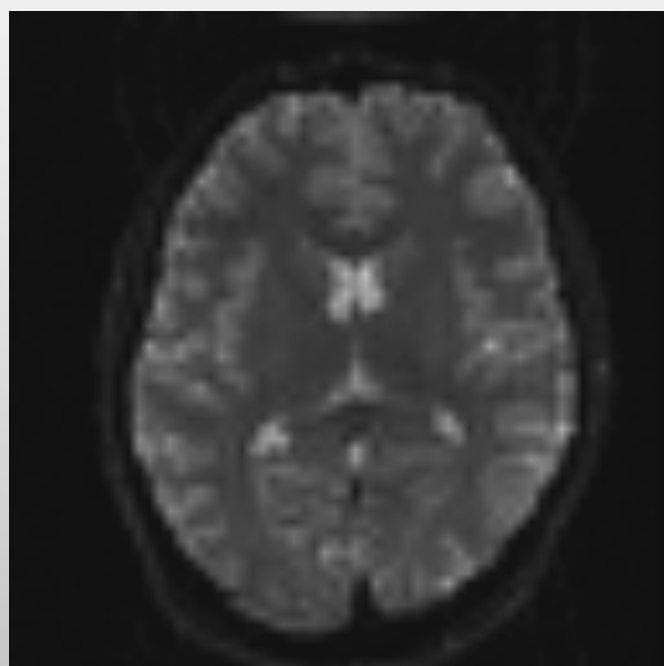
The Inflow Effect : TOF Angiography



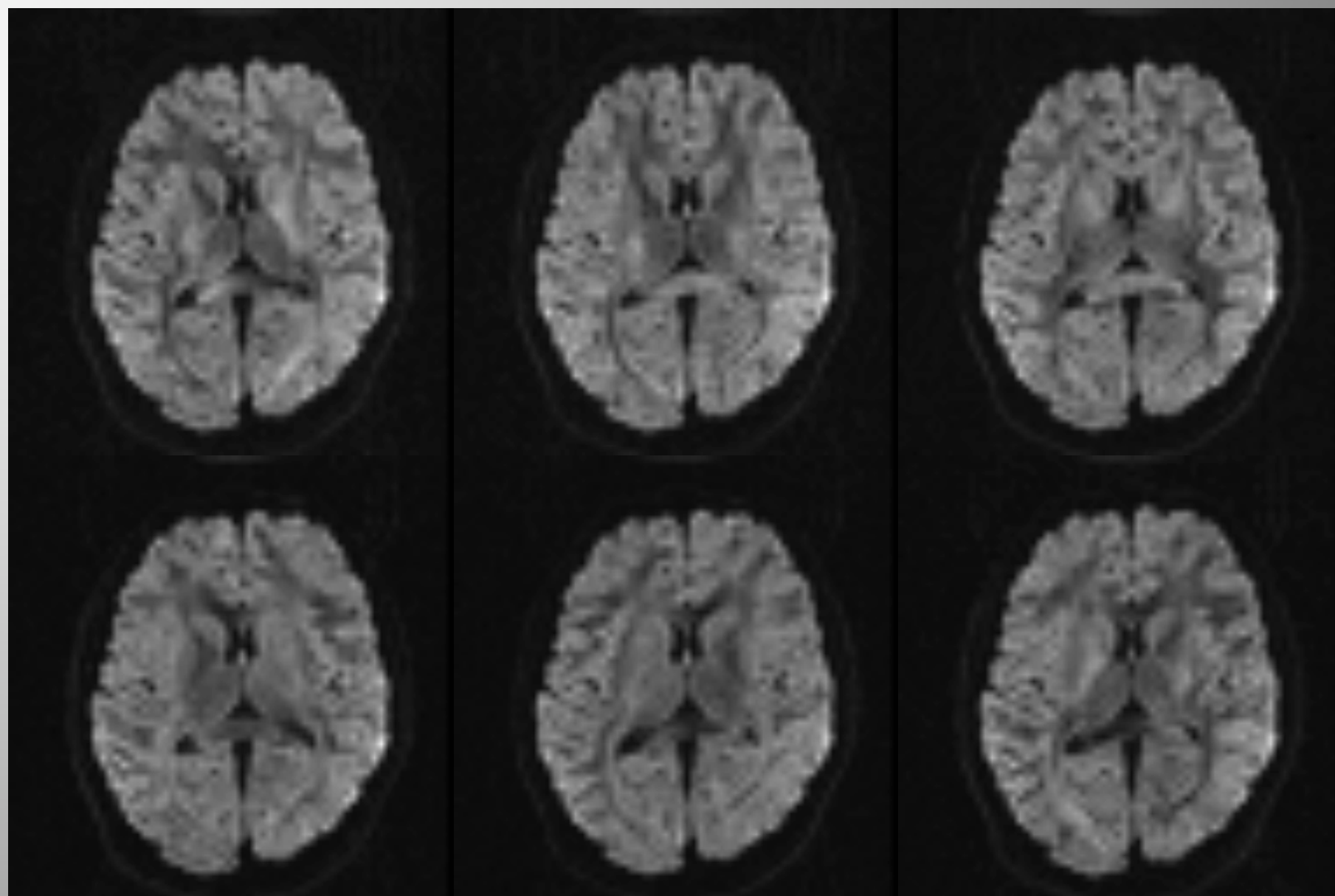
Velocity Phase Contrast



Diffusion Weighting MRI

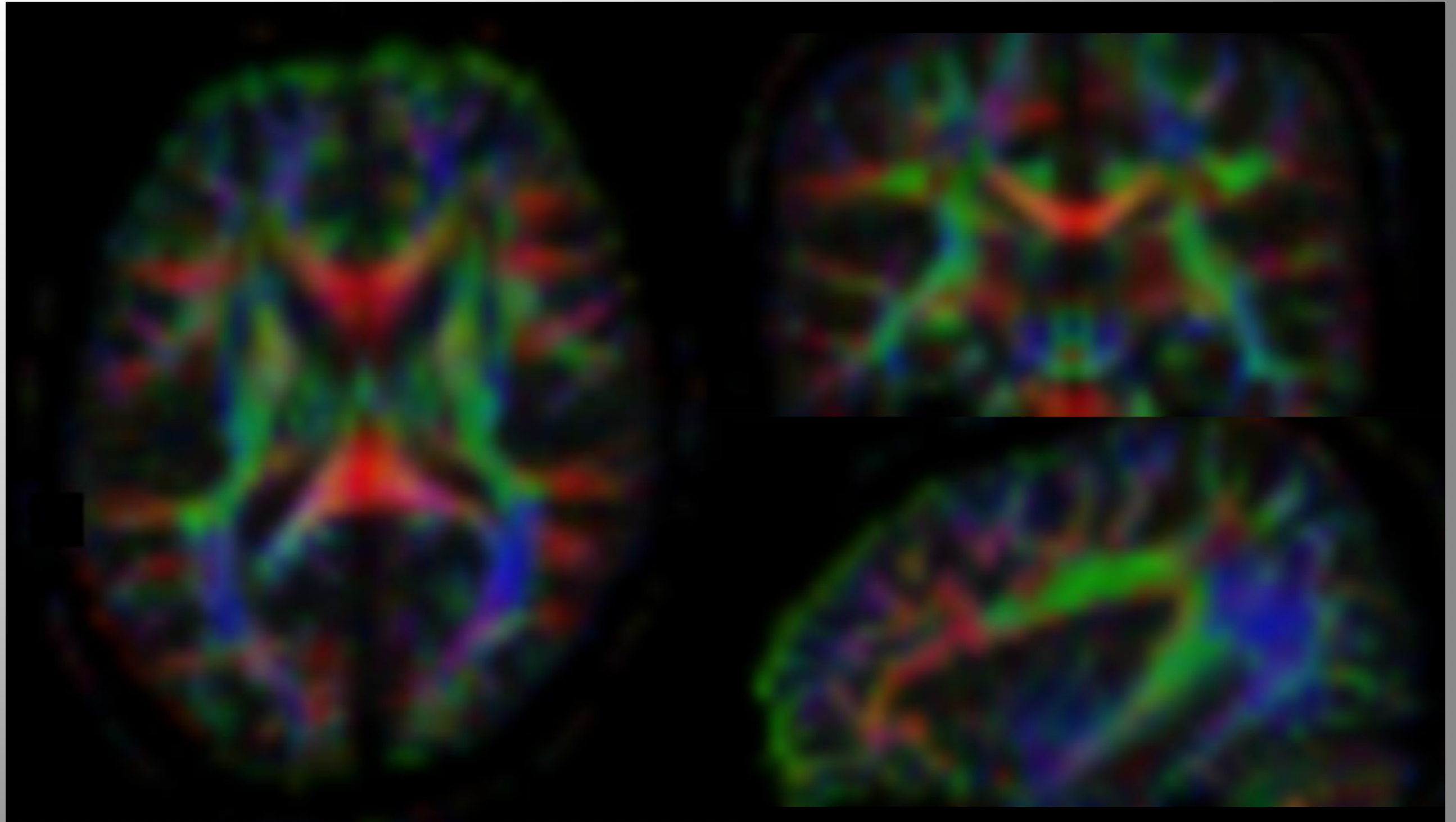


No Diffusion
Weighting



Diffusion Weighted

Diffusion Tensor Imaging



Next Lecture : Practical MRI

- Hardware
- Image quality
- Artifacts
- Parameter optimization