Rad229 – MRI Signals and Sequences

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Lecture-9D — Gradient Echo Sequences

RF-Spoiled Sequences and Comparisons

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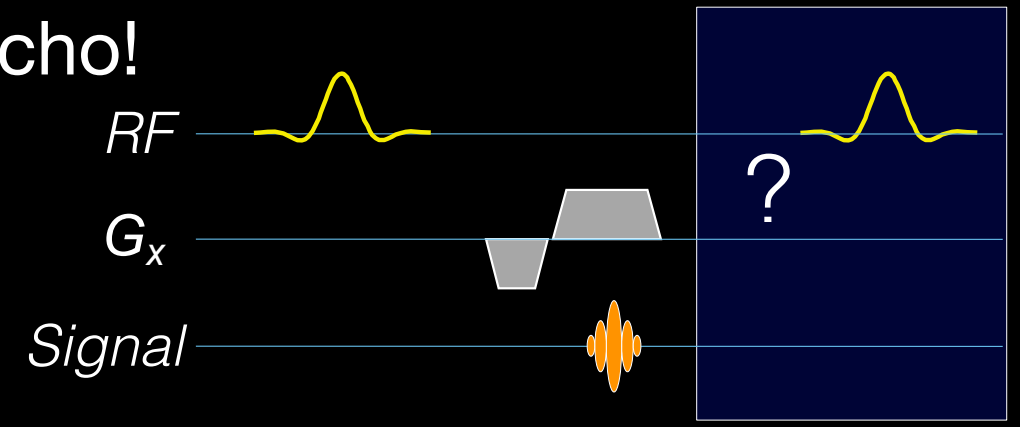
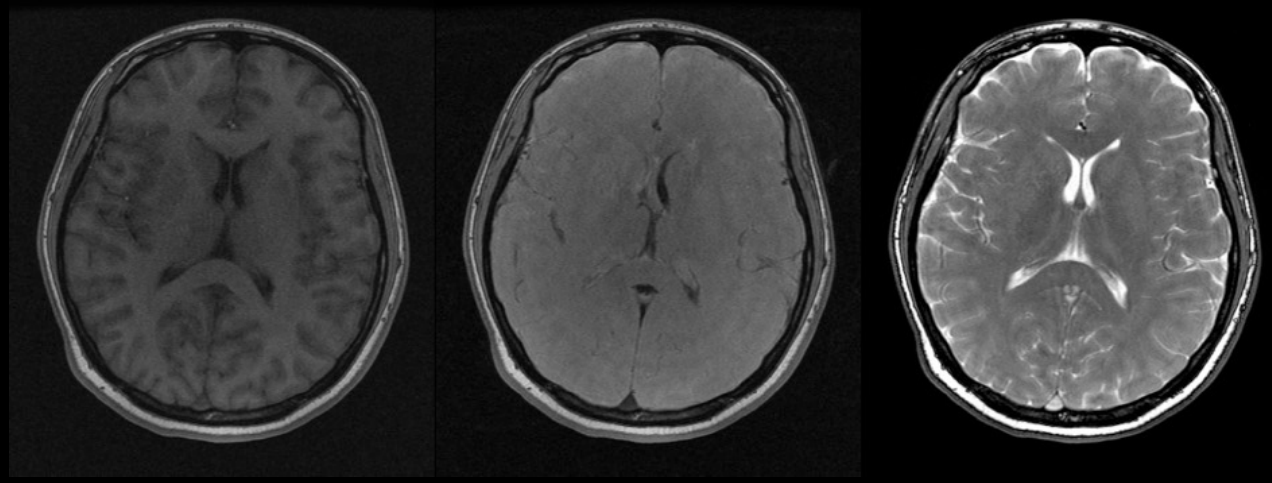
Learning Objectives

- Explain the motivation and mechanism of RF-spoiling
- Explain the choice of phase-increment in RF spoiling
- Identify spoiling types from different images
- Compare advantages and disadvantages of spoiling methods

Outline: Gradient Echo Sequences

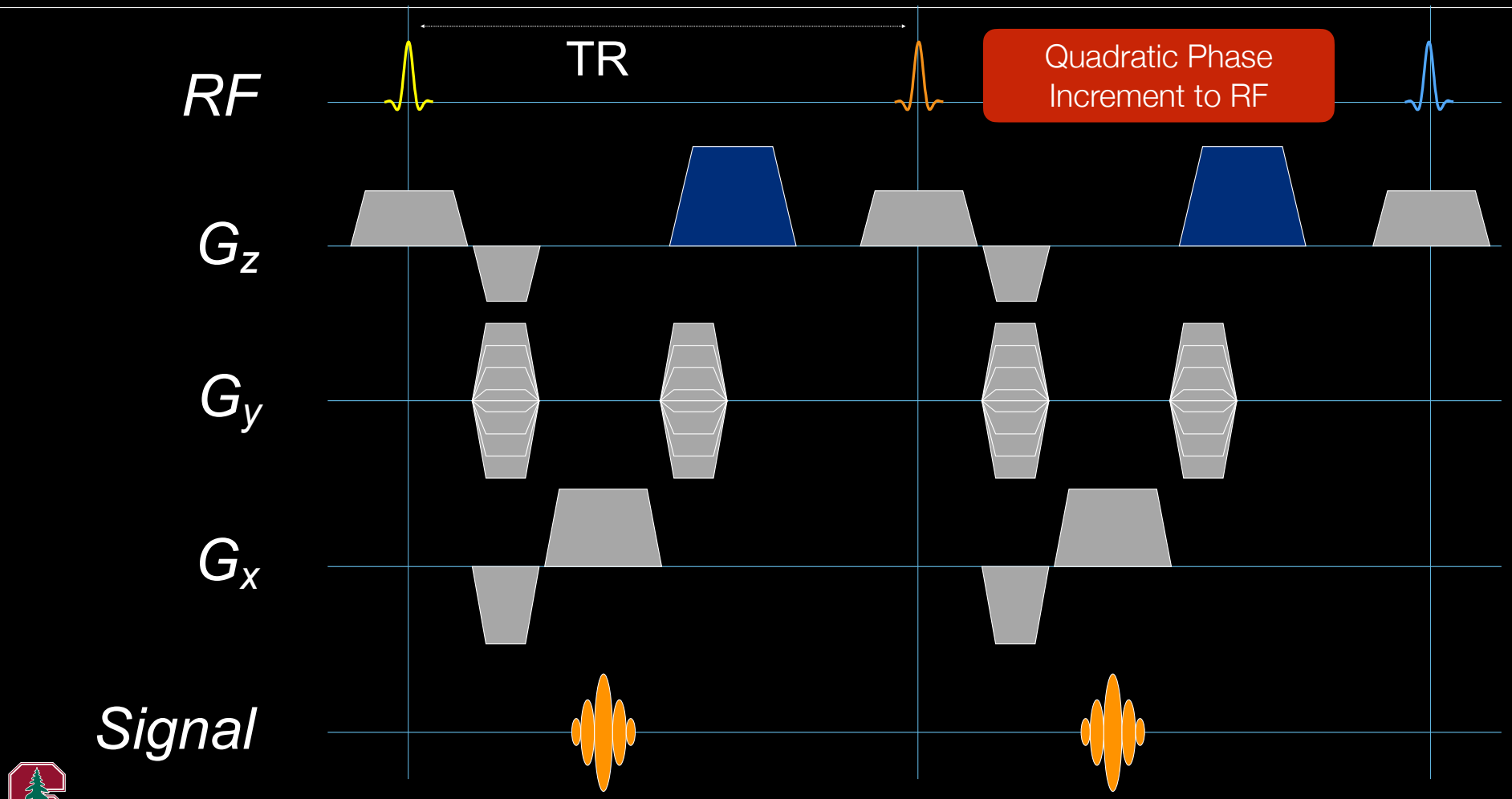
- Gradient Echo = No spin echo!
- Spoiling Types
- Properties





Contrast is based primarily on the end-of-TR action

RF-Spoiled Sequences (FLASH, SPGR, T1-FFE)



Gradient spoiling uses an unbalanced gradient at the end of the TR (Gx and Gz here)

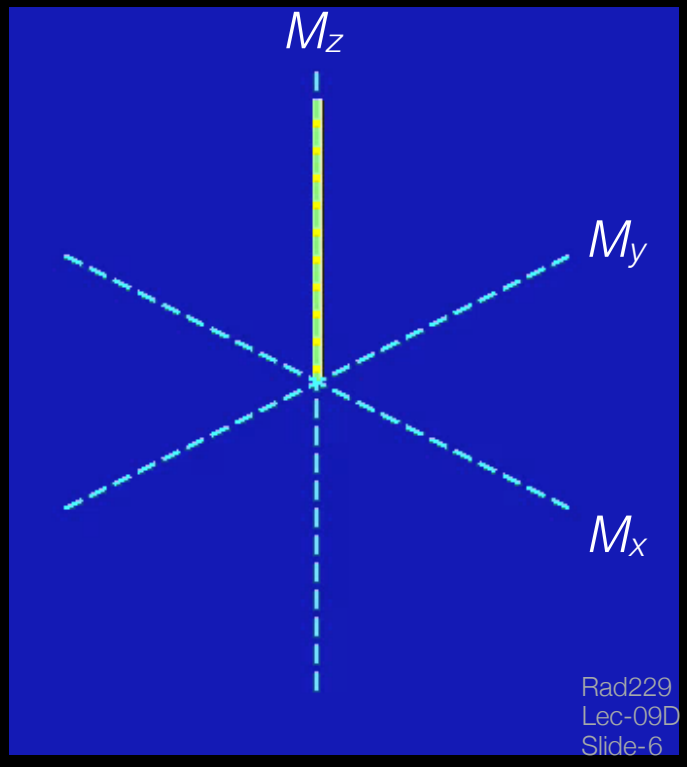
RF Spoiling

- Goal: *Eliminate* transverse magnetization
- Quadratic phase increment + gradient spoiling:

$$\phi_k = (0.5)117° \, k^2$$

- Shifting, spoiled (averaged) profile
- Transverse magnetization "cancels"
- T_1 contrast

T1-FFE, FLASH, SPGR, Spoiled(!)

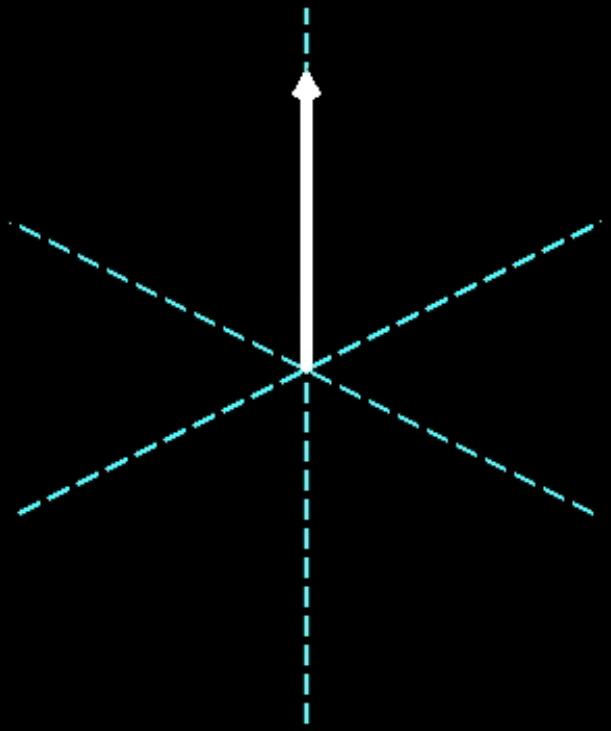


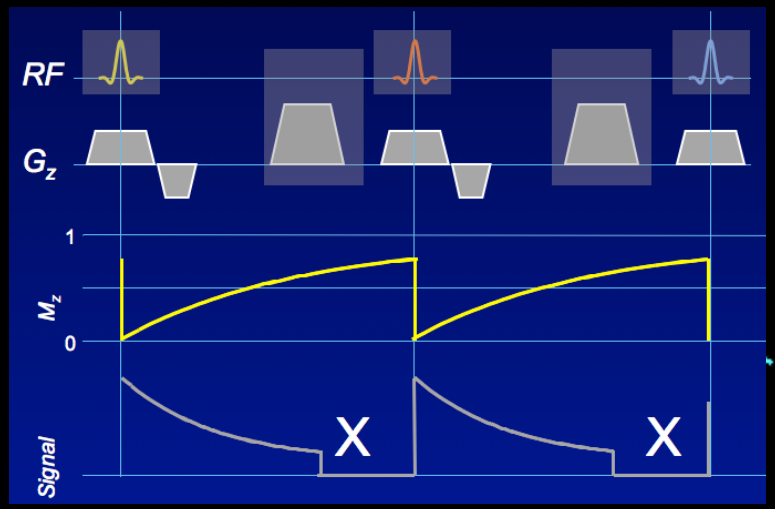
Quadratic phase increment cancels transverse magnetization. Frahm 1987, Zur 1991

Question 1: Spoiling Increment?

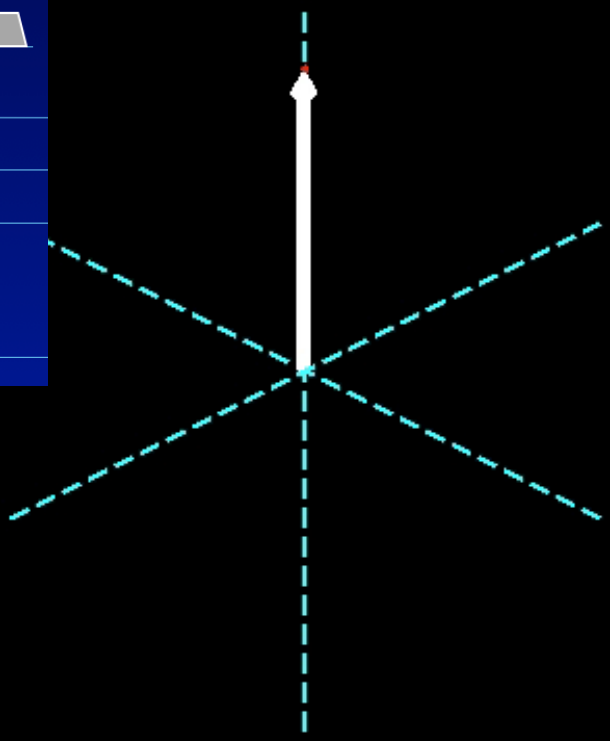
RF-Spoiled Gradient Echo

Quadratic Phase RF Spoiling
(Rotated to last RF phase)





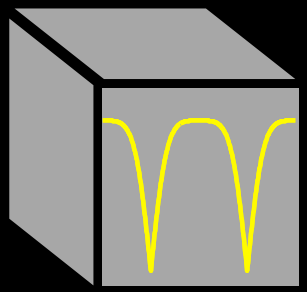
Explicitly Zeroing M_{xy}
prior to RF pulse



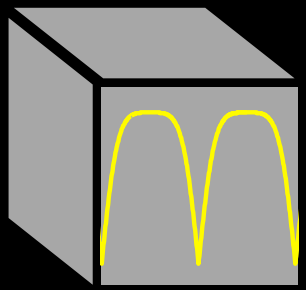
The use of quaratic phase (RF spoiling) can approximate the case where transverse magnetization is set to 0

Balanced, Gradient-Spoiled and RF-Spoiled

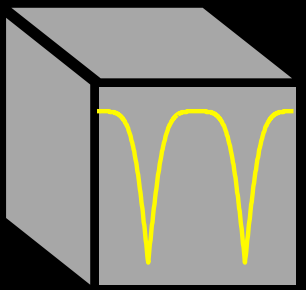
Gradient-Spoiled

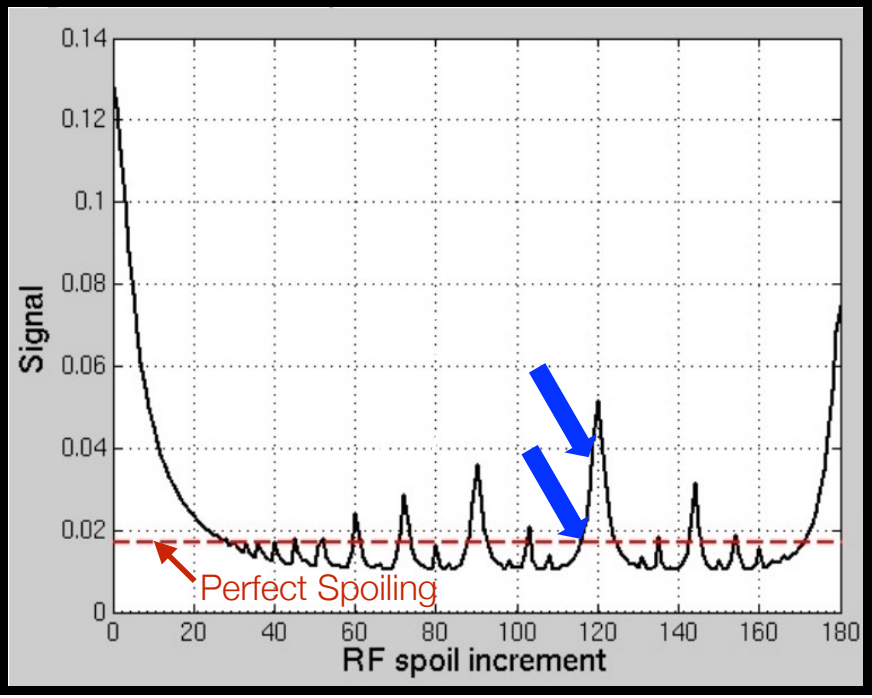


Constant RF Phase Increment

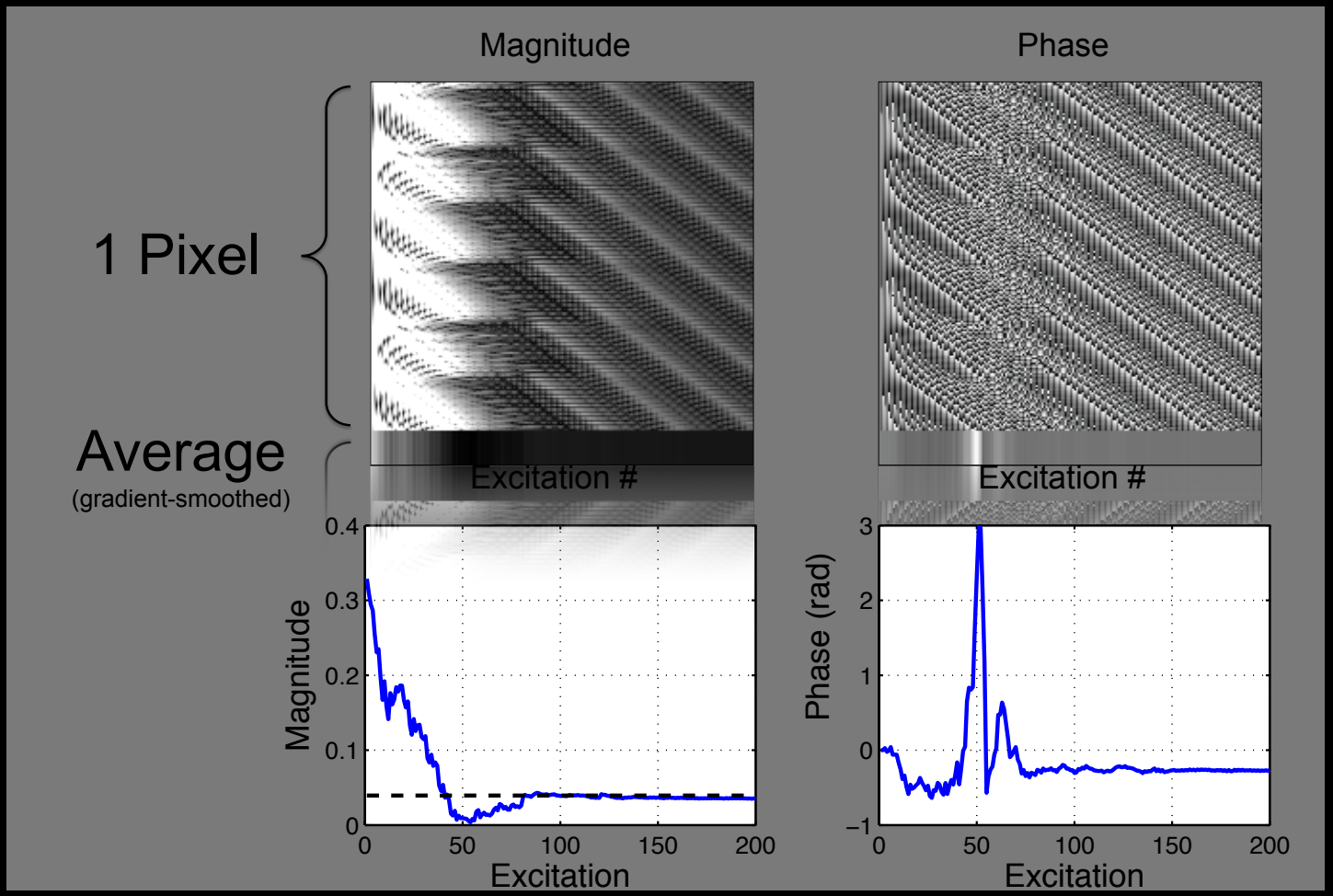


Quadratic Phase (Increasing Phase Increment)





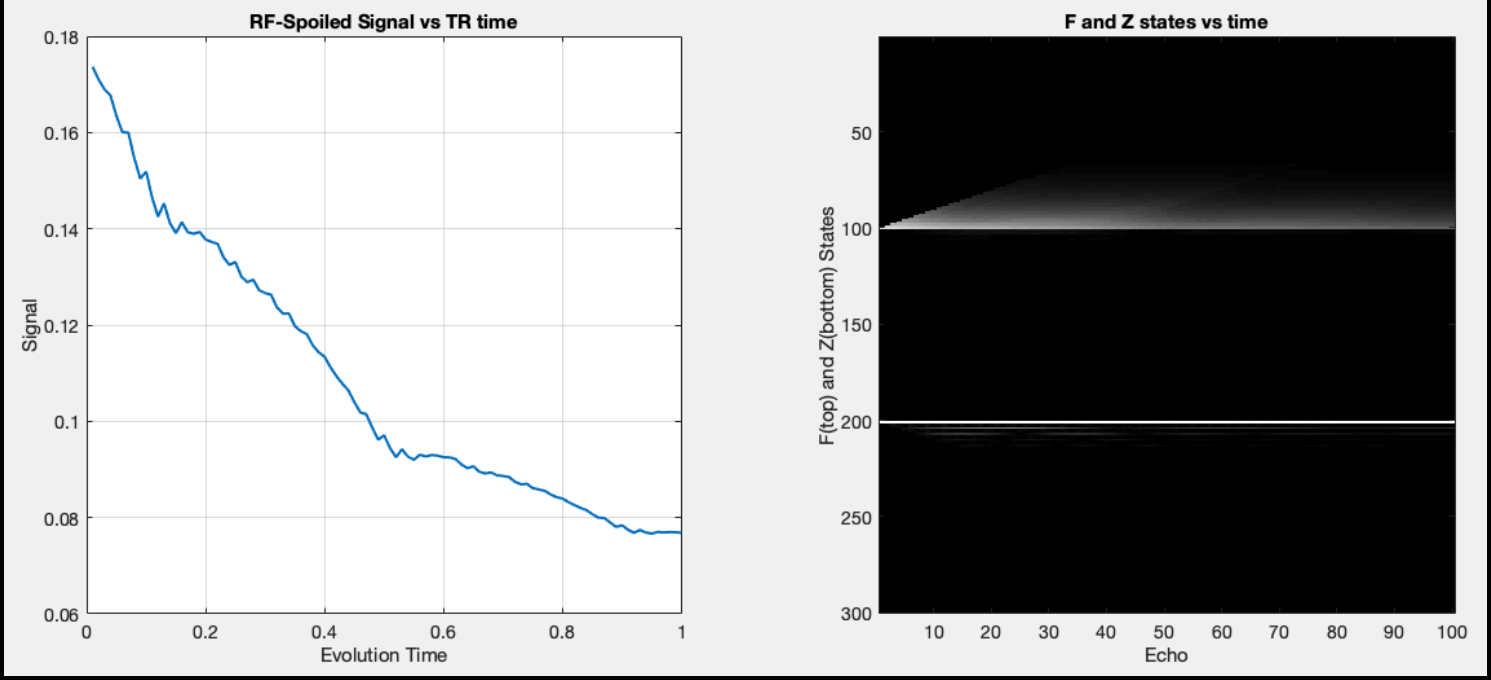
SPGR Signal Evolution (Bloch simulation)



In steady state the magnetiation is periodic in both time and space

EPG and RF spoiling

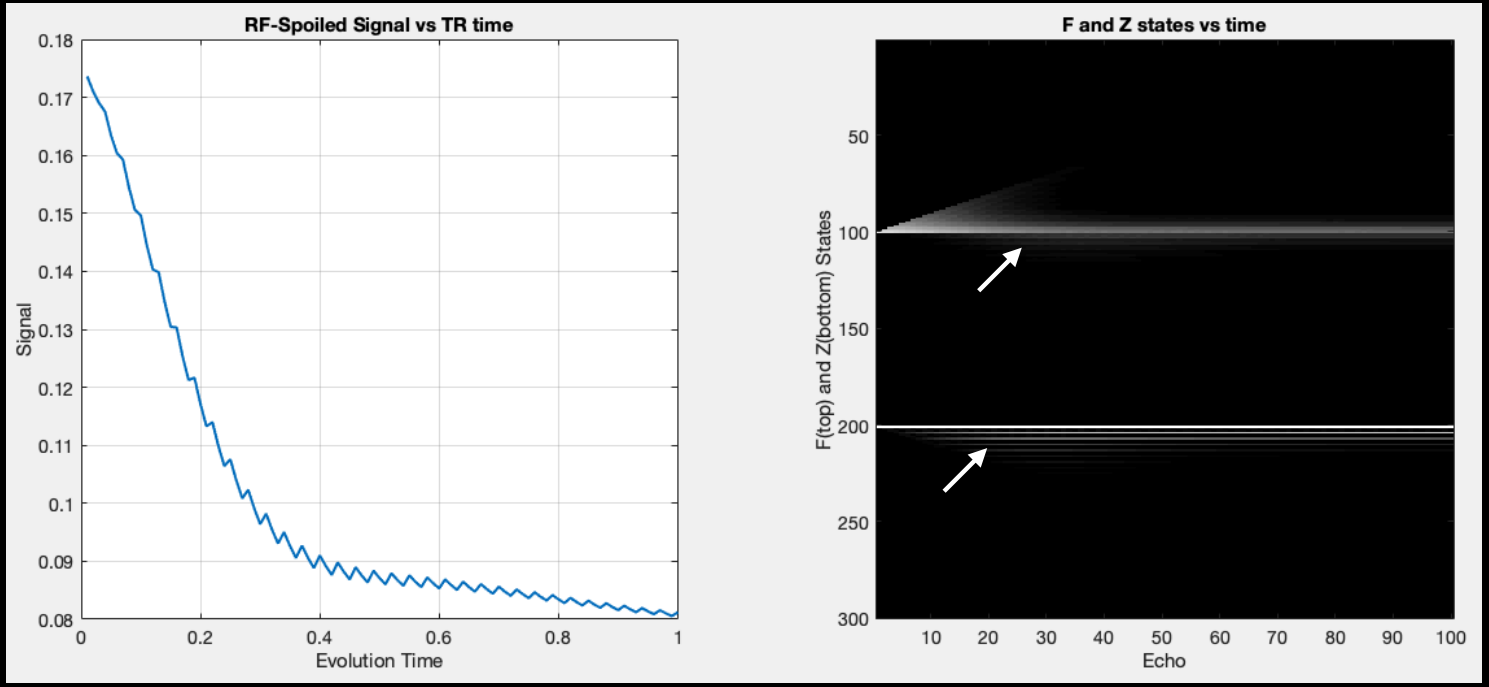
- Same coherence diagram… but almost no spin-echoes or stimulated echoes



Question 2: EPG States and RF Spoiling

RF Spoiling - 120° is a Bad Phase Increment!

- Note Z states, and fluctuations
- Still periodic in time and space



The phase increment is chosen to avoid fluctuations

RF-Spoiled Contrast-Enhanced MR

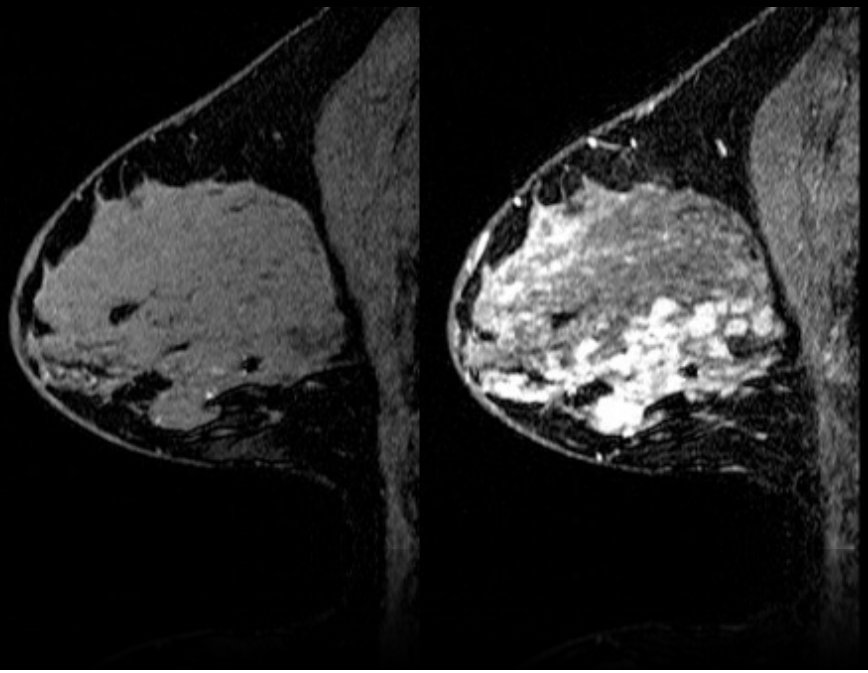
Pre-Contrast SPGR

Post-Contrast SPGR

Courtesy Lewis Shin

RF Spoiling: Summary

- Gradient spoiling + Quadratic phase RF
- "Eliminates" transverse magnetization
  - Lower signal than GRE or balanced SSFP
  - Pure T_1 contrast

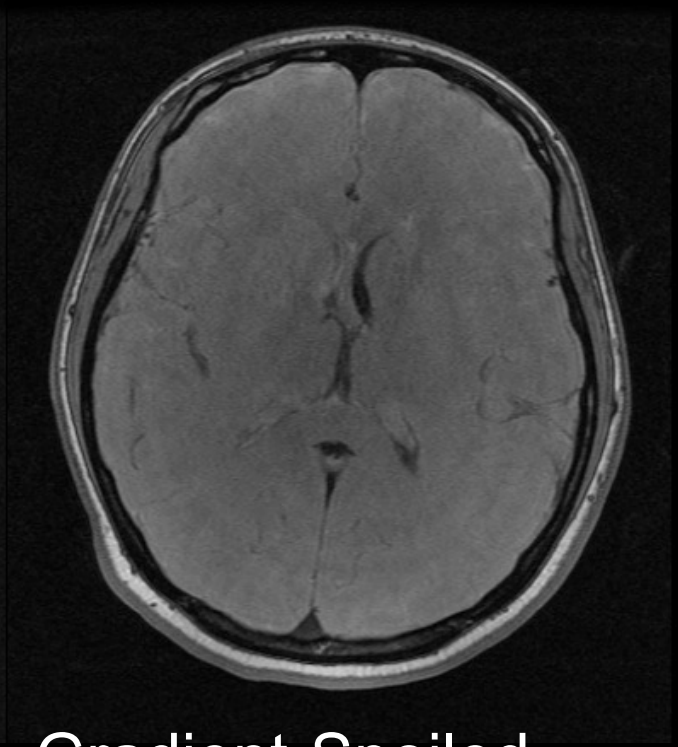


T1-FFE, FLASH, SPGR, Spoiled(!)

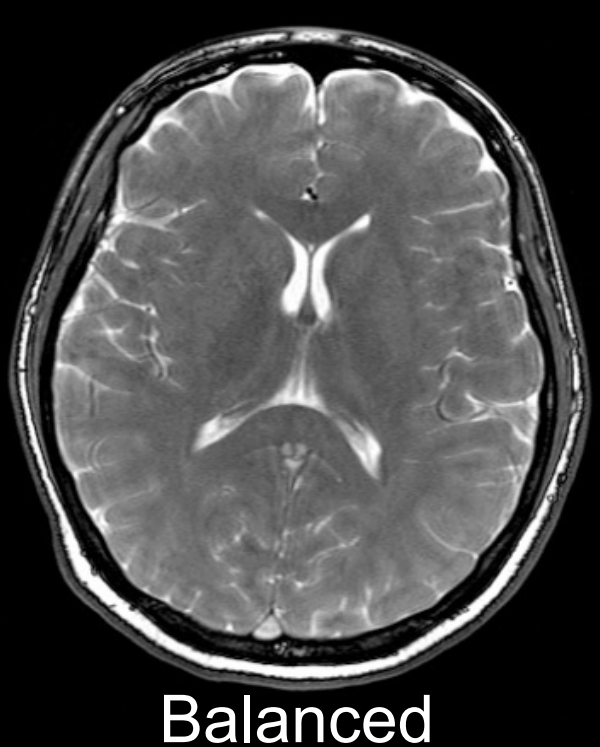
Contrast Example

- Contrast based solely on end-of-TR action

RF-Spoiled
T1-weighted



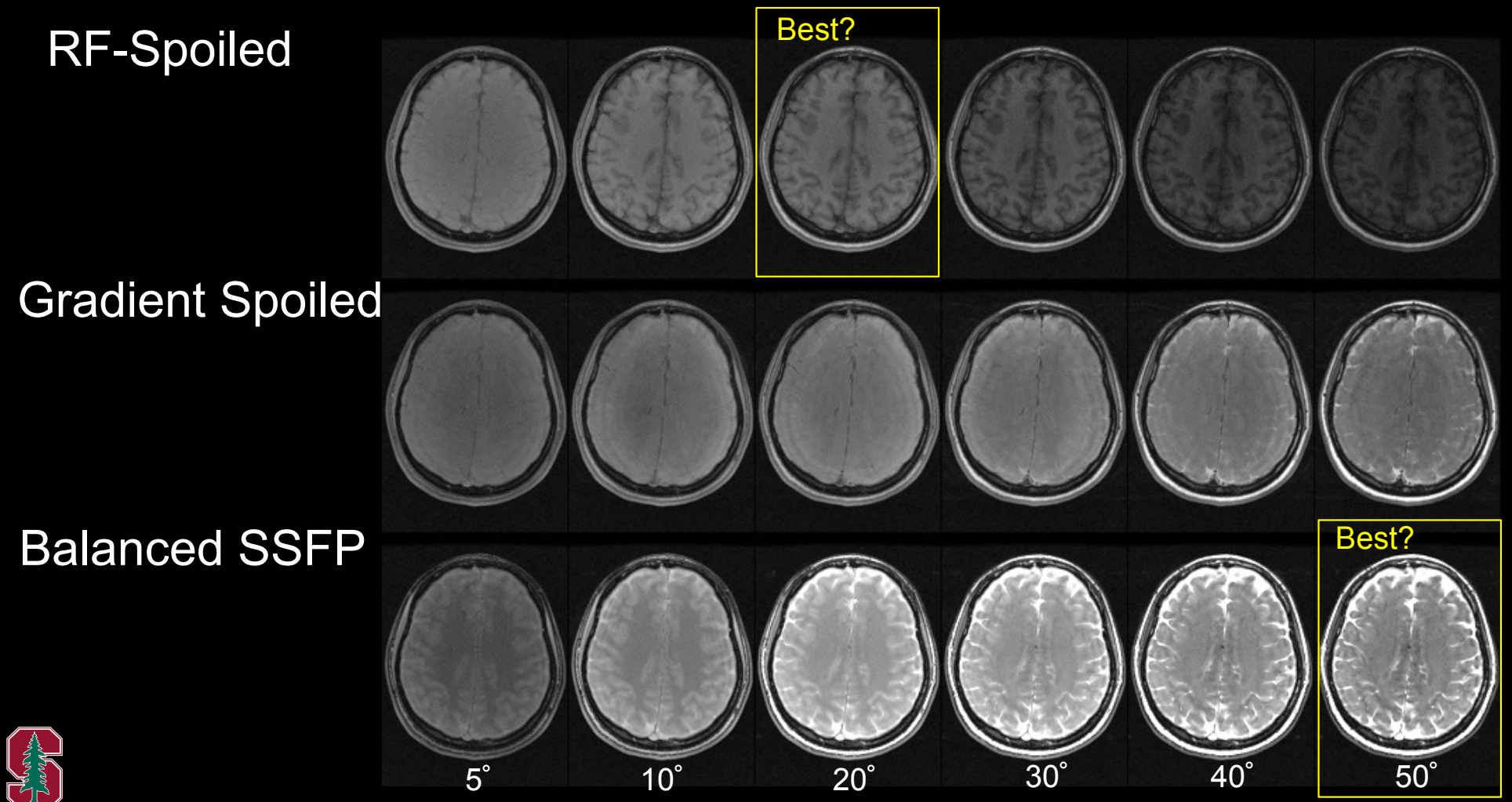
Gradient-Spoiled



Balanced
T_2/T_1 Weighted

Question 3: Which Gradient-Echo Sequence?

Gradient Echo: Flip Angle



Gradient Echo Sequence Comparison

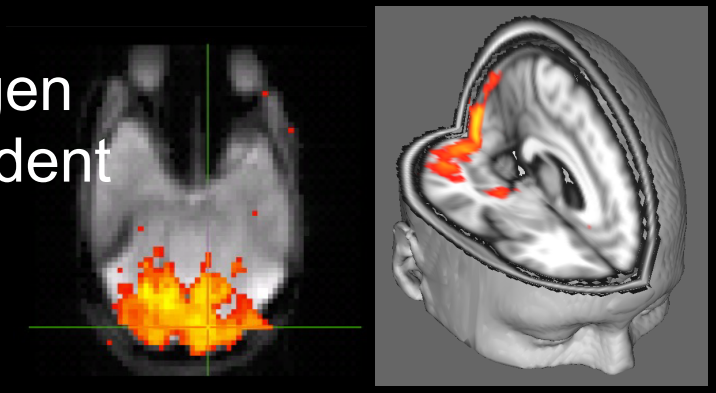
Sequence	Balanced SSFP	Gradient Echo	RF-Spoiled
Spoiling	None	Gradient	RF + Gradient
Transverse Magnetization	Retained	Averaged	Cancelled
Contrast	T_2/T_1	T_2/T_1	T_1
SNR	High (but Banding)	Moderate	Lower

Echo Time Considerations

Magnitude: $S = S_0 e^{-TE/T_2^*}$

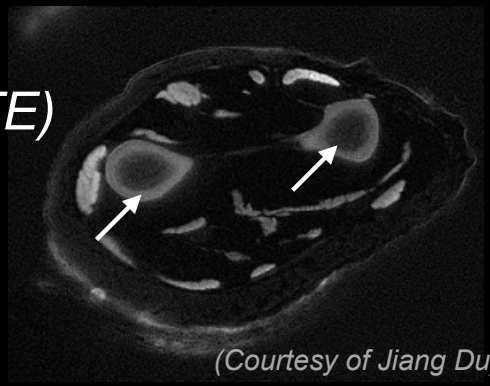
Phase: $\phi = \Delta f TE$

Blood-Oxygen Level Dependent (BOLD)

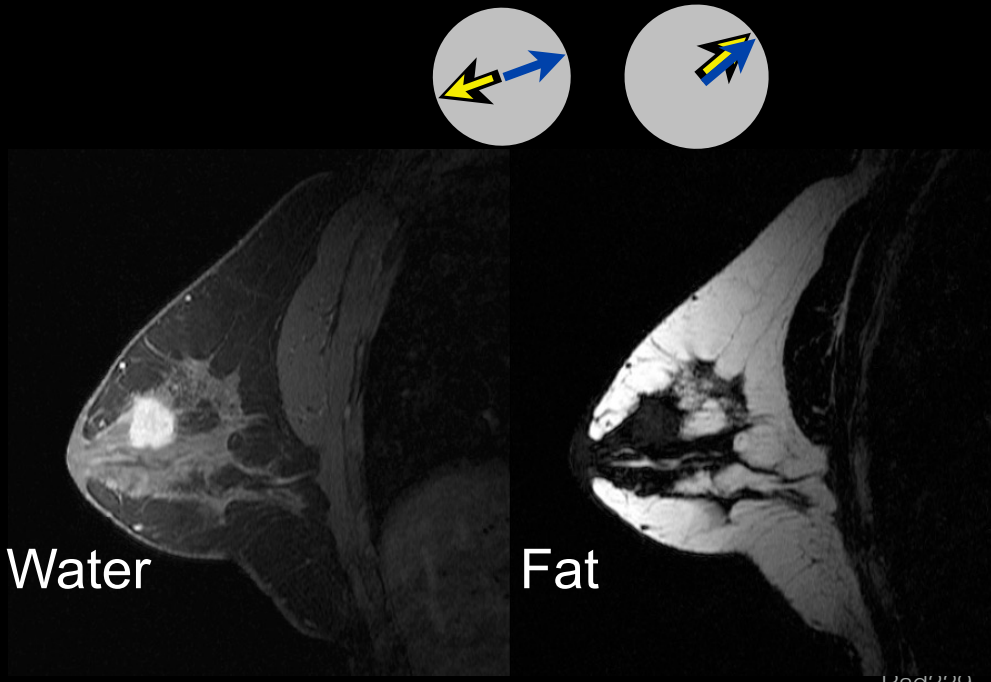


(Courtesy of Karla Miller)

Ultrashort TE
(Short TE - Long TE)

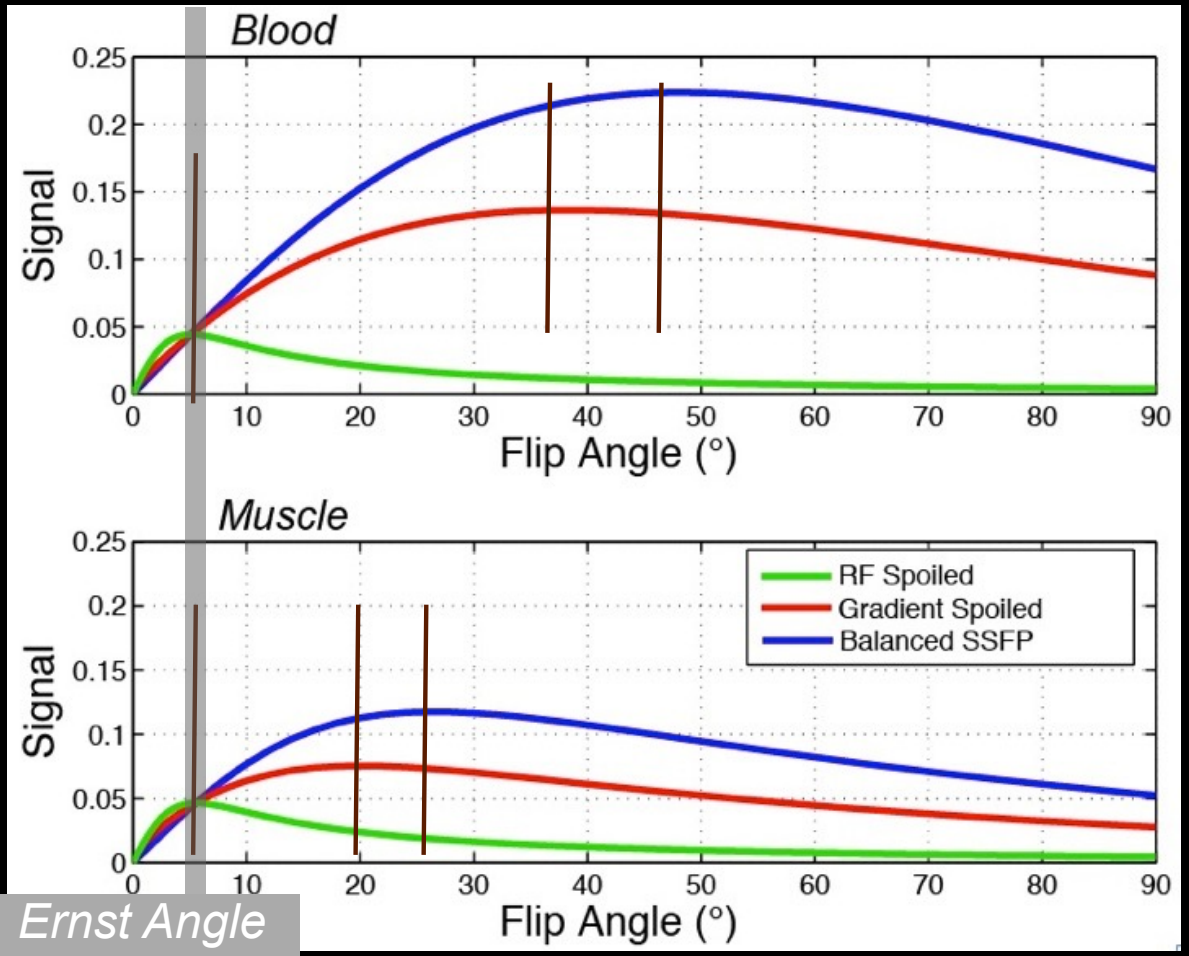


(Courtesy of Jiang Du)



Choice of TE influences T2* contrast, and relative phase

Flip Angle Selection



Ernst Angle

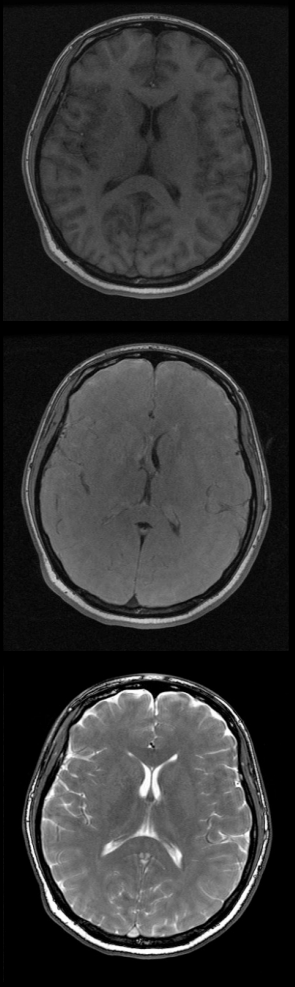
Buxton 1990

All 3 sequences have the same signal at the Ernst Angle ($\alpha=\arccos(E_1)$)

Question 2: Flip Angle Selection?

Summary

- Long TR ~ Simple Dynamics
- Short TR ~ Steady States
  - Balanced, Gradient-Spoiled, RF-Spoiled
  - Contrast variations (T1, T2/T1)
  - Magnetization preparation often used
- Tools
  - Bloch Equations
  - Extended Phase Graphs
  - Intuition!



Acronyms primarily at mr-tip.com

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