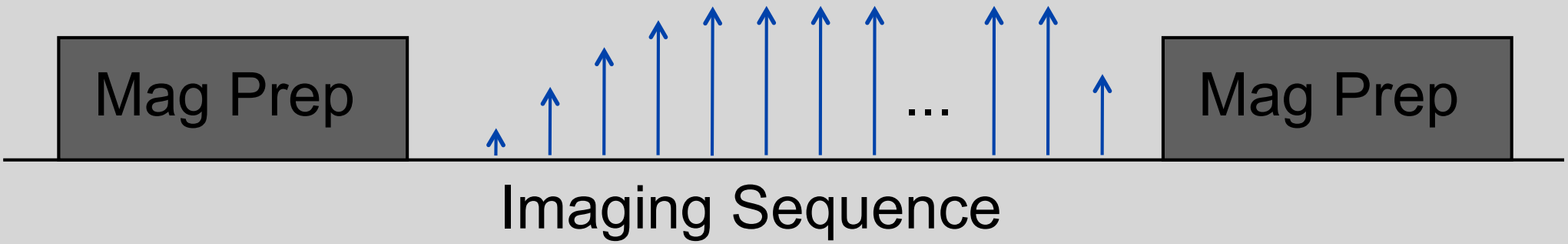
Magnetization Preparation Sequences

- Acquisition method may not give desired contrast
- "Prep" block adds contrast (and/or encoding)
  - MP-RAGE = Magnetization prepared rapid acquisition with gradient echo (Mugler, ~1990)
  - Inversion-recovery (IR) prep
  - Fat saturation
  - T_2-prep
  - Diffusion-weighted imaging



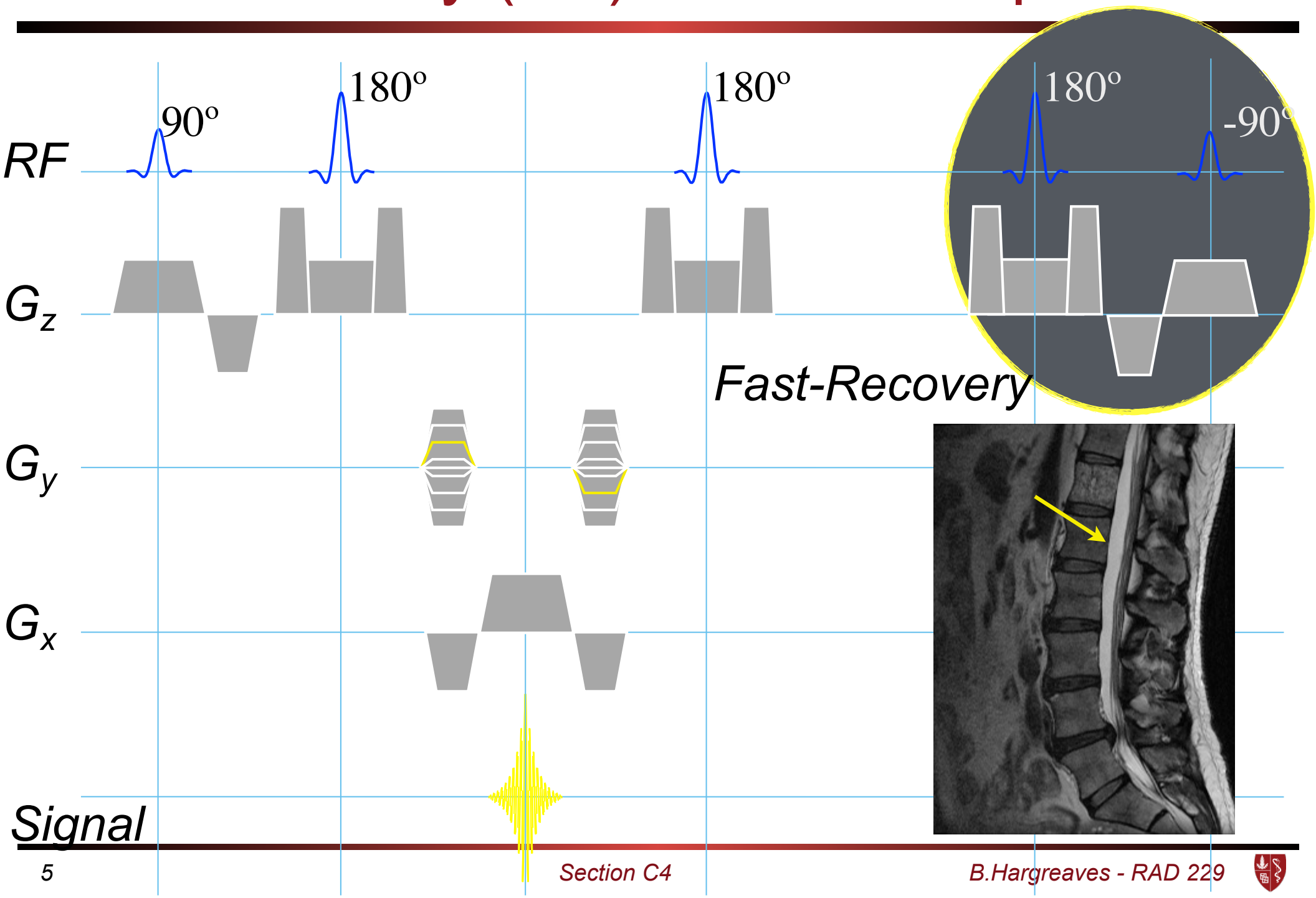
(From Previous) Challenge: Diffusion

Challenge: Diffusion (Solution)

Contrast Review

- Spin Echo
  - PD, T1, T2
  - Echo-train effects
- Gradient Echo
  - bSSFP, Gradient Spoiled (T2/T1)
  - RF spoiled (T1)
  - PD (how?) is inefficient, T2 is not possible

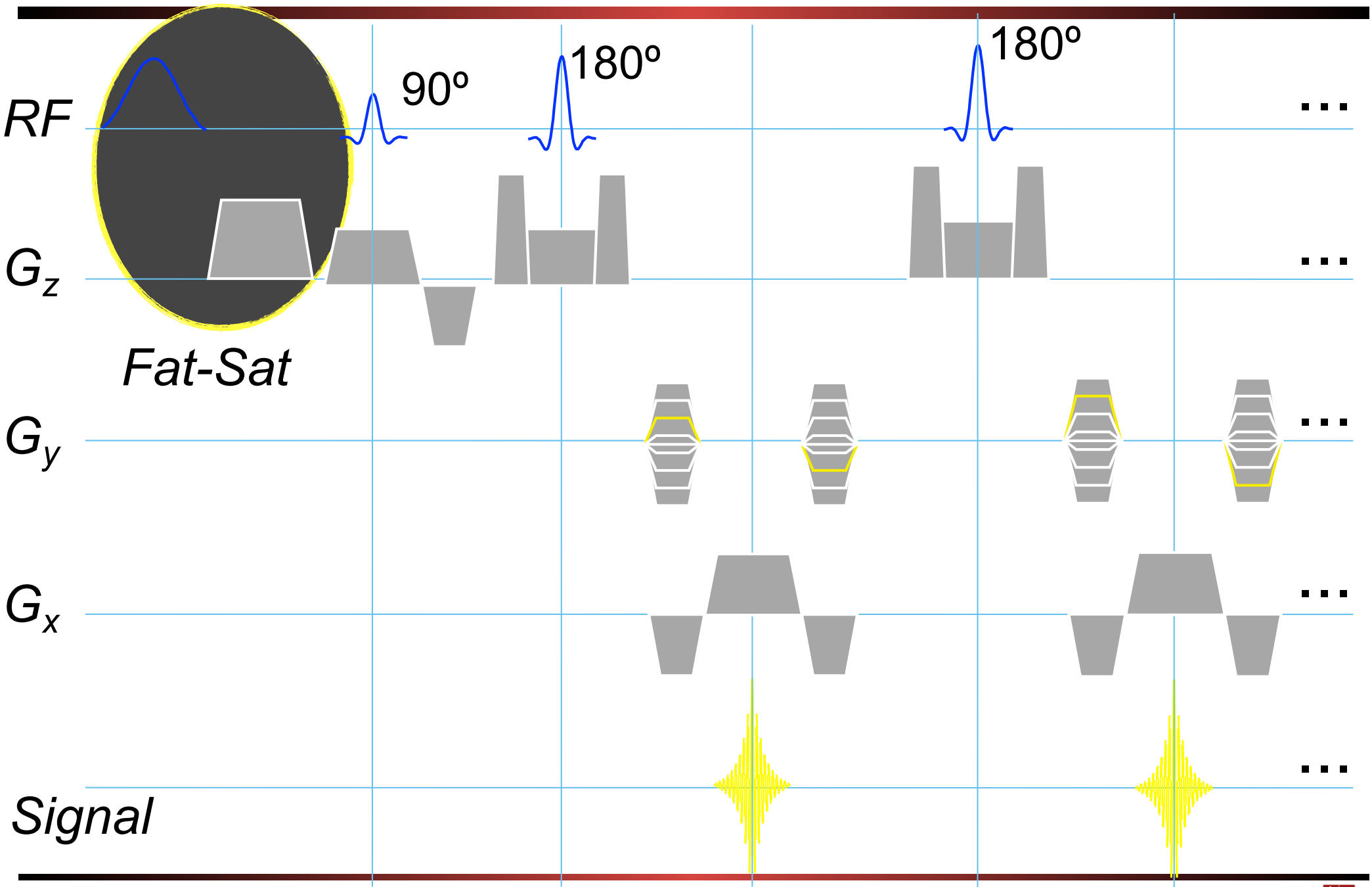
Fast Recovery (FR) or Driven Equilibrium



Saturation or Nulling

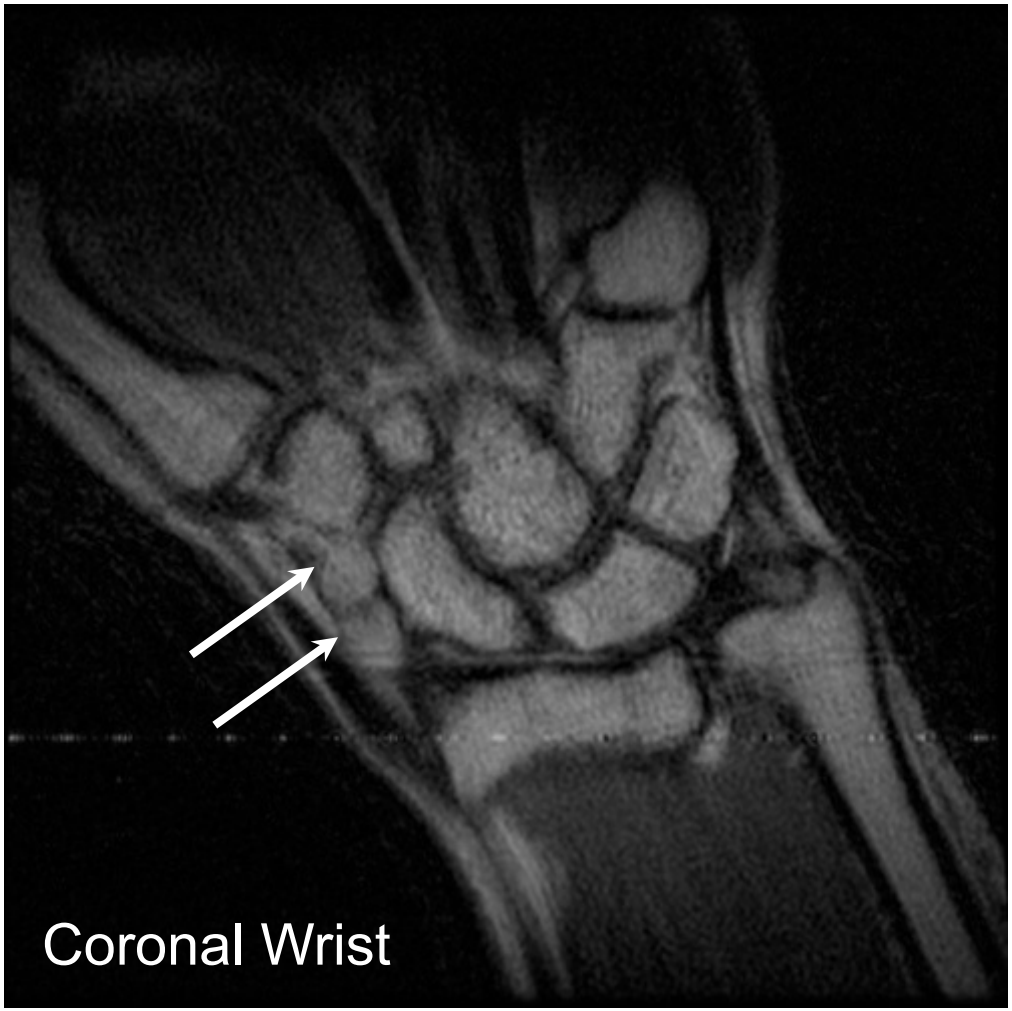
- Eliminate the signal from something
  - Chemical species
  - Regions of image
- Advantages
  - Minimal cost (example, can do short TE)
  - Increase dynamic range for desired signal
- Disadvantages
  - Exciting unwanted signal - it can come back!

Fat-Saturated FSE

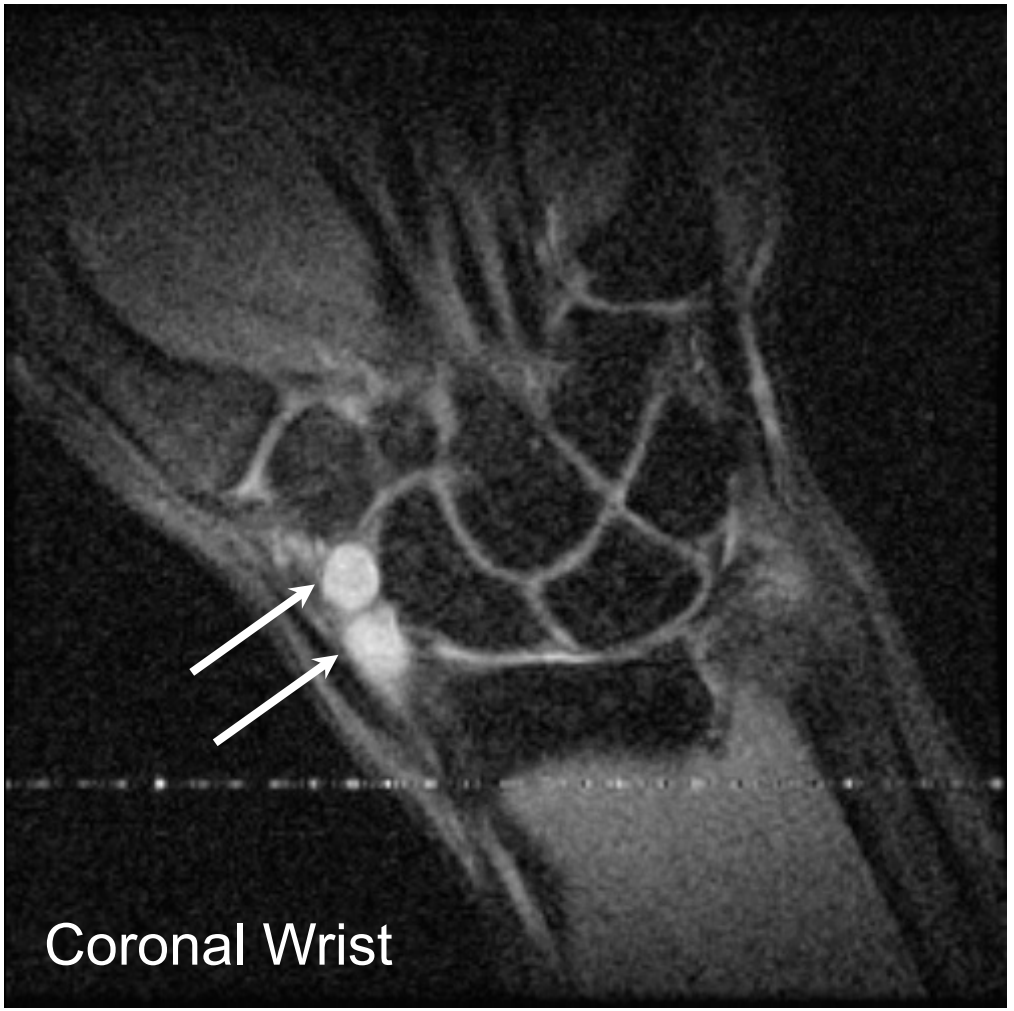


Fat Suppression for Contrast

PD FSE

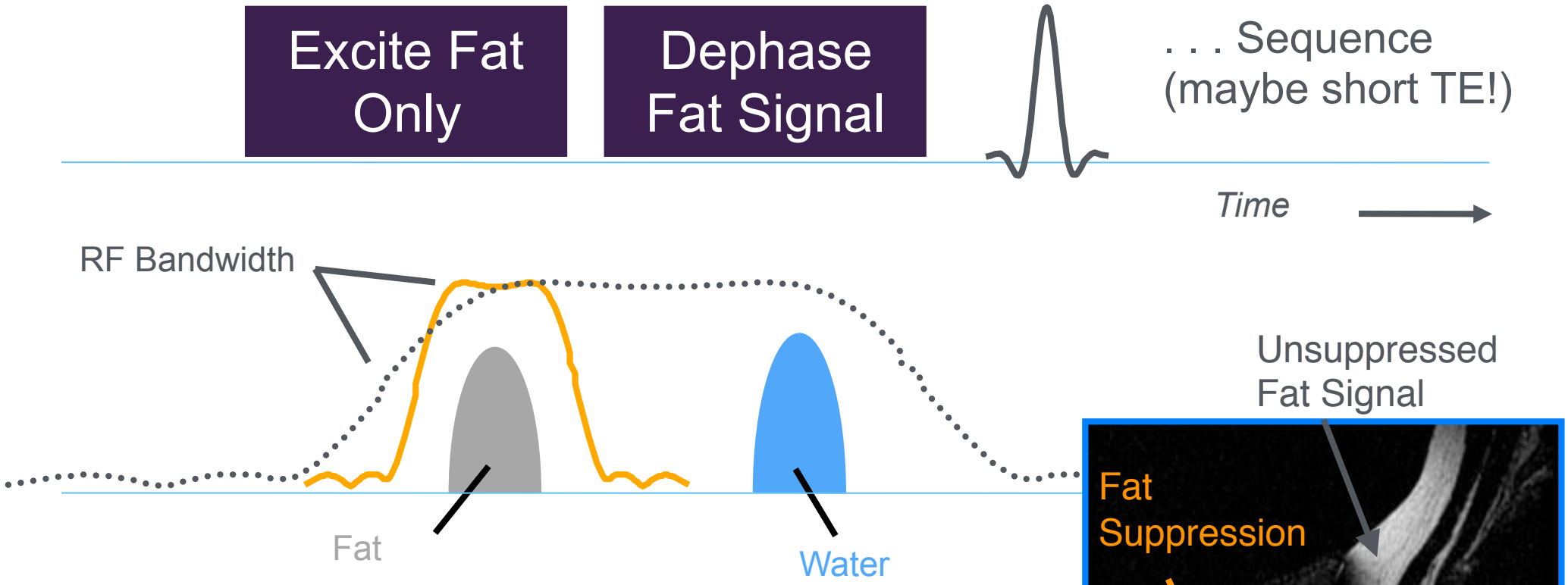


Fat-Sat PD FSE

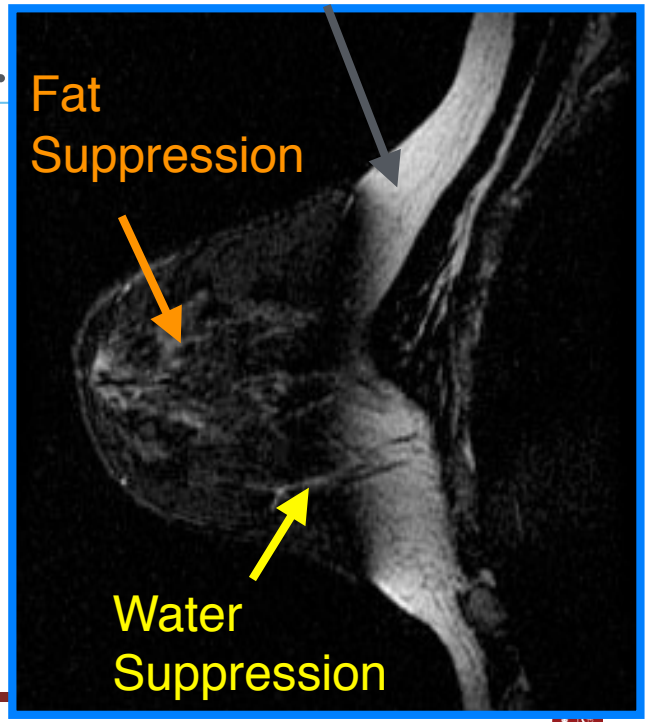


Radial cyst was otherwise iso-intense with fat

Fat Saturation



- Chemically-selective excitation
- Dephaser gradient
- Normal imaging sequence



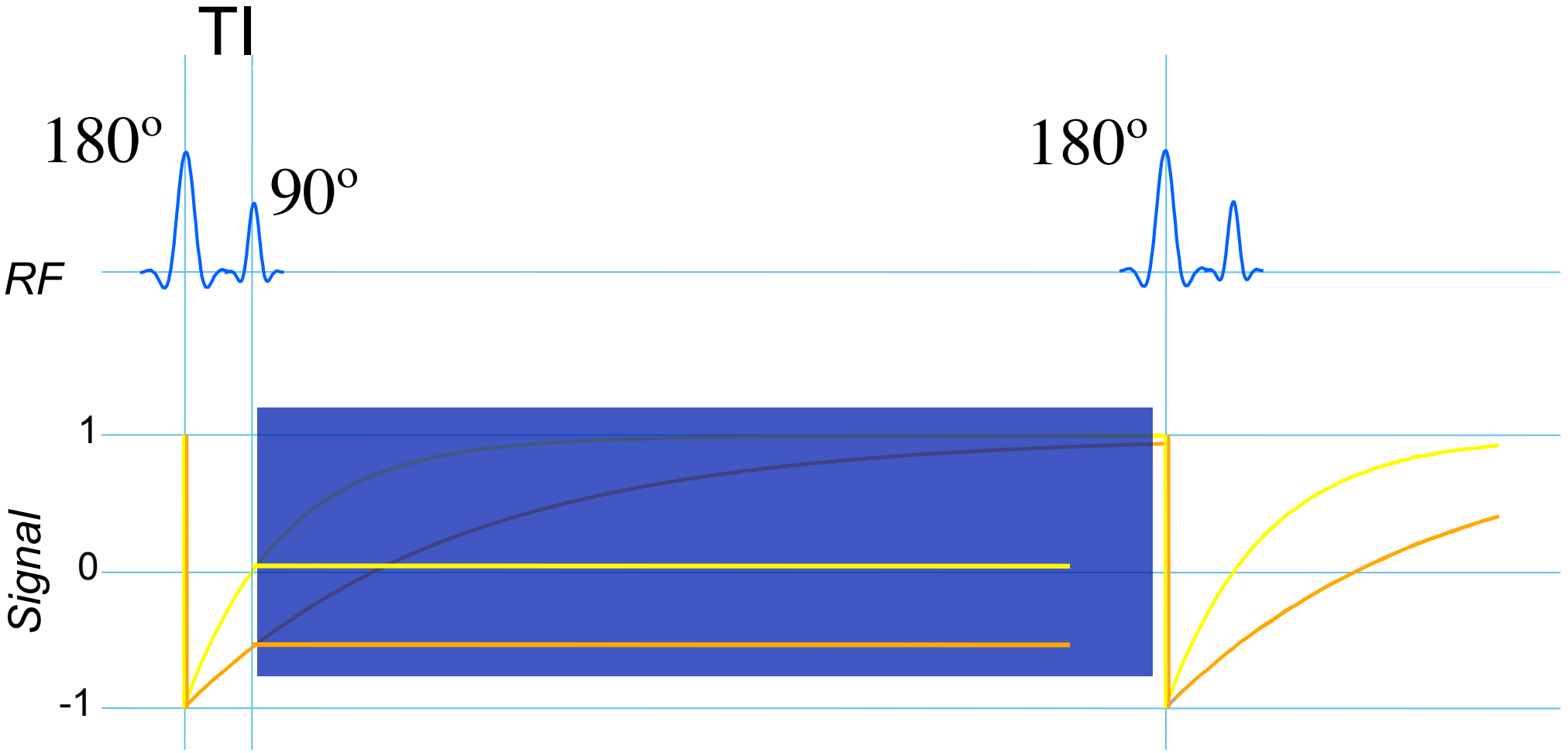
Effect of Fat Saturation

Fat-Saturated (PD)

Not Fat-Saturated (T1w)

Questions: Fat Saturation

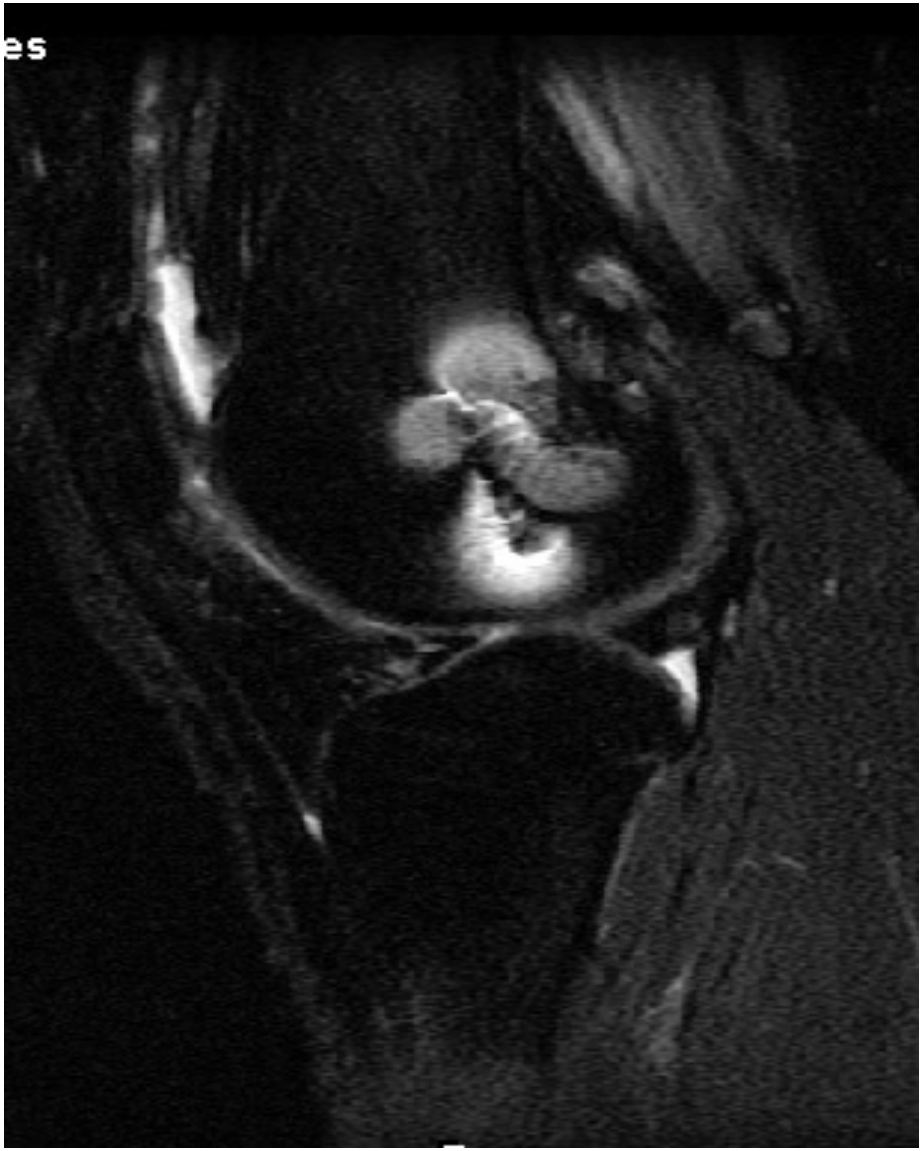
Inversion-Recovery



Fat suppression based on T_1

Short TI Inversion Recovery (STIR)

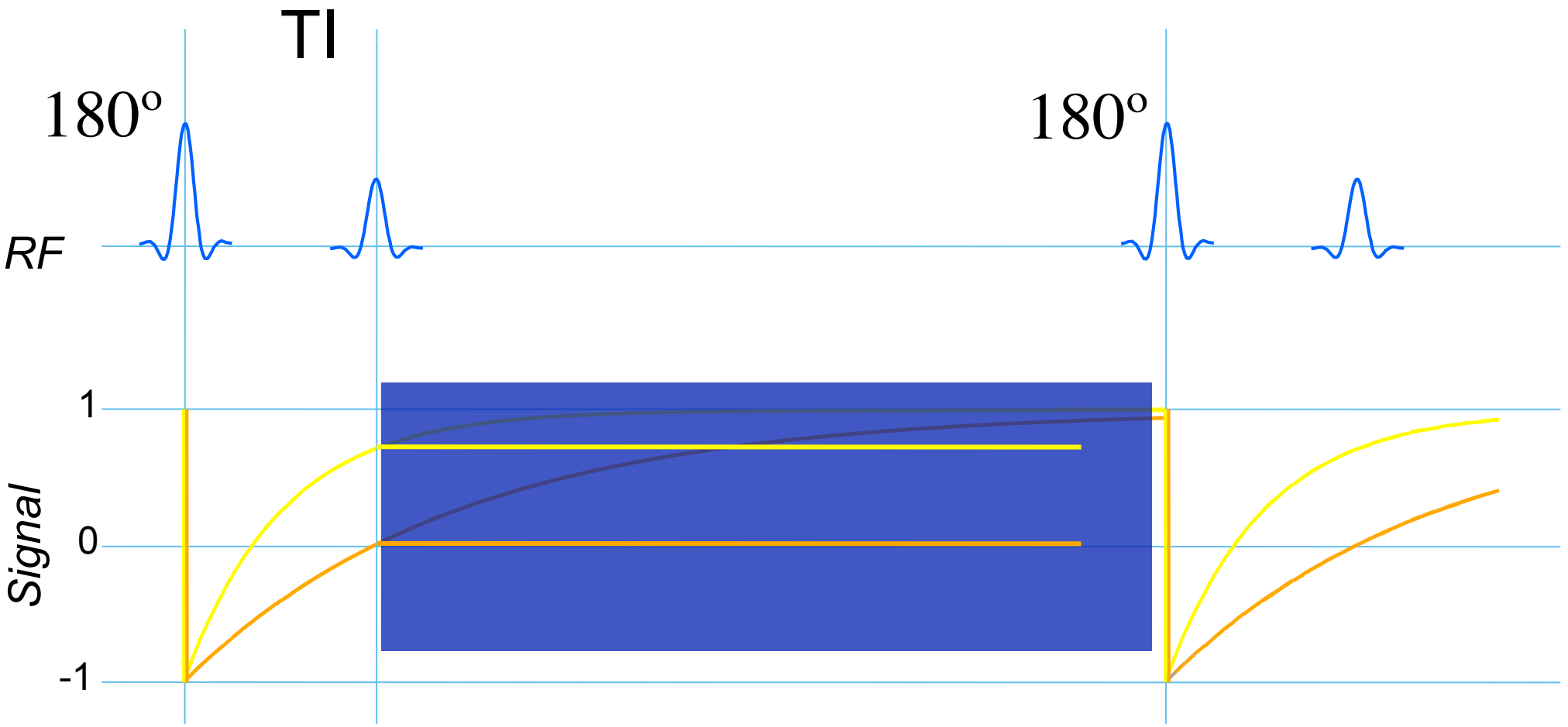
Fat Suppression near B_0 Inhomogeneity



Fat Sat

STIR

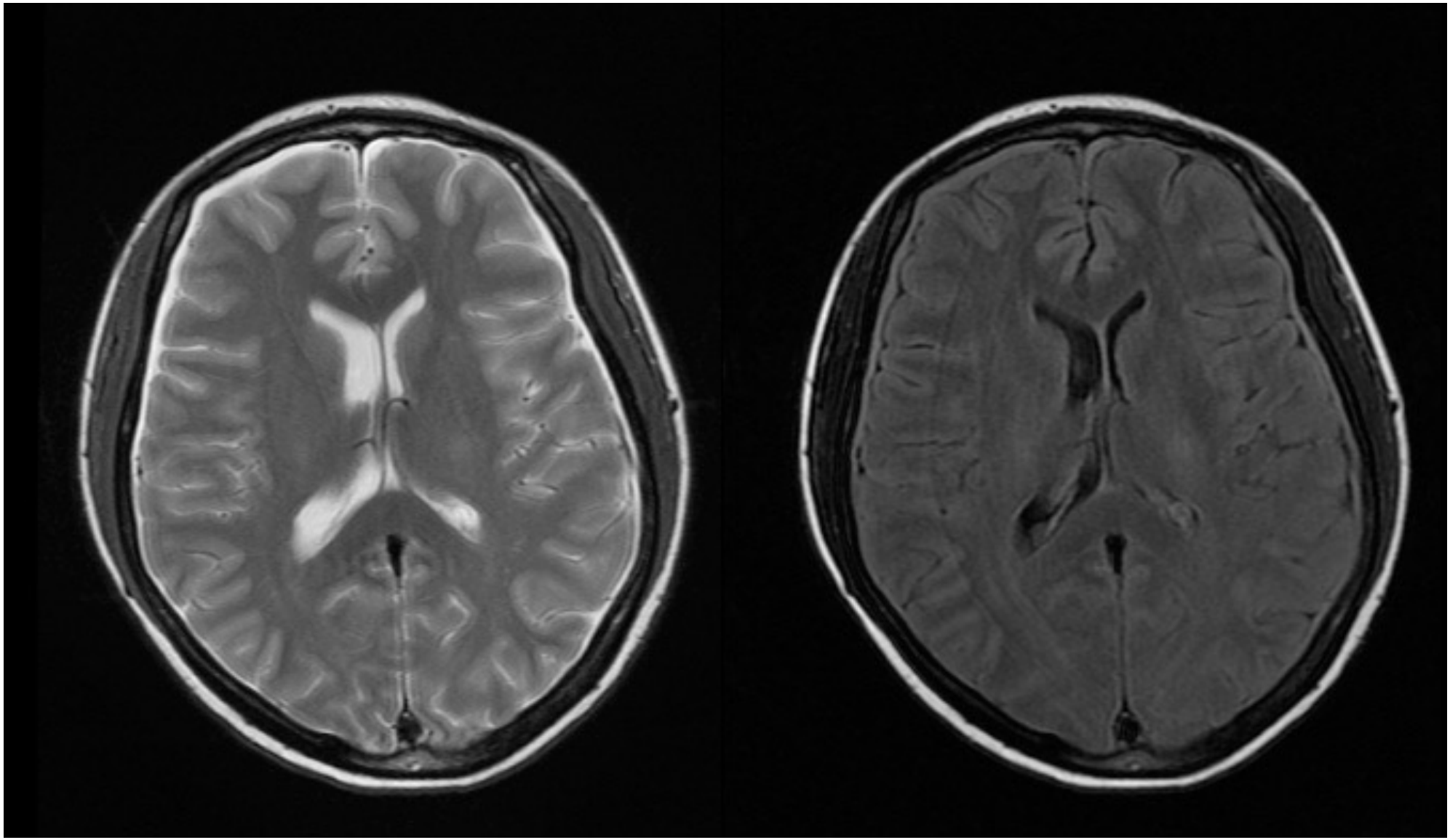
Fluid Attenuated Inversion-Recovery



Fluid suppression based on T_1

FLAIR

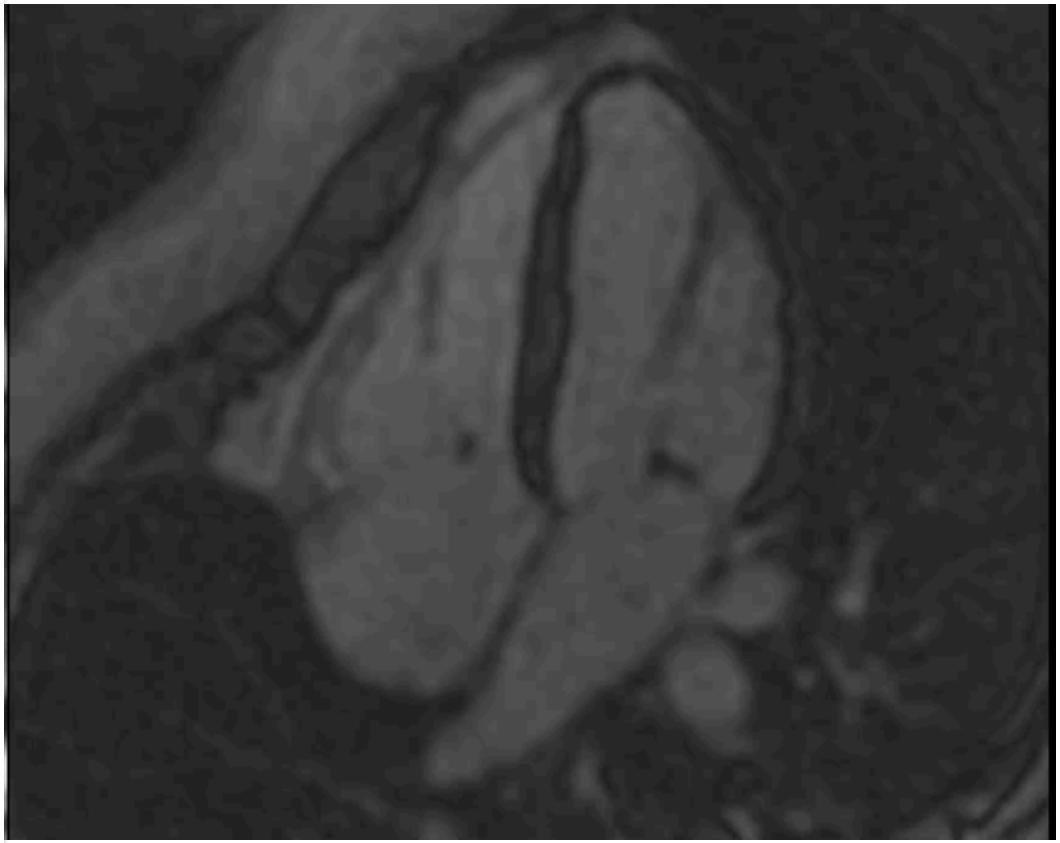
Long Inversion Time (TI) - FLAIR



Long TI suppresses fluid signal

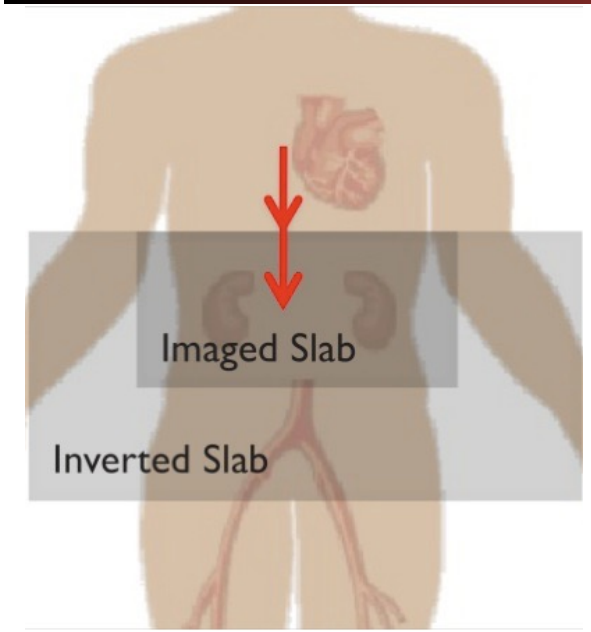
IR Prep to enhance T1 contrast

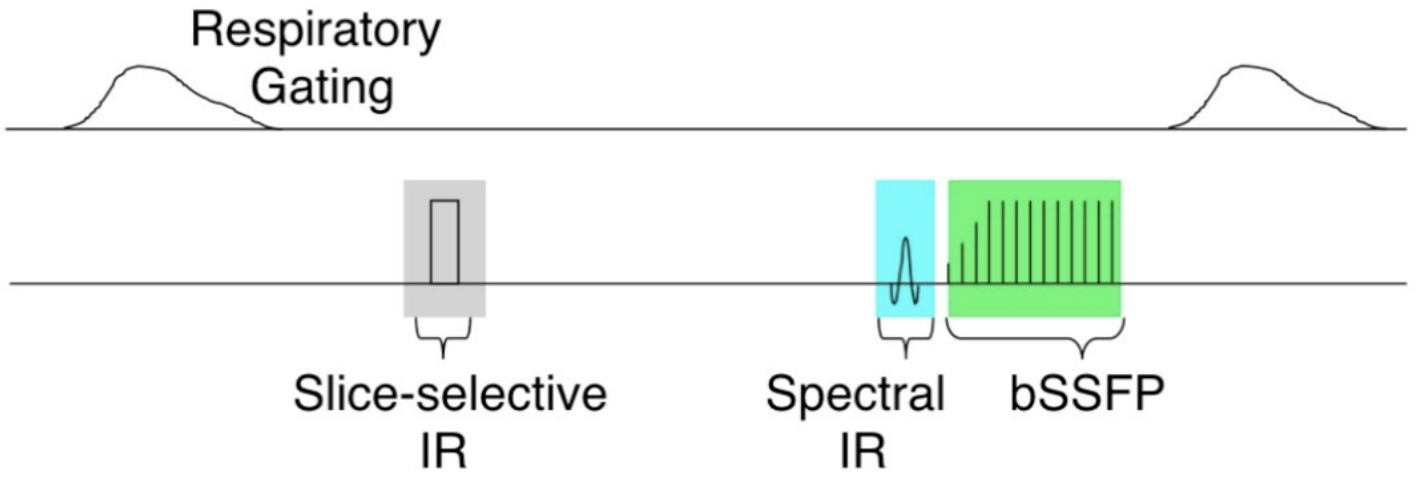
- Often used with GRE (MP-RAGE)
- Example: Cardiac CINE, IR at start (note septum)



IR-Prep RF-Spoiled

Mag-Prep: Inflow-enhanced MRA





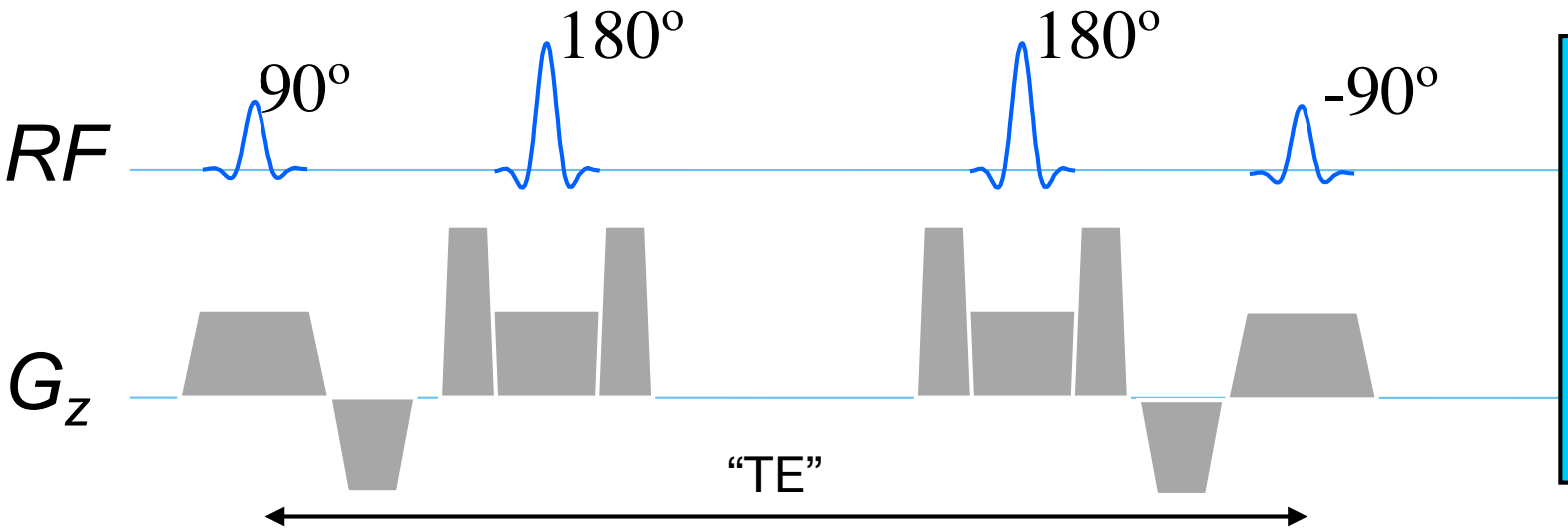
Preparation:

- Background Suppression
- Fat Suppression

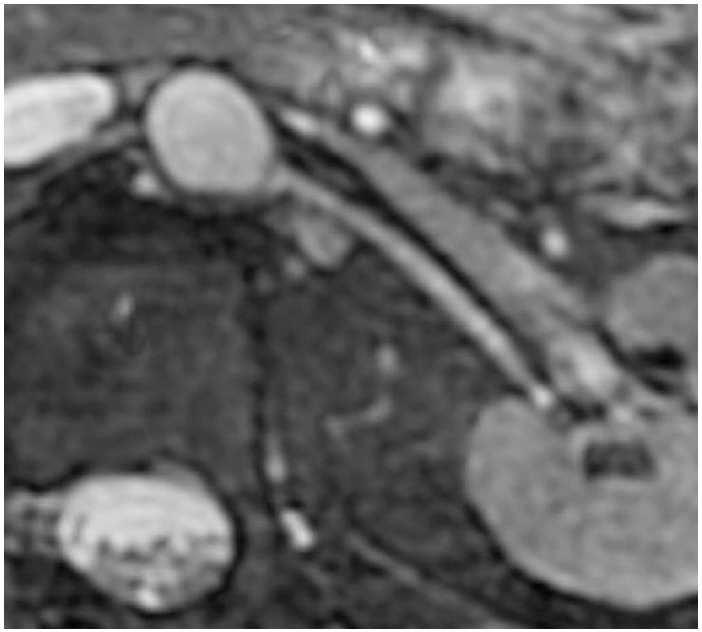
Courtesy Pauline Worters

Questions: Inversion-Recovery

T2-Prep (Enhance T2 contrast)



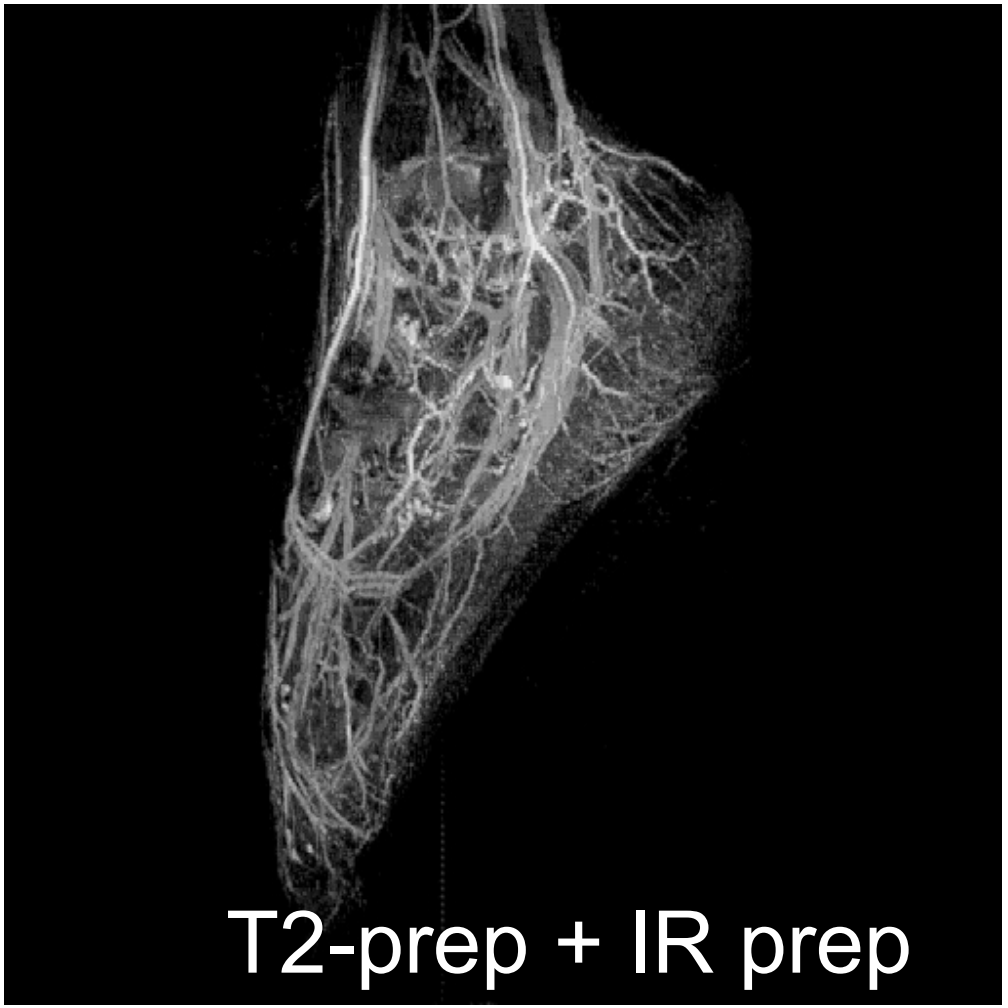
Regular Imaging Sequence



T2-prep + Fat-Sat Renal Artery

T2-Prep: Flow-Independent Angiography

- Inversion: Suppress synovial fluid
- T2-prep: Arterial-venous contrast

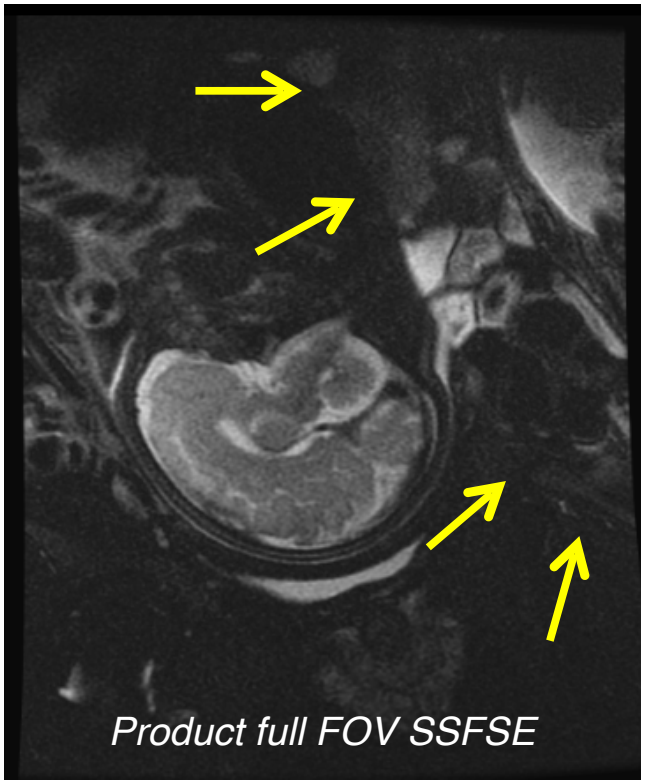


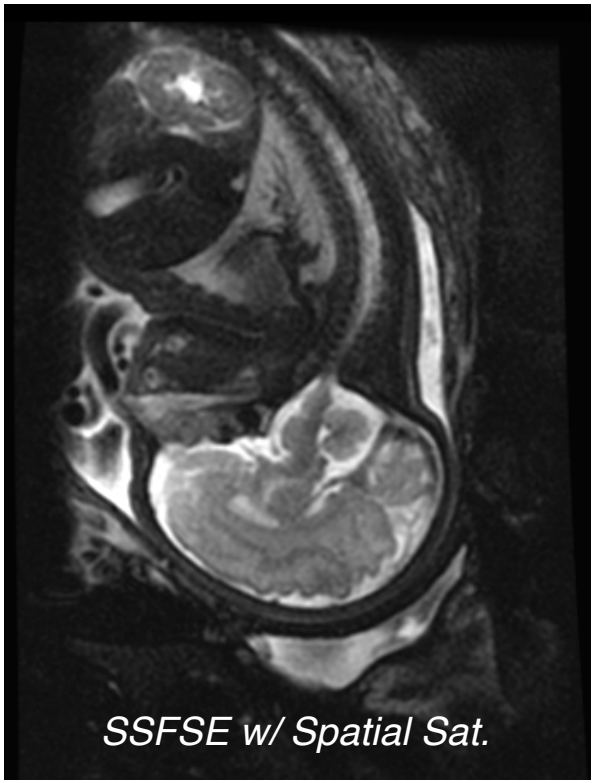
Courtesy Neal Bangerter

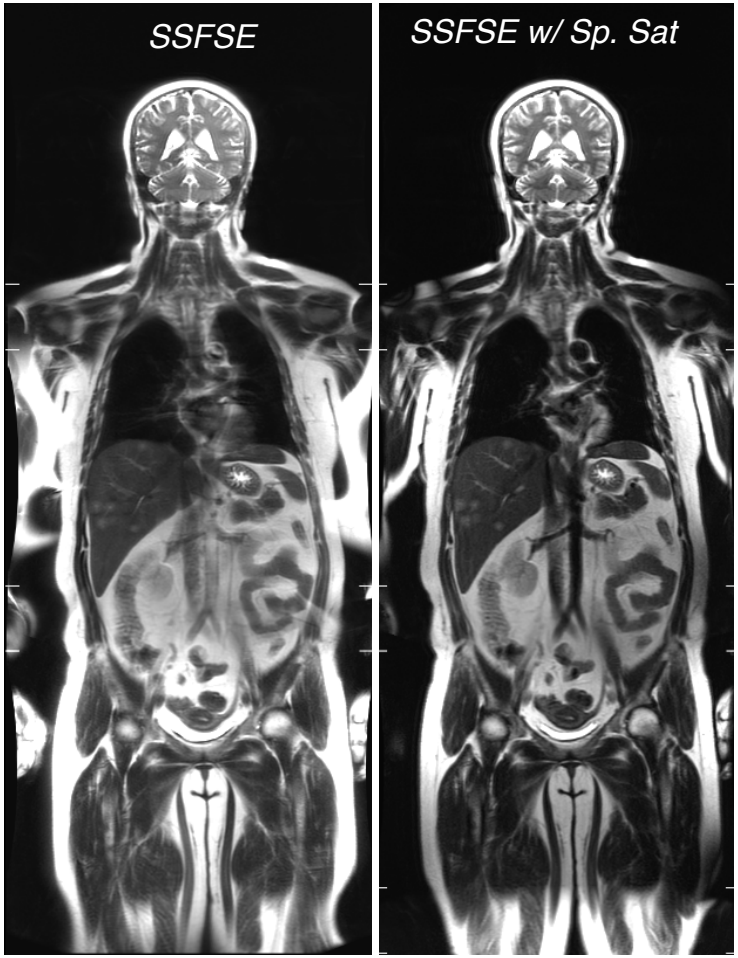
Questions: T2-prep

Spatial Saturation

- Reduced FOV imaging
- Saturate “bands” outside FOV to prevent aliasing

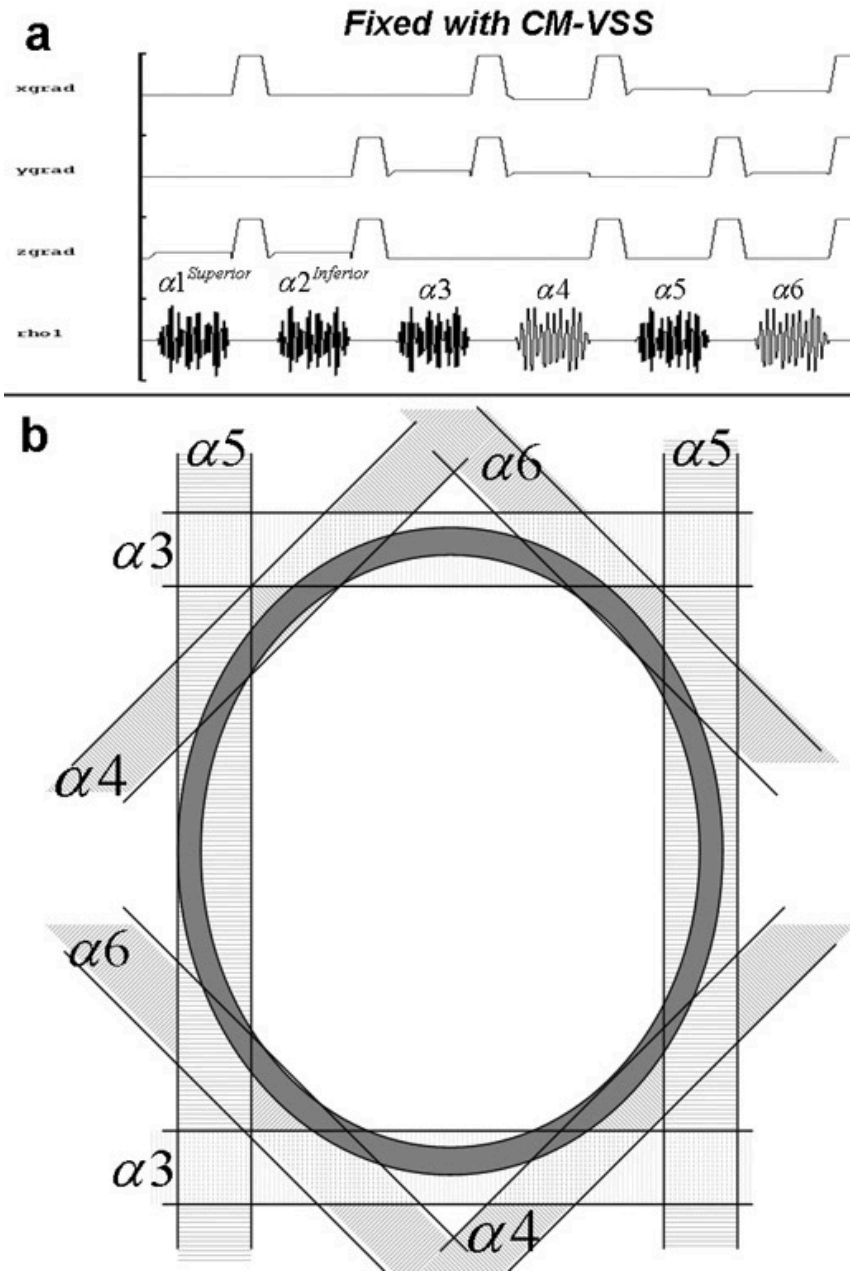






Spatial Saturation

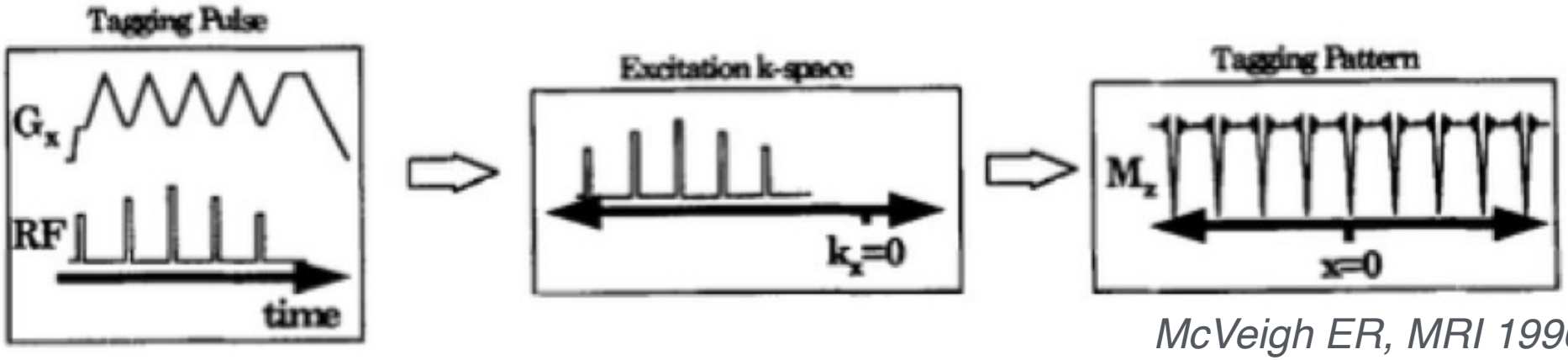
- Use with arbitrary sequences
  - Save time with reduced FOV
- Very selective w/o time penalty
- Cosine modulate (dual-band)
  - *Osorio JA, et al. MRM 2009*



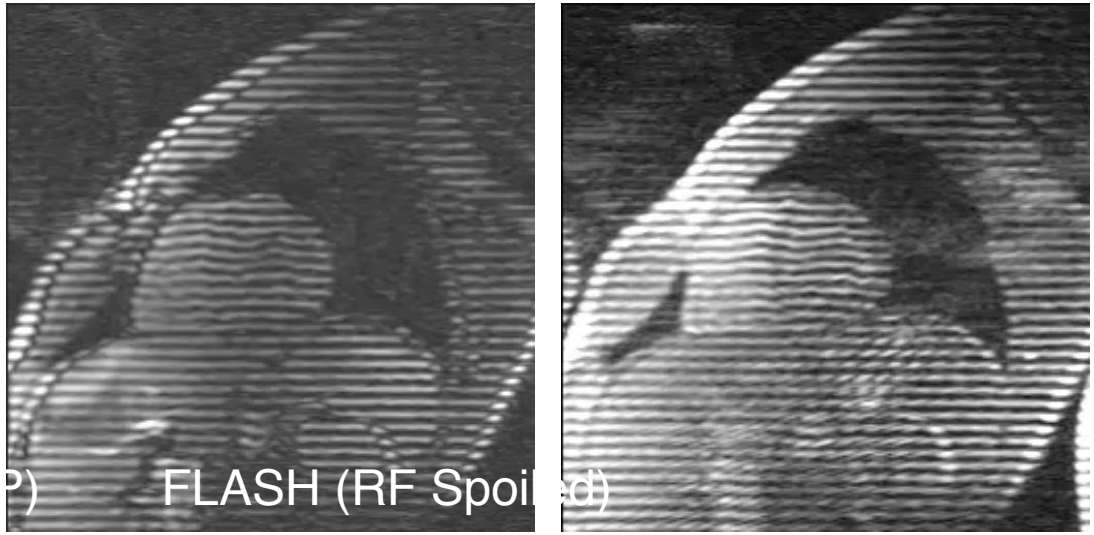
Myocardial Tagging

Zerhouni E, 1988

- Spatially selective saturation pattern (lines, grid)
- Often ‘cine’ acquisition

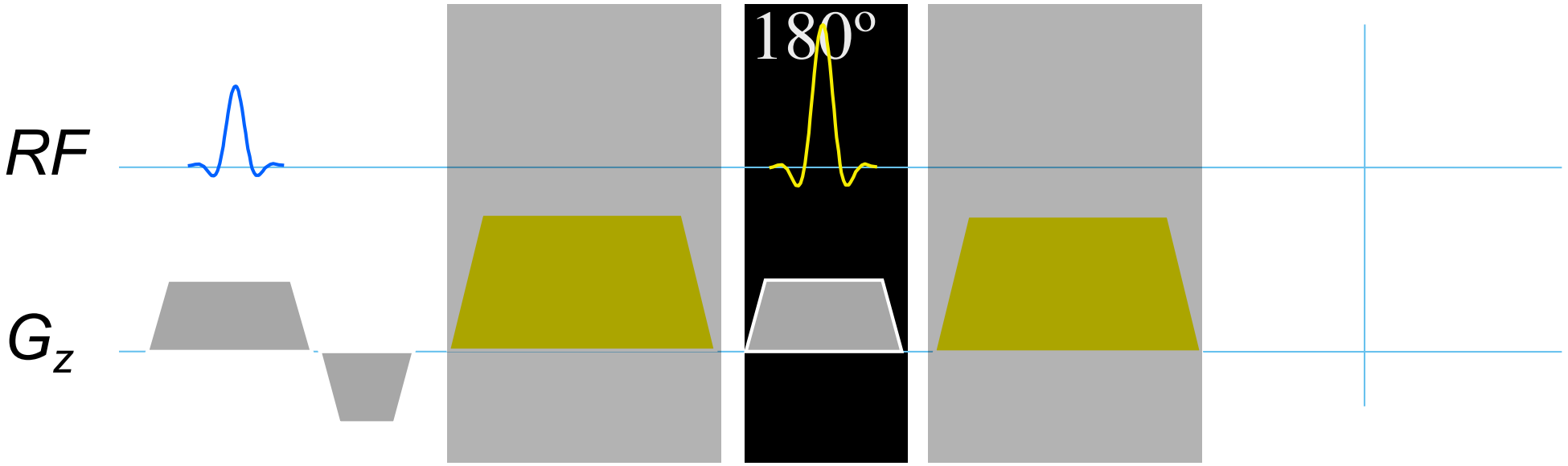


McVeigh ER, MRI 1996

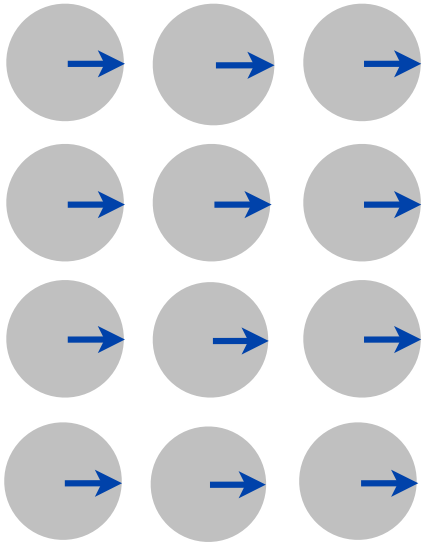


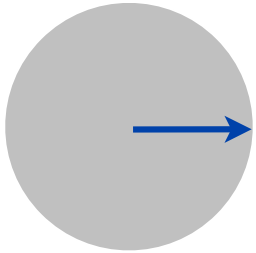
Courtesy J. Zwanenburg (MRM 2003)

Diffusion-Weighted Imaging (DWI)

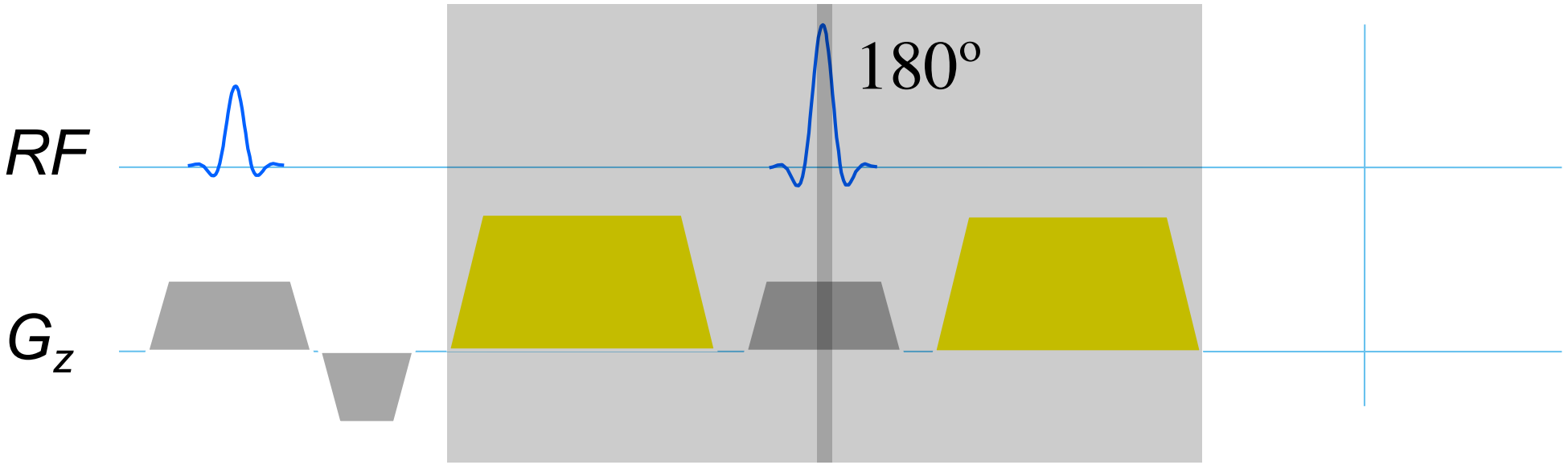


No Diffusion

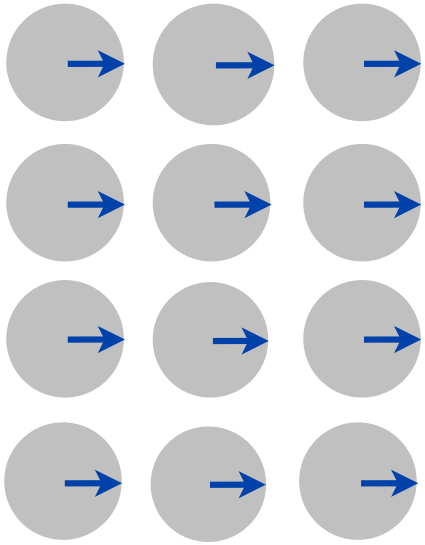


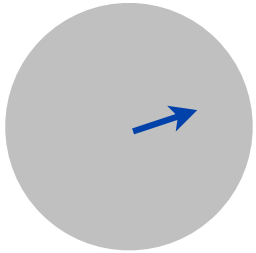


Diffusion-Weighted Imaging (DWI)



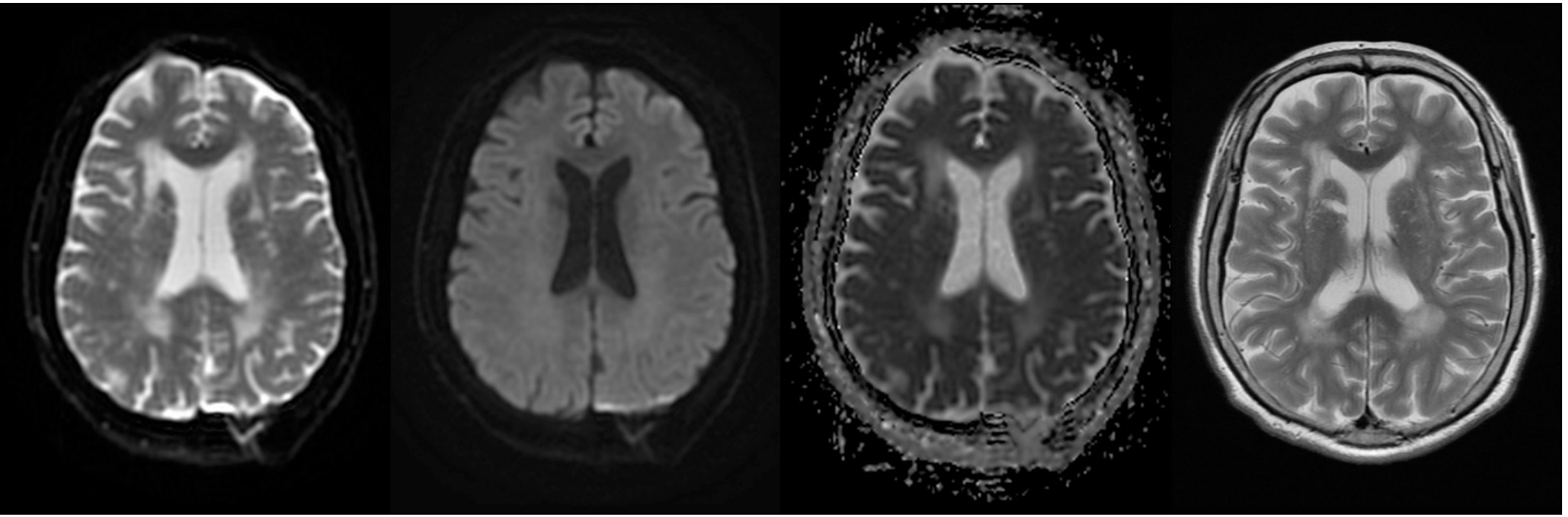
Diffusing Spins



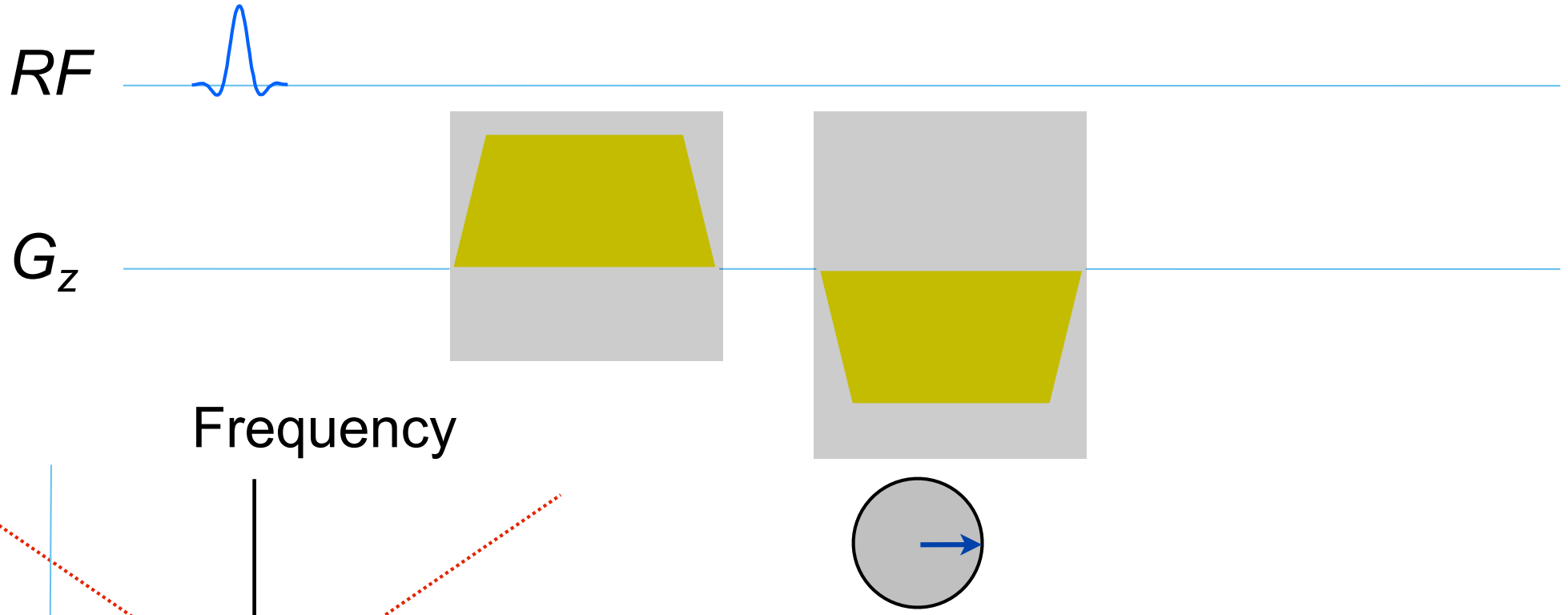


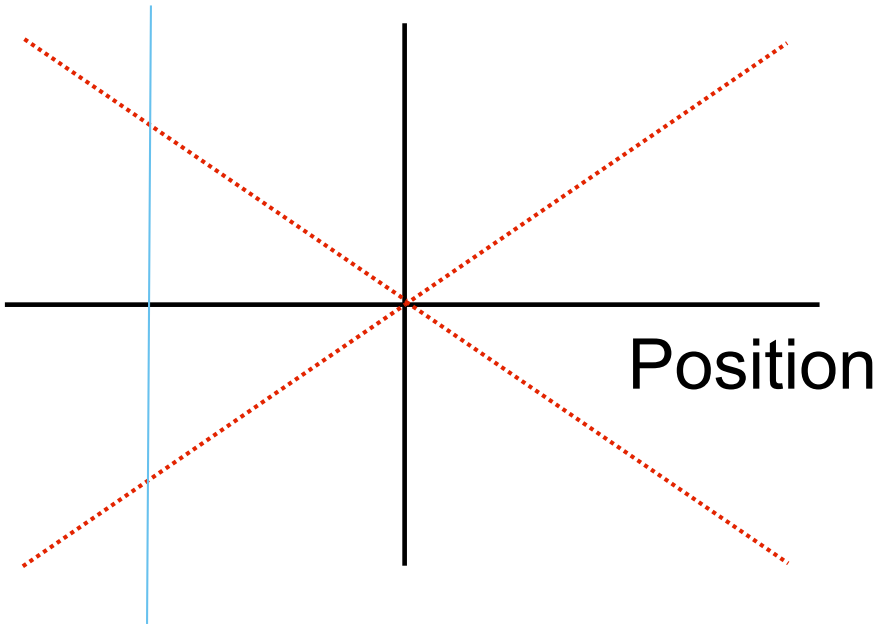
Diffusion-Weighted Imaging (DWI)

Low b-value High b-value ADC T2 FSE



Phase Contrast



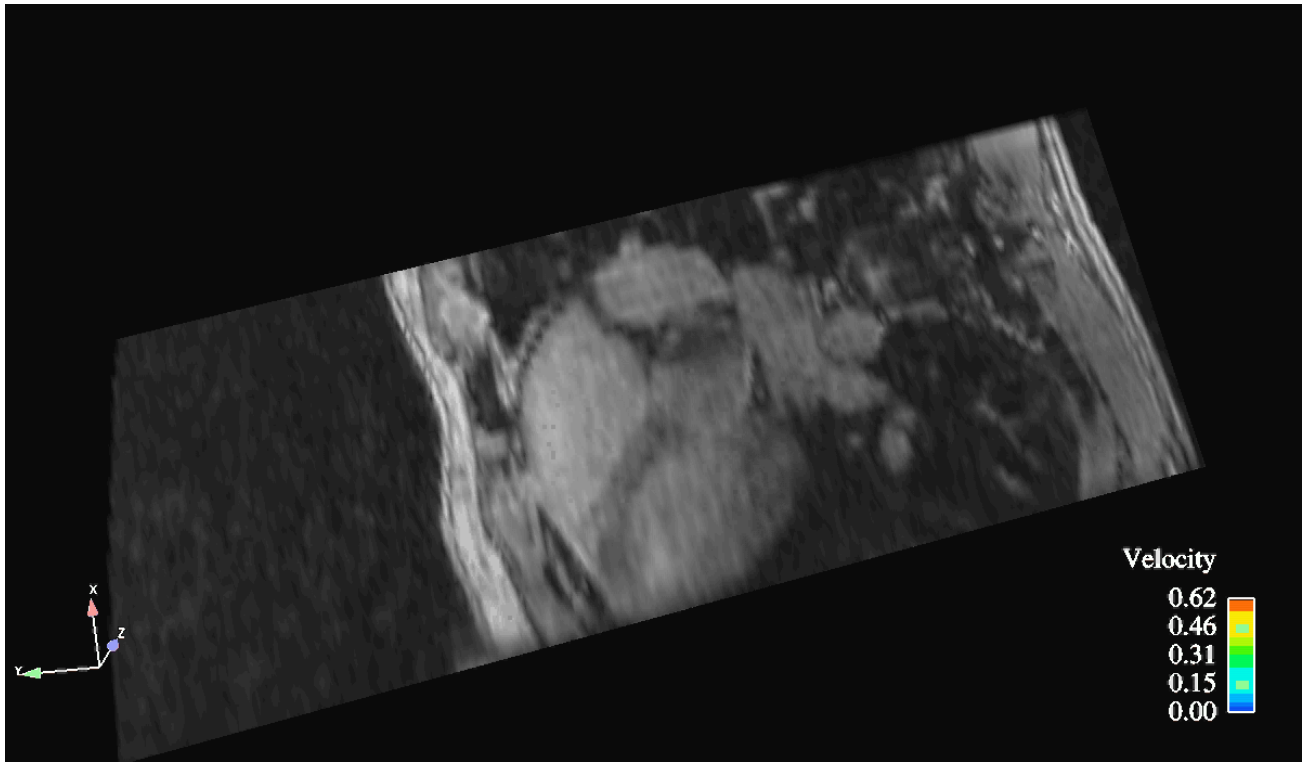


Phase is not zero!
(any position)

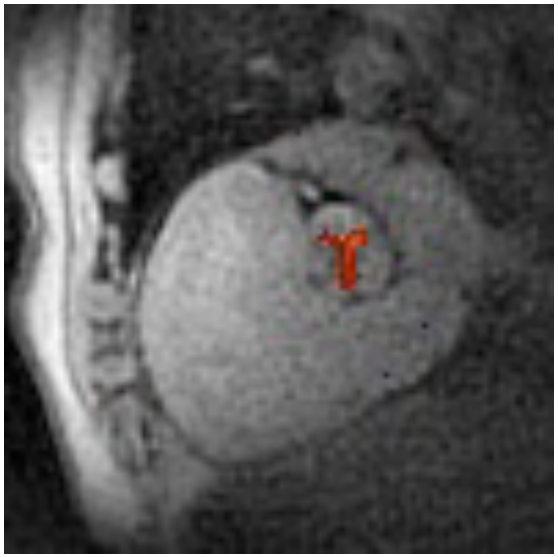
$$\phi = \gamma(x \int G_x dt + x' \int G_x t dt)$$

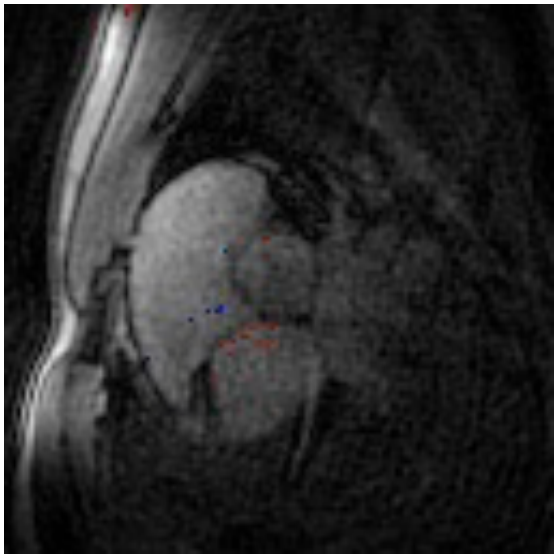
"Zero Moment" "First Moment"

Flow Encoded Imaging



Marcus Alley

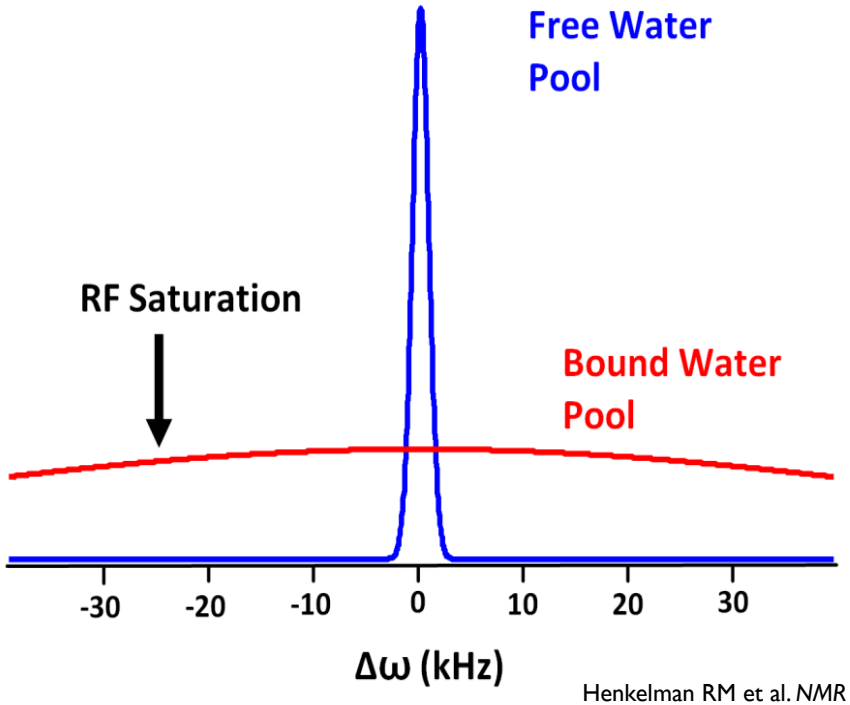




Krishna Nayak

Magnetization Transfer (MT)

- Saturate very-short-T_2 water bound to macromolecules
- MT effect causes saturation of free water (signal loss)
- More RF generally causes more MT saturation (adverse)
- CEST: Saturation at specific frequency



$$MTR = \frac{M_0 - M_{sat}}{M_0}$$

Henkelman RM et al. *NMR in Biomedicine* 2001; 14(2):57-64.

Courtesy of Feliks Kogan

MT and EPG!

- *"EPG-X: An Extended Phase Graph formalism for systems with Magnetization Transfer or Exchange." Shaihan J Malik, Rui PAG Teixeira, Joseph V Hajnal. ISMRM Workshop on MR Fingerprinting*
- Add state for bound Mz

$$[\tilde{F}_n^a \ \tilde{F}_{-n}^{*a} \ \tilde{Z}_n^a \ \tilde{Z}_n^b]^T$$

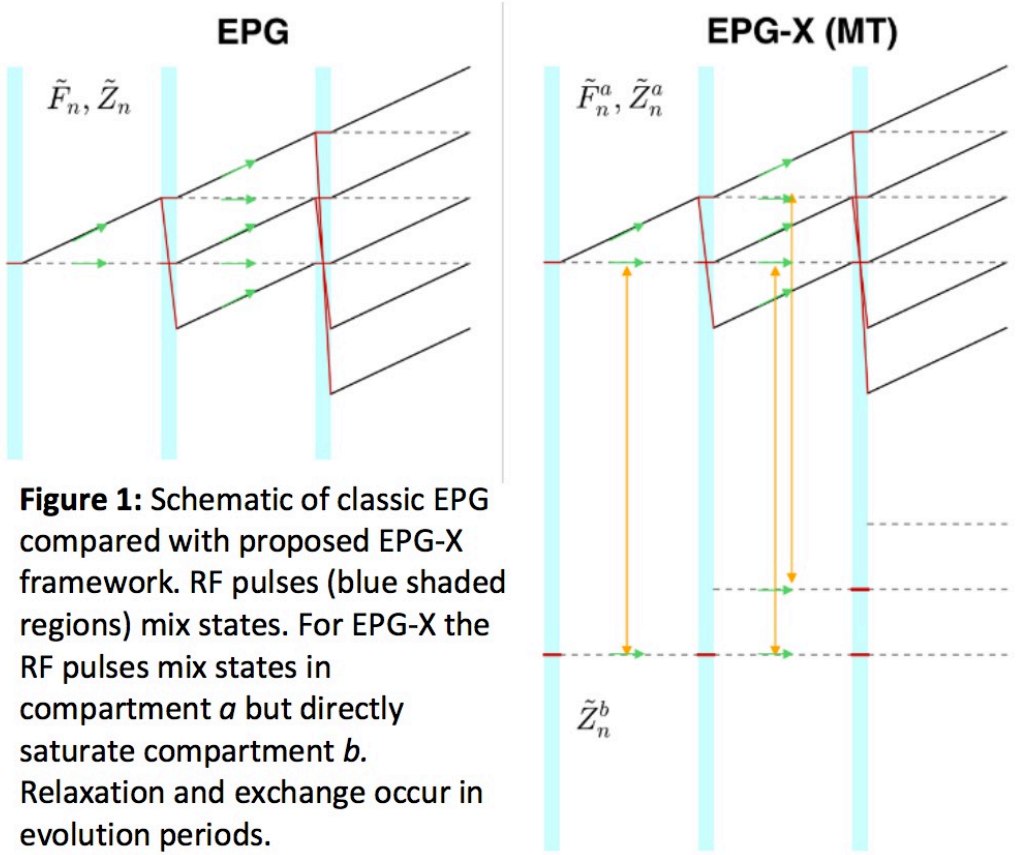


Figure 1: Schematic of classic EPG compared with proposed EPG-X framework. RF pulses (blue shaded regions) mix states. For EPG-X the RF pulses mix states in compartment *a* but directly saturate compartment *b*. Relaxation and exchange occur in evolution periods.

Other Preparations

- Double IR: Non-selective, then selective
  - “Black Blood”
- Multiple IR: Null multiple species simultaneously
- Arterial spin labeling (Invert blood, subtract reference)
- Diffusion preparation (tip-up)
  - Motion-sensitized driven equilibrium (MSDE)
  - Null vessel signal

Summary of Magnetization Prep

- Suppression: Spatial, Fat, Blood, Fluid
- Contrast: Inversion, T2-prep, Diffusion
- Encoding: Flow/motion, Diffusion, Tagging