Rad229 – MRI Signals and Sequences

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Lecture-14B — Magnetization Preparation

Saturation, Inversion, and Contrast Preparations

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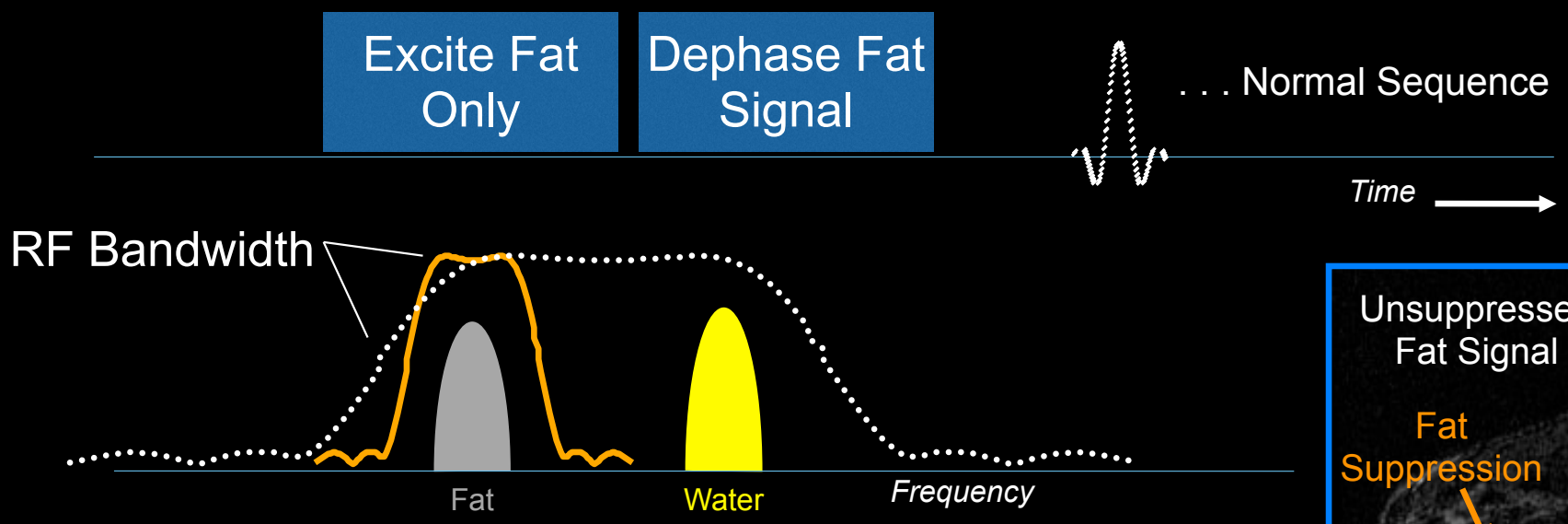
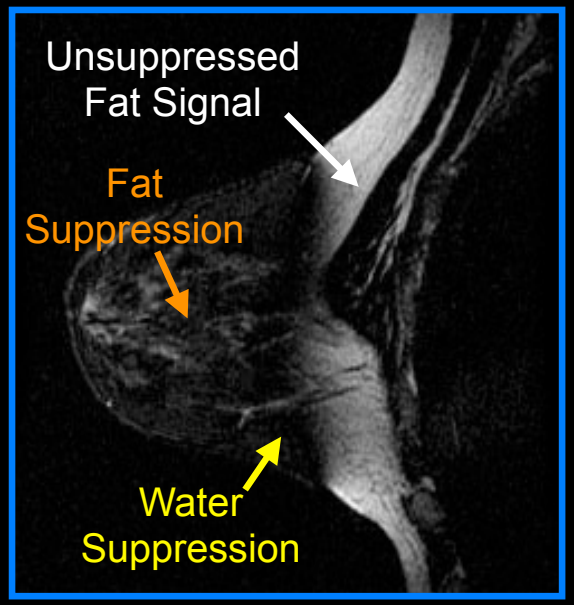
Learning Objectives

- Describe several forms of saturation pulse
- List and explain three uses of inversion nulling
- Describe T2-prep sequences and their effect
- Describe a driven-equilibrium sequence
- Explain magnetization transfer and CEST
- Explain long-T2 suppression
- Qualitatively describe diffusion encoding

Fat Saturation

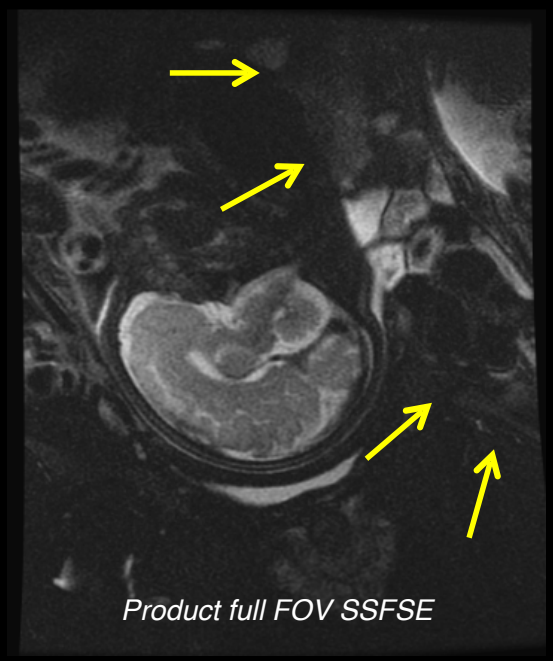


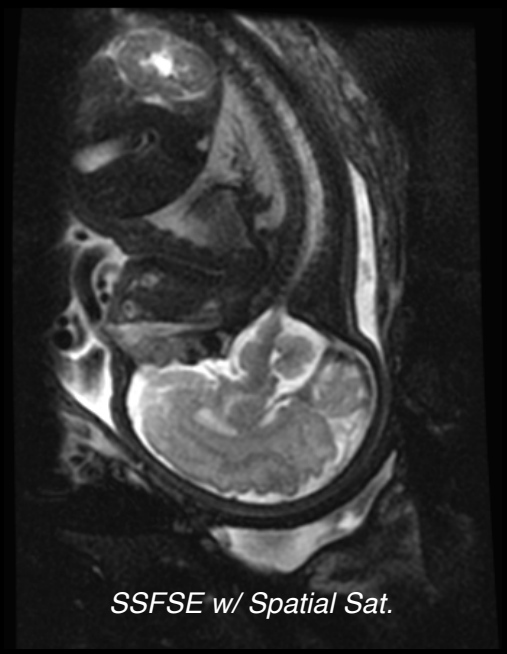


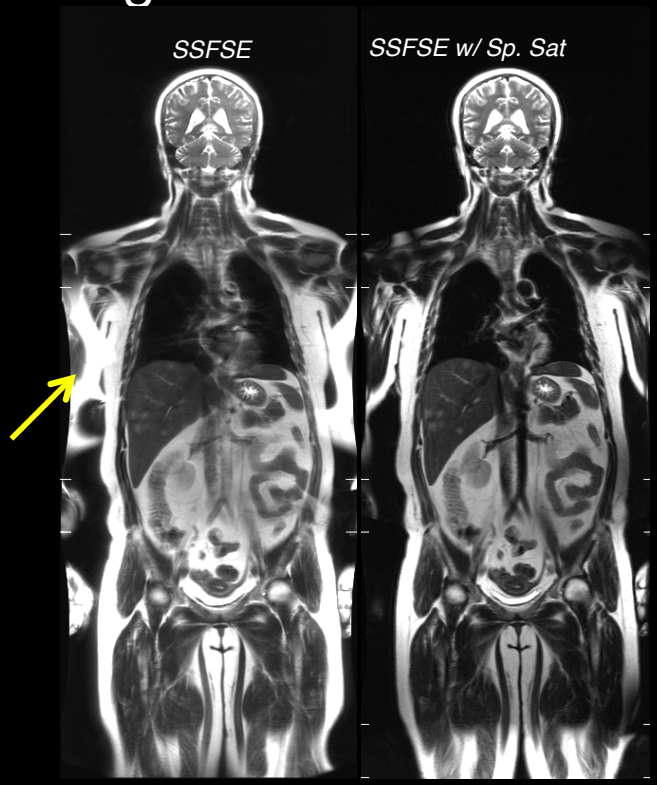
- Chemically-selective excitation
- Dephaser gradient
- Normal imaging sequence

Spatial Saturation

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





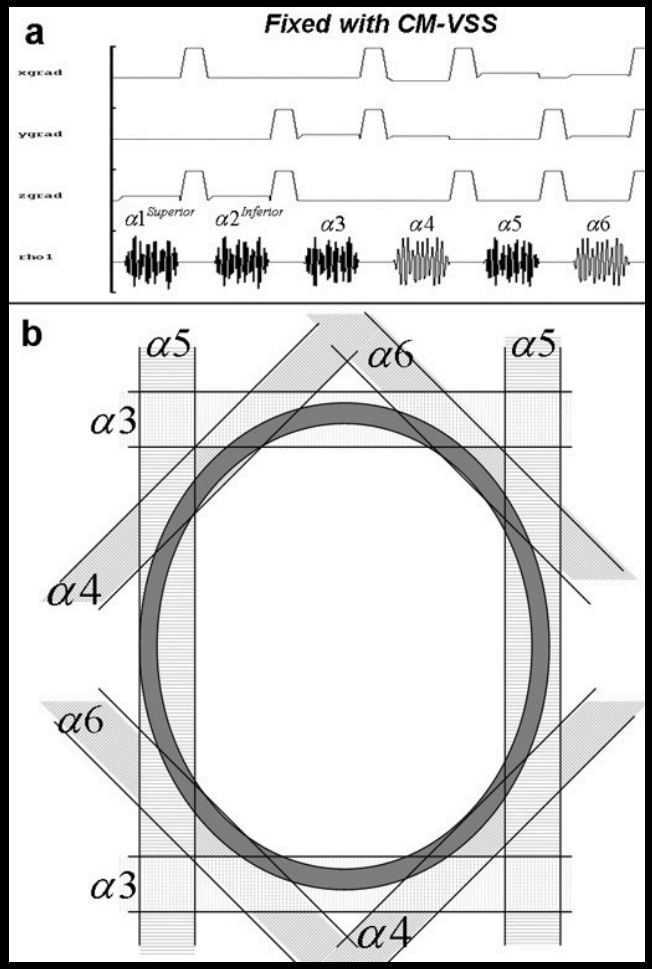


Courtesy Valentina Taviani, Andreas Loening

Spatial saturation (“Outer volume suppression”) selectively crops the field-of-view before imaging

Spatial Saturation

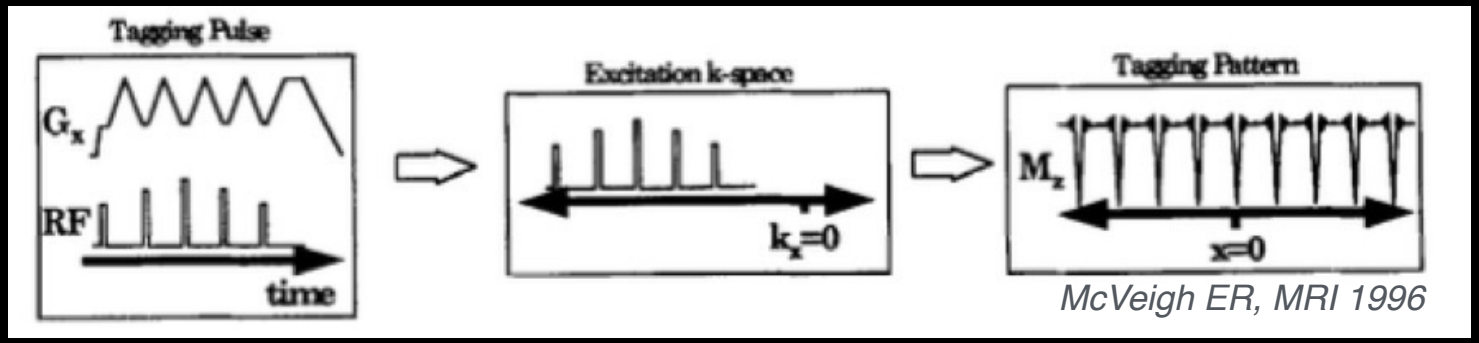
- Use with arbitrary sequences
  - Save time with reduced FOV
- Very selective w/o time penalty
- Cosine modulate (dual-band)
  - *Osorio JA, et al. MRM 2009*



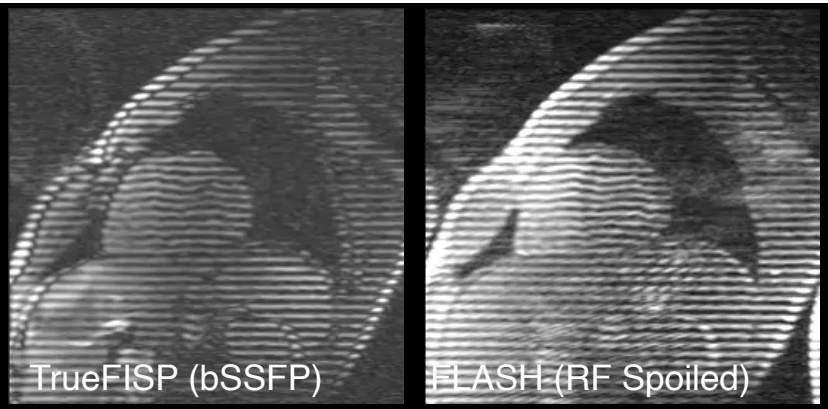
Myocardial Tagging

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

Zerhouni E, 1988



McVeigh ER, MRI 1996

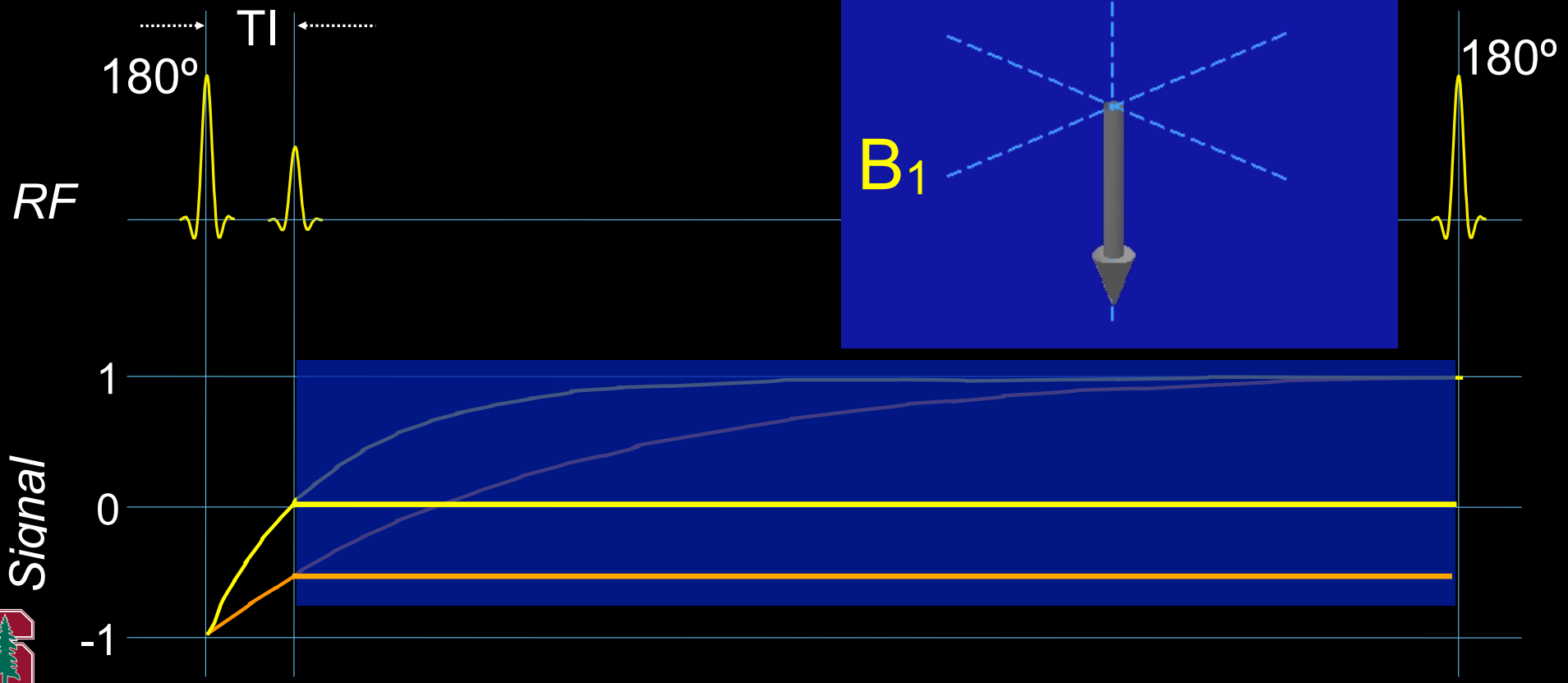


Courtesy J. Zwanenburg (MRM 2003)

Exciting a pattern in the heart can allow visualization of cardiac motion

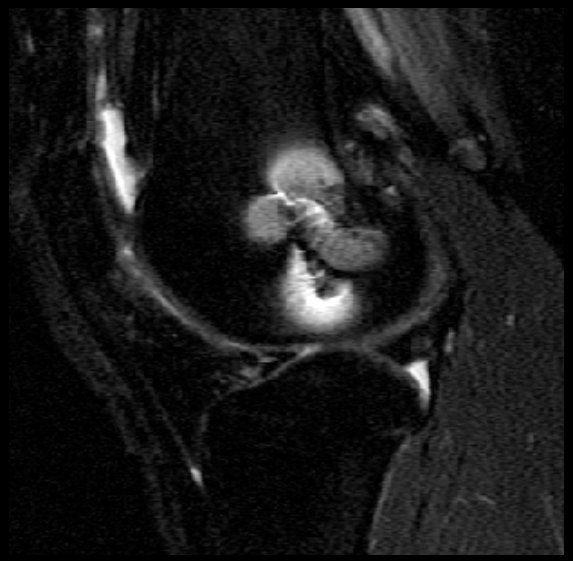
Inversion-Recovery Nulling (STIR)

- *Fat suppression based on T_1*
- *Short TI Inversion Recovery (STIR)*



STIR vs Fat Saturation

- STIR is T_1-based and less senstive to B_0 variations
- STIR costs SNR
- STIR can suppress gadolinium-enhanced signal (Short-T_1)

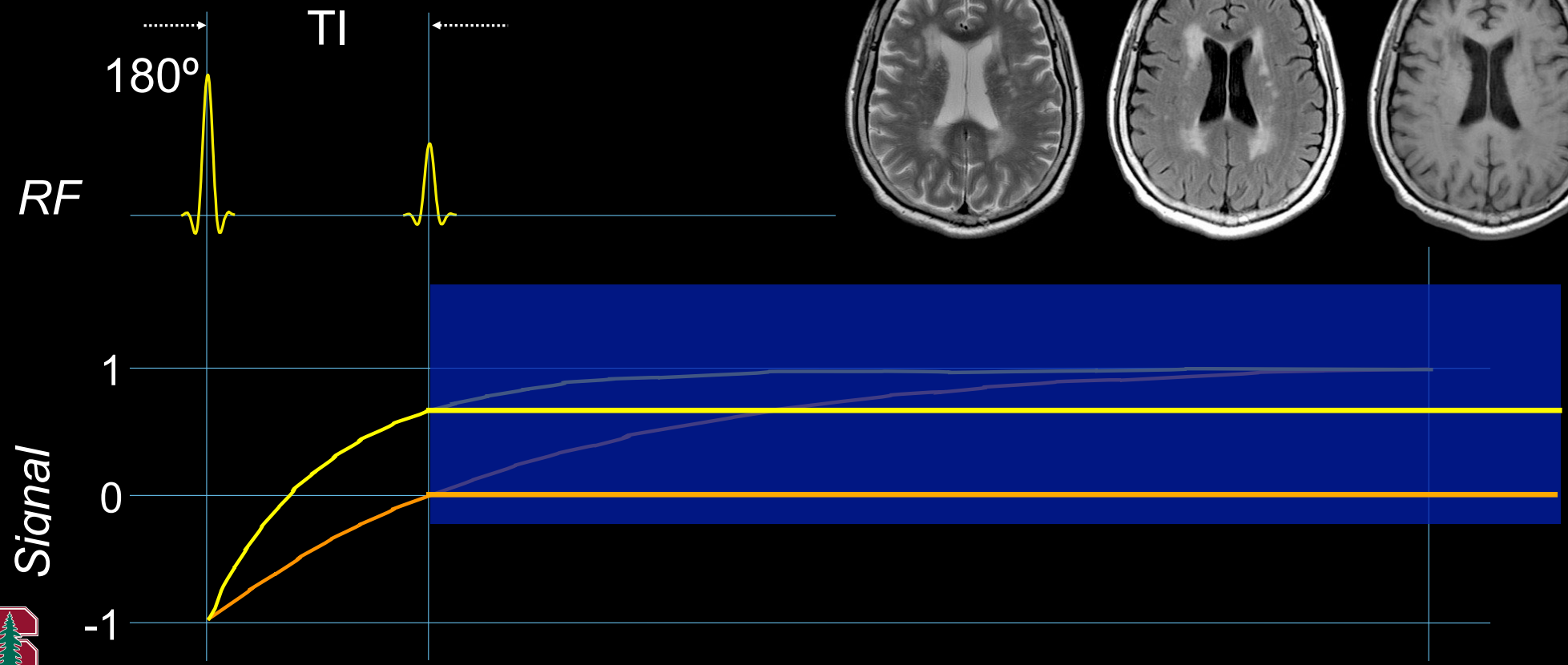


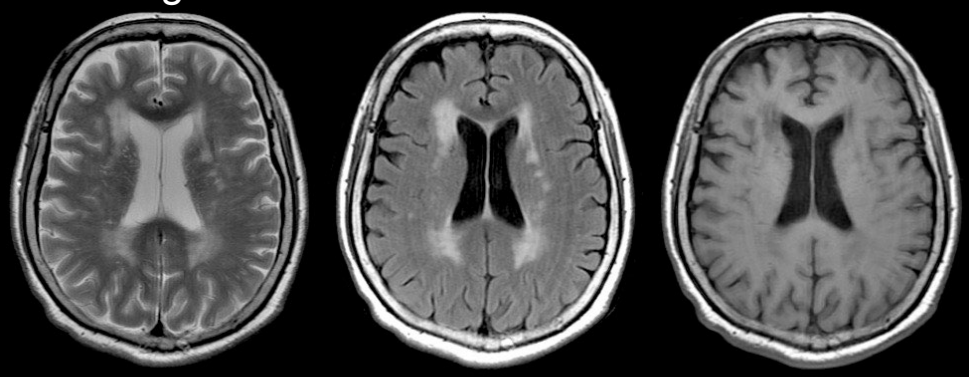
Fat Saturation

STIR

Fluid-Attenuated Inversion Recovery (FLAIR)

- *Fluid suppression based on T_1*

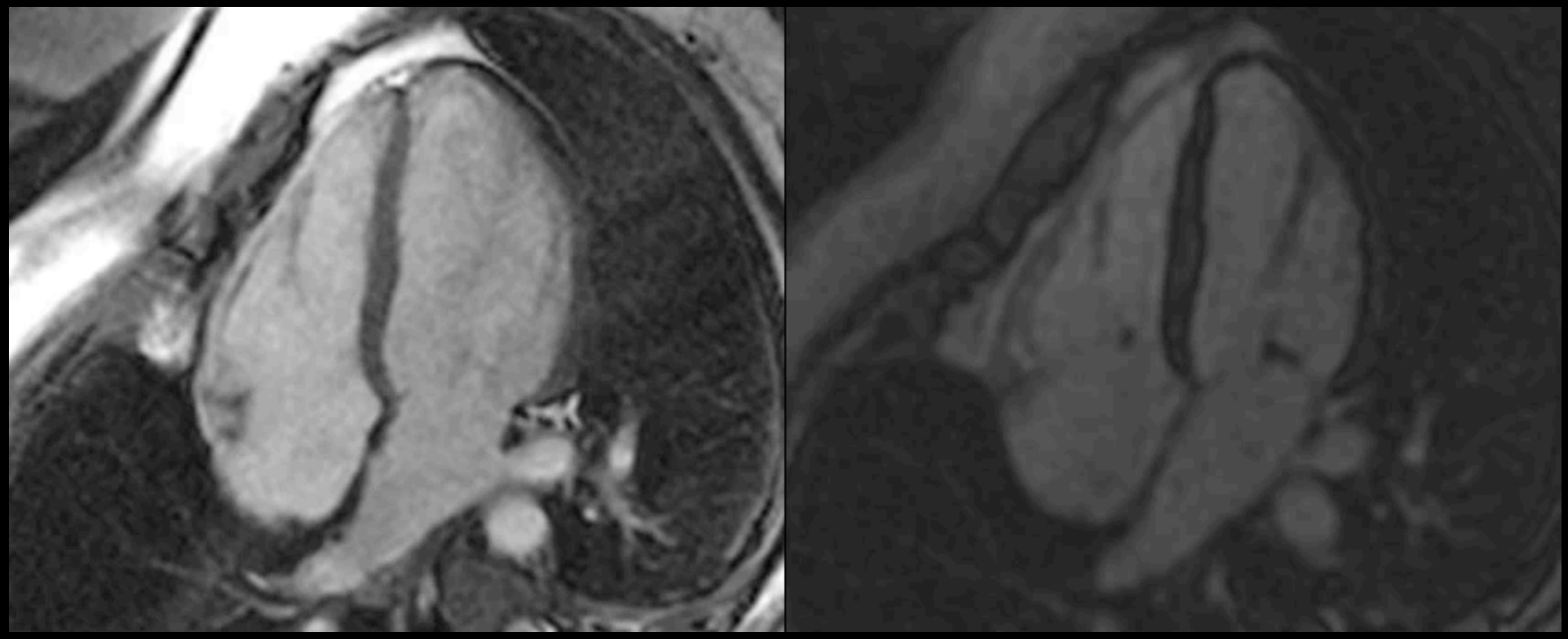




Question 1: Inversion Nulling

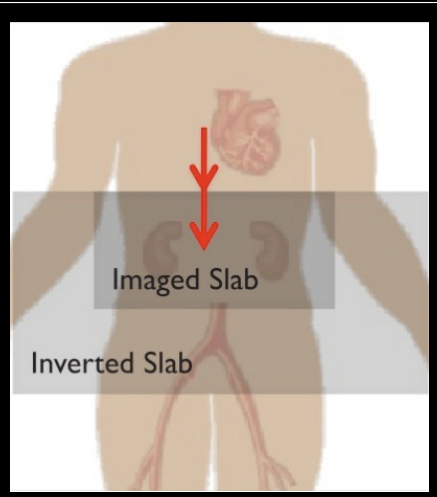
IR Prep to enhance T1 contrast

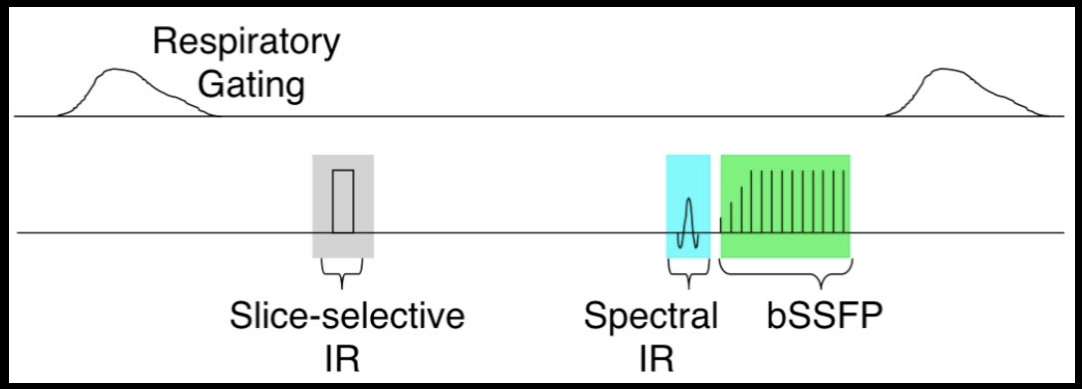
- Often used with GRE (MP-RAGE)
- Example: Cardiac CINE, IR at start (note septum)



bSSFP IR-Prep RF-Spoiled

Mag-Prep: Inflow-enhanced MRA



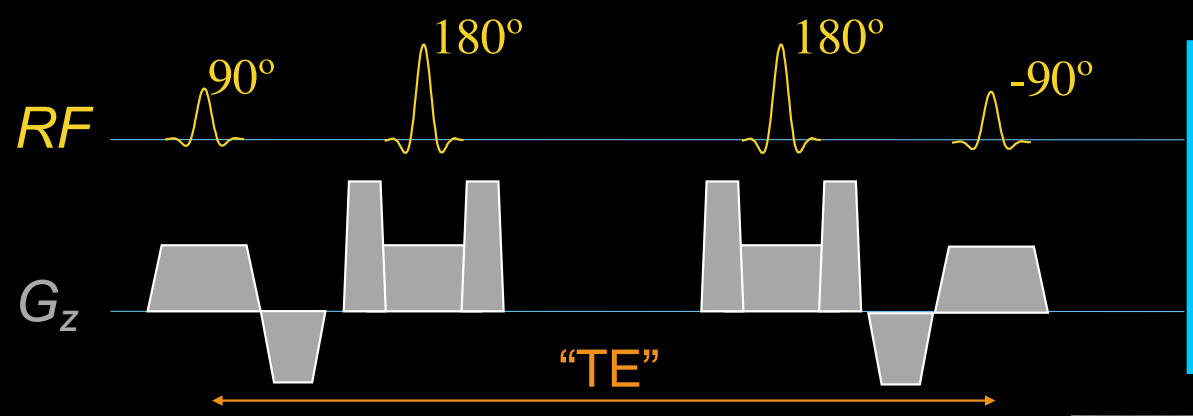


- Preparation:
- Background Suppression
- Fat Suppression

Courtesy Pauline Worters

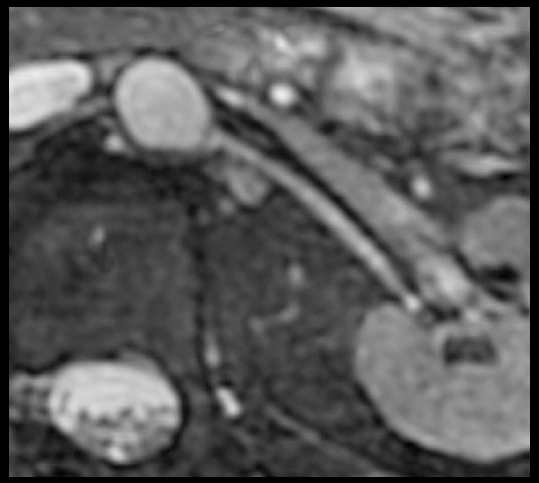
Question 2: Inversion-Recovery Flip Angle

T2-Prep (Enhance T2 contrast)



Regular Imaging Sequence

- Tip magnetization into transverse plane
- Restore magnetization following some T_2 decay



T2-prep + Fat-Sat Renal Artery

IR + T2-Prep: Flow-Independent Angiography

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

No Prep

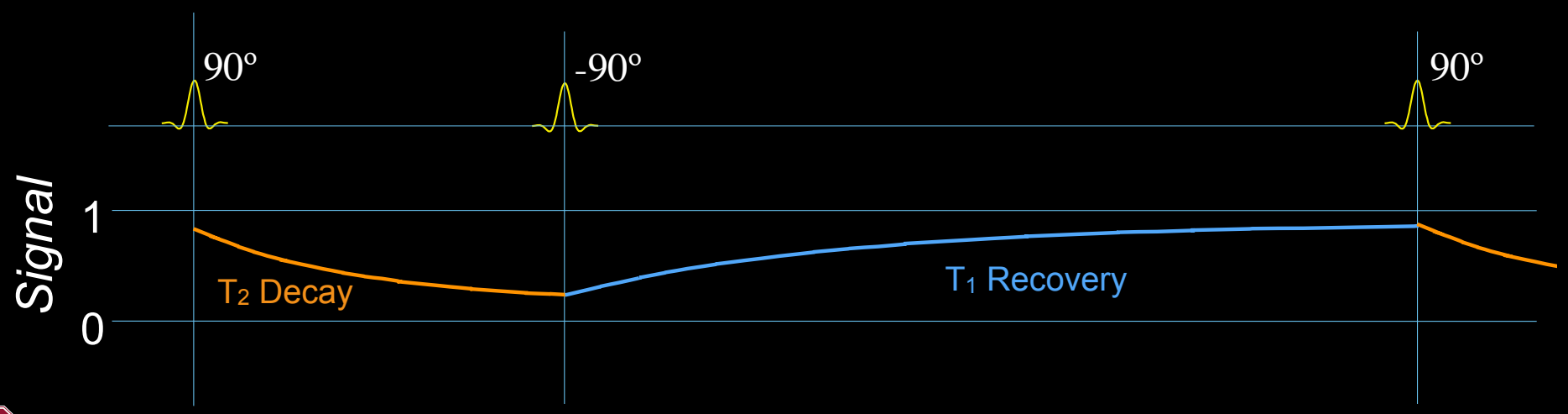
T2-prep + IR prep

Courtesy Neal Bangerter

Question 3: T2-prep

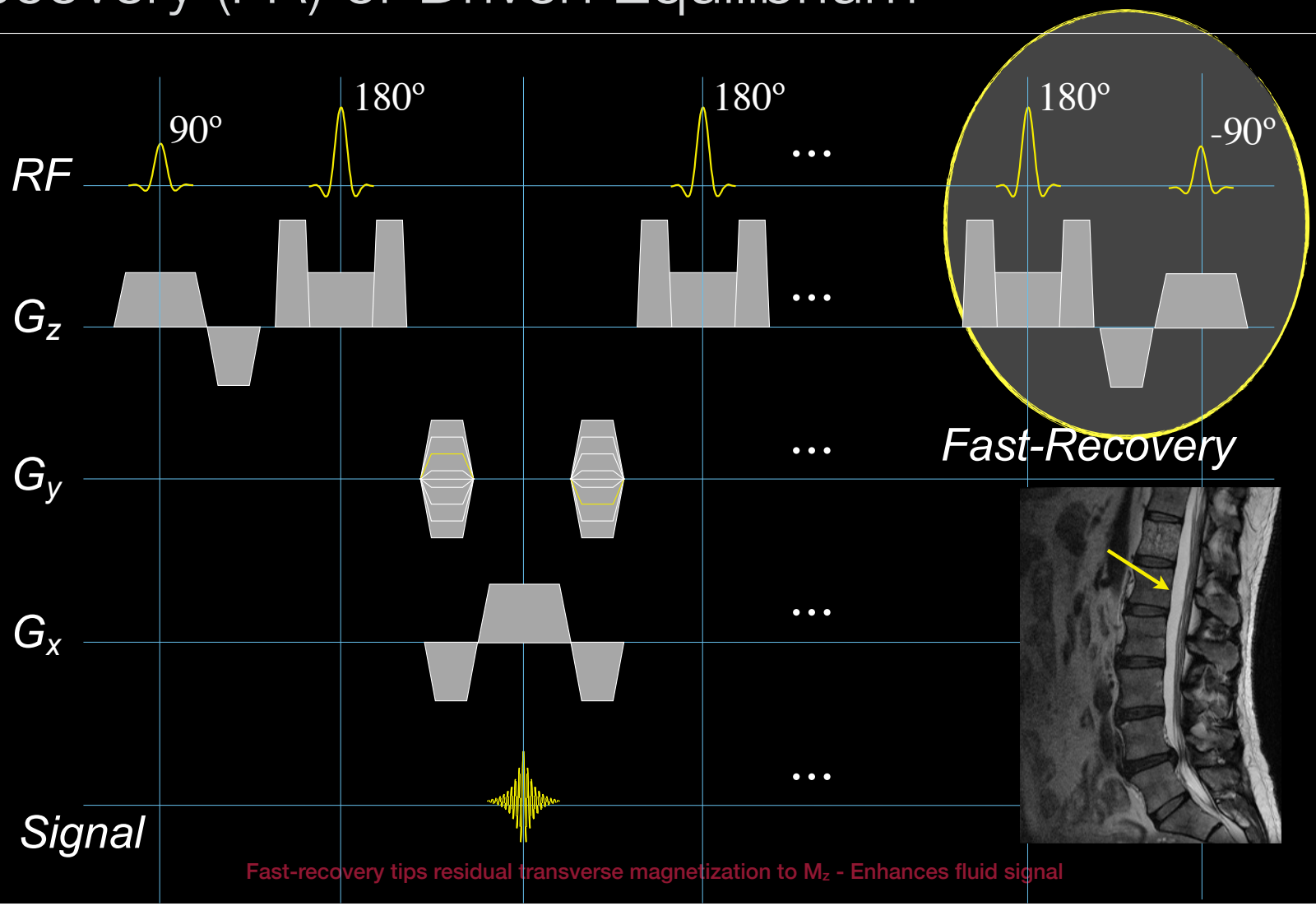
Fast Recovery or Driven Equilibrium "Tip-up"

- After sequence, restore transverse magnetization
- Enhances T_1 recovery, *if T_2 is long!*
- Contrast becomes T_2/T_1 weighted



Fast recovery restores residual transverse magnetization to the M_z to speed recovery

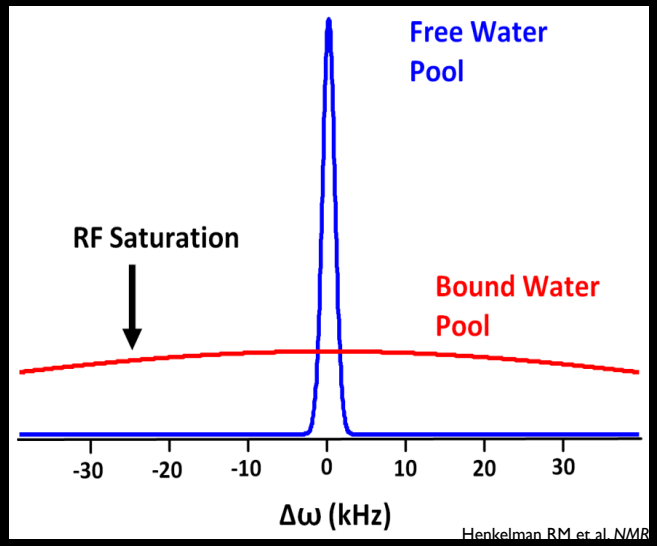
Fast Recovery (FR) or Driven Equilibrium



Fast-recovery tips residual transverse magnetization to M_z - Enhances fluid signal

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



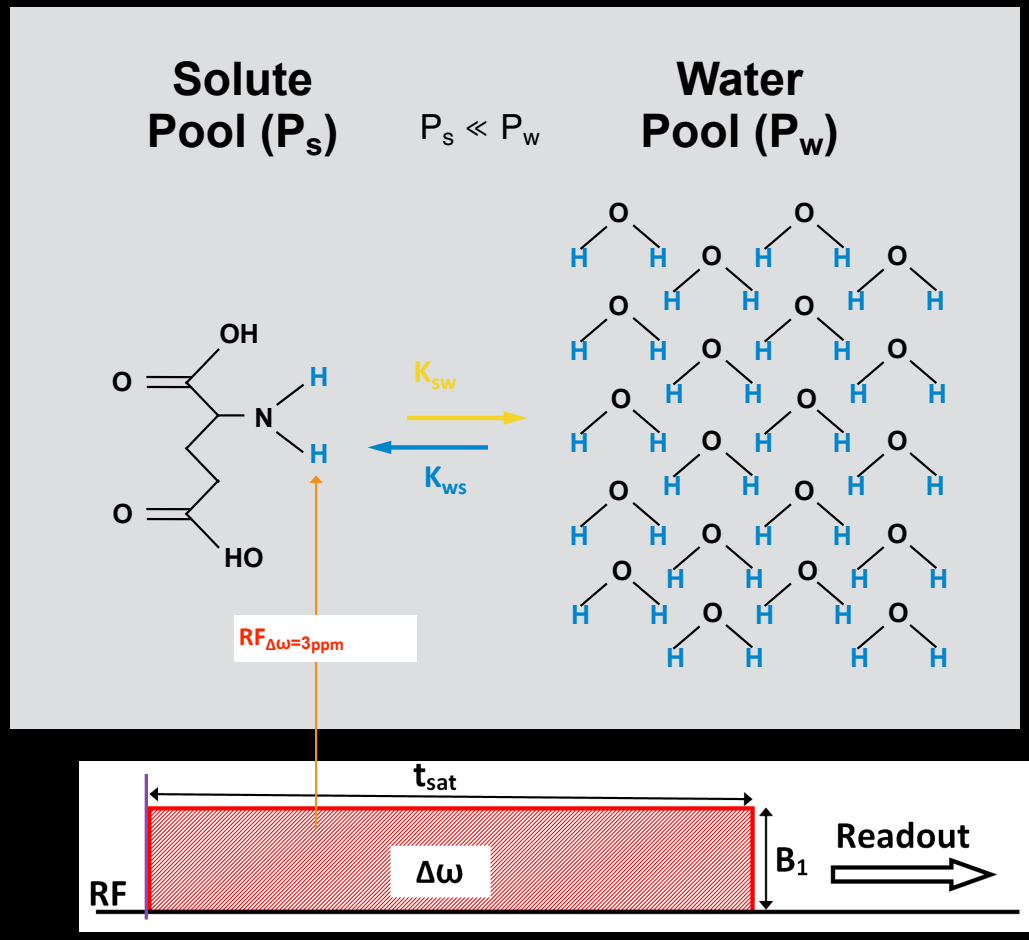
$$MTR = \frac{M_0 - M_{sat}}{M_0}$$

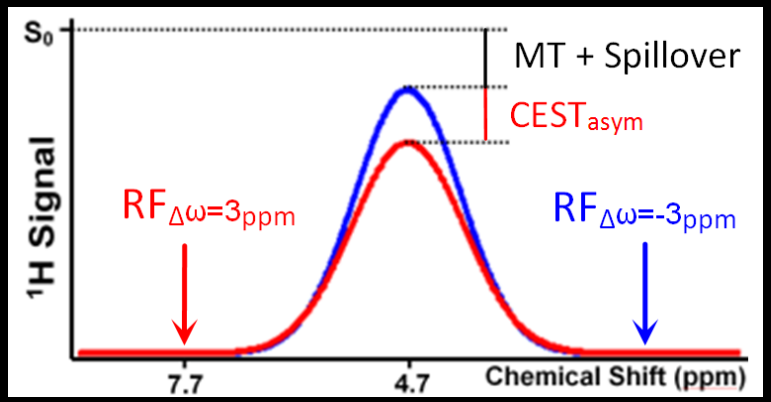
Courtesy of Feliks Kogan

MT Example

- Interleaved multislice has off-resonance pulses (other slices!)
- MT saturation can suppress signals

Chemical Exchange Saturation Transfer (CEST)





MT and EPG

- *"EPG-X: An Extended Phase Graph formalism for systems with Magnetization Transfer or Exchange." Malik SJ et al. MRM 2017*
- Add state for bound Mz

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

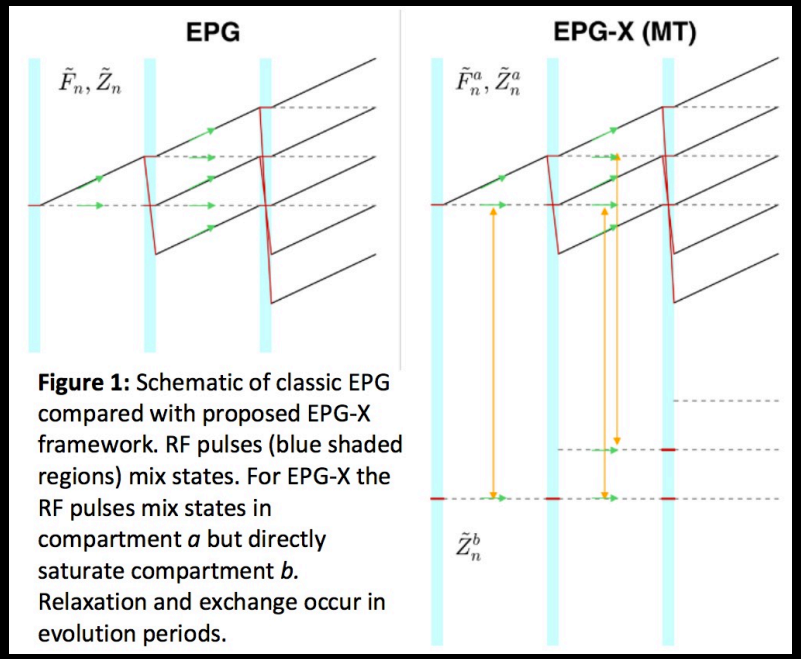
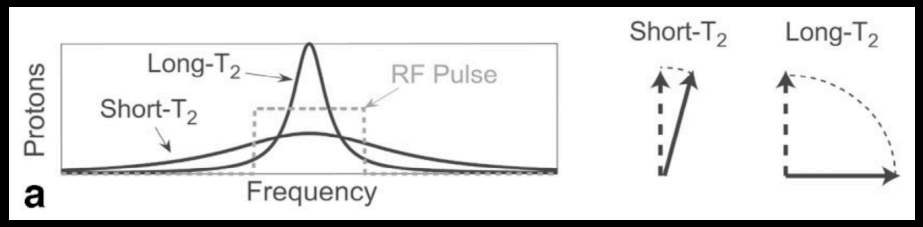
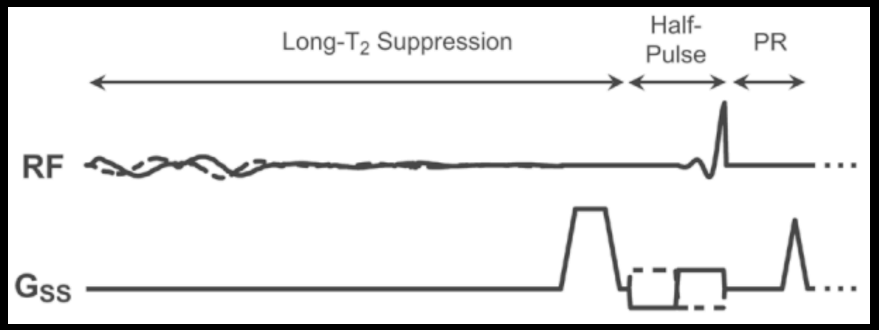


Figure 1: Schematic of classic EPG compared with proposed EPG-X framework. RF pulses (blue shaded regions) mix states. For EPG-X the RF pulses mix states in compartment *a* but directly saturate compartment *b*. Relaxation and exchange occur in evolution periods.

Long-T2 Suppression

- Ultrashort TE (UTE) shows cortical bone, connective tissue
- Suppression of long-T2 tissue improves contrast
- Subtraction (short-long TE) or long-T2 suppression

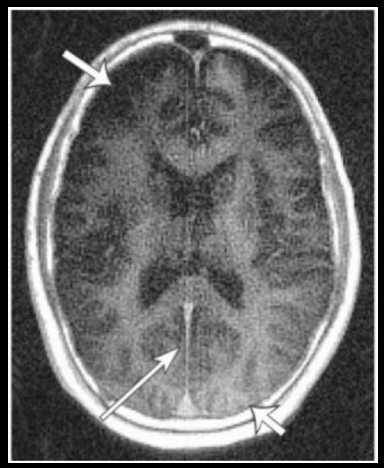




Larson PZ, MRM 2006

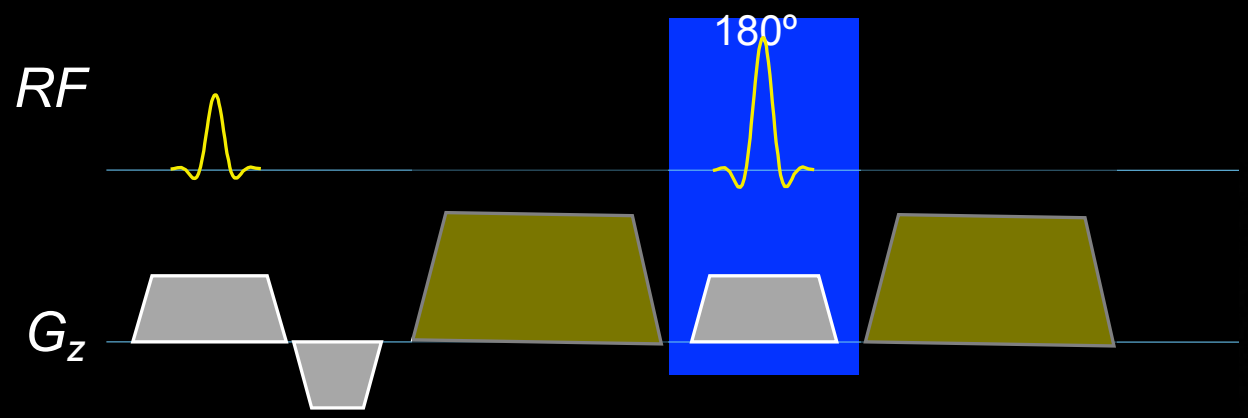
UTE Image

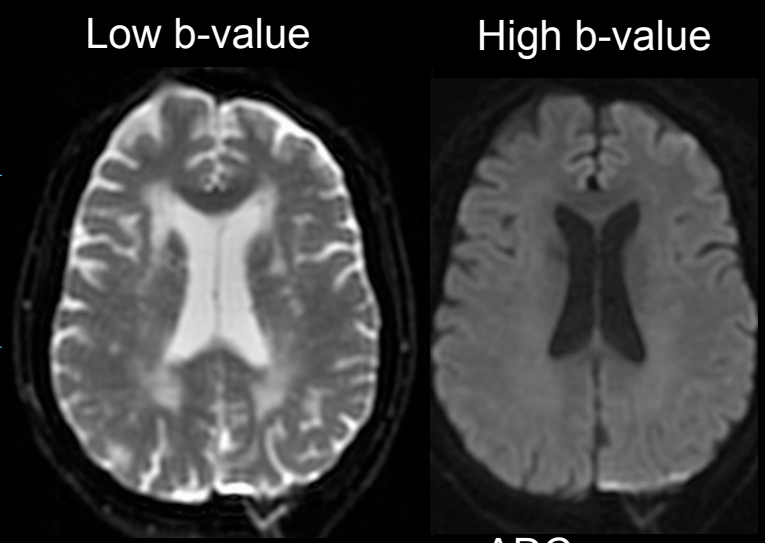
UTE with Long-T2 Suppression

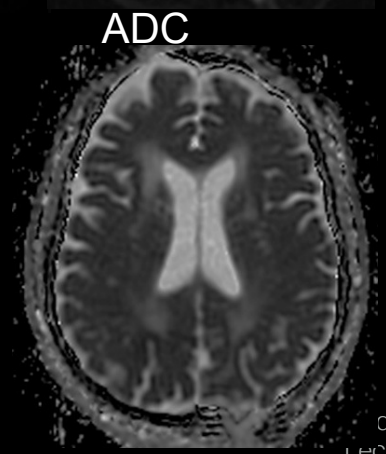


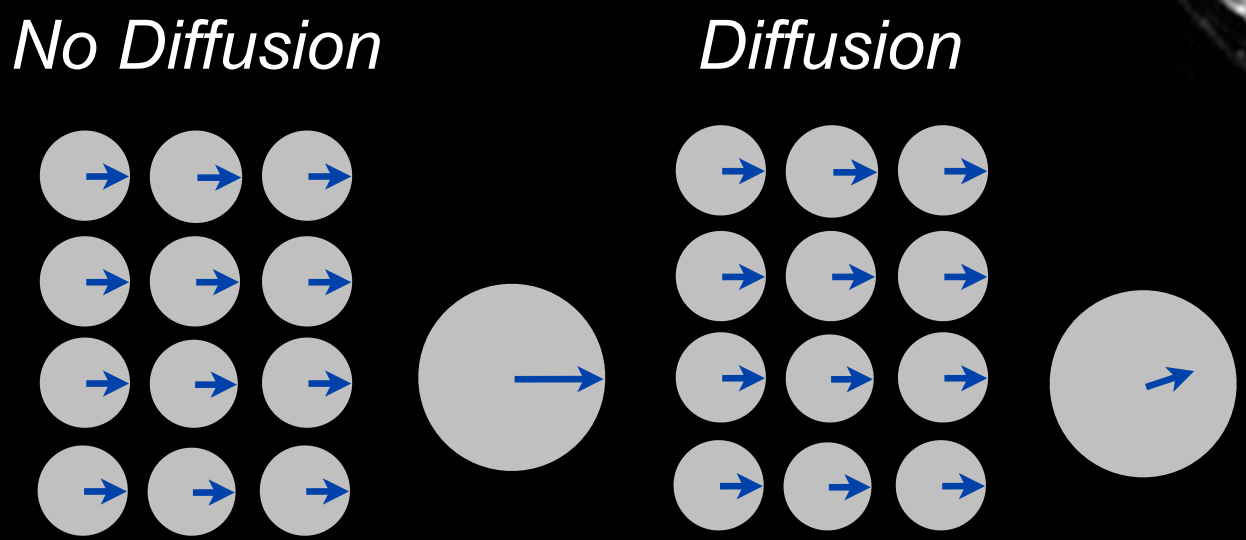
Long-T2 suppression removes long-T2 signal from the image, leaving short T2 alone

Diffusion-Weighted Imaging (DWI)









Other Preparations

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

There are many, many other magnetization preparation approaches used in MRI

Summary of Magnetization Preparation

- Modify contrast before an imaging sequence
- Suppression: remove / null signals:
  - Spatial Saturation, Fat Saturation, Blood, Fluid
- Contrast: alter contrast of sequence:
  - Inversion (T_1), T_2-prep, Diffusion, MT
- Encoding: Flow/motion, Diffusion, Tagging

How is diffusion preparation used for numerous applications?

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