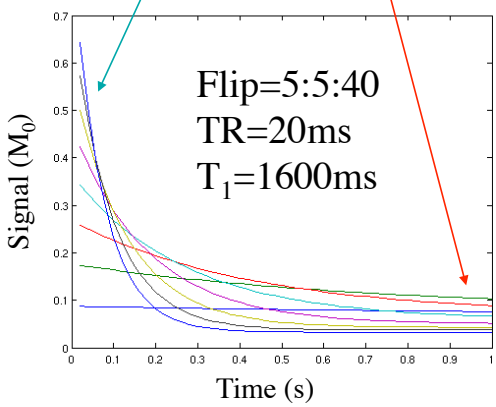
Bioengineering 278
Magnetic Resonance Imaging

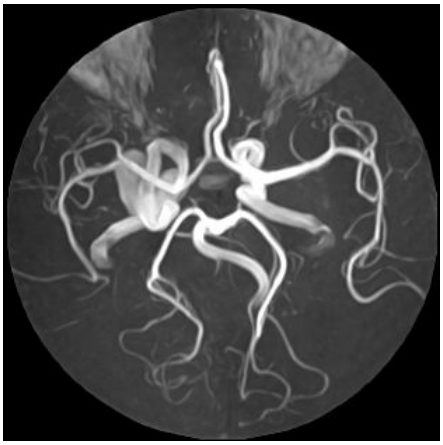
Winter 2011
Lecture 9

- Motion Encoding using Longitudinal Magnetization:
  - Magnetic Resonance Angiography
    - Time of Flight
    - Contrast Enhanced
  - Arterial Spin Labeling
    - ASL Basics
    - ASL for fMRI
    - Velocity Selective ASL
    - Vessel Encoded ASL

Time of Flight MRA

- Spoiled gradient echo with high flip angle and short TR
- Static magnetization becomes highly saturated
- Relaxed inflowing blood has much higher signal





$$M_z(tr) = M_0(1-((1-M_z(tr-1)\cos(\alpha))e^{-TR/T_1}))$$

$$Signal(tr) = M_z(tr)\sin(\alpha)$$

Contrast Enhanced MRA

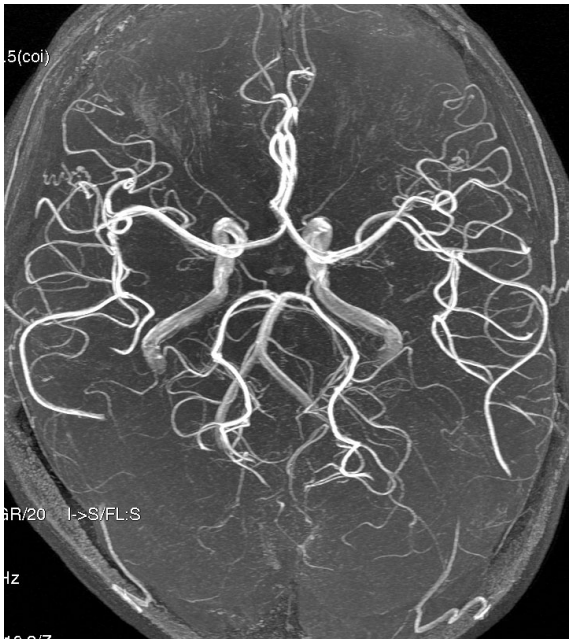
- MRA acquired during the passage of a bolus of Gd based contrast agent
- T_1 reduced as low as 50ms
- T_1 is so short, no need to rely on TOF effect for contrast
- Allows for very short TR and high flip angle
- Dramatically improves speed and/or SNR
- After first pass, Gd leaks into tissues

4s per frame

http://www.mr.ethz.ch/sense/sense_application.html

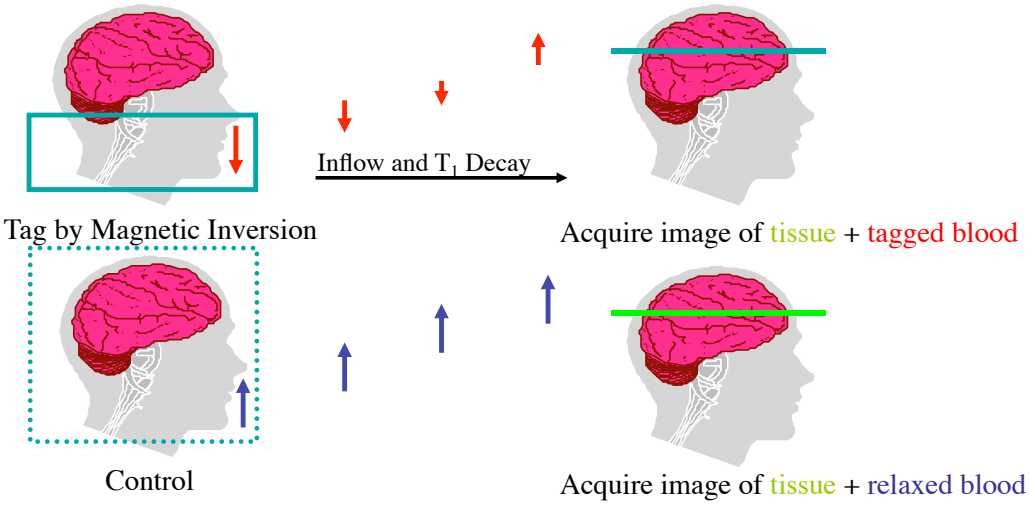
Contrast Enhanced MRA

GEMS web site



http://www.m.ehime-u.ac.jp/school/radiology/mra/3T-MRA.jpg

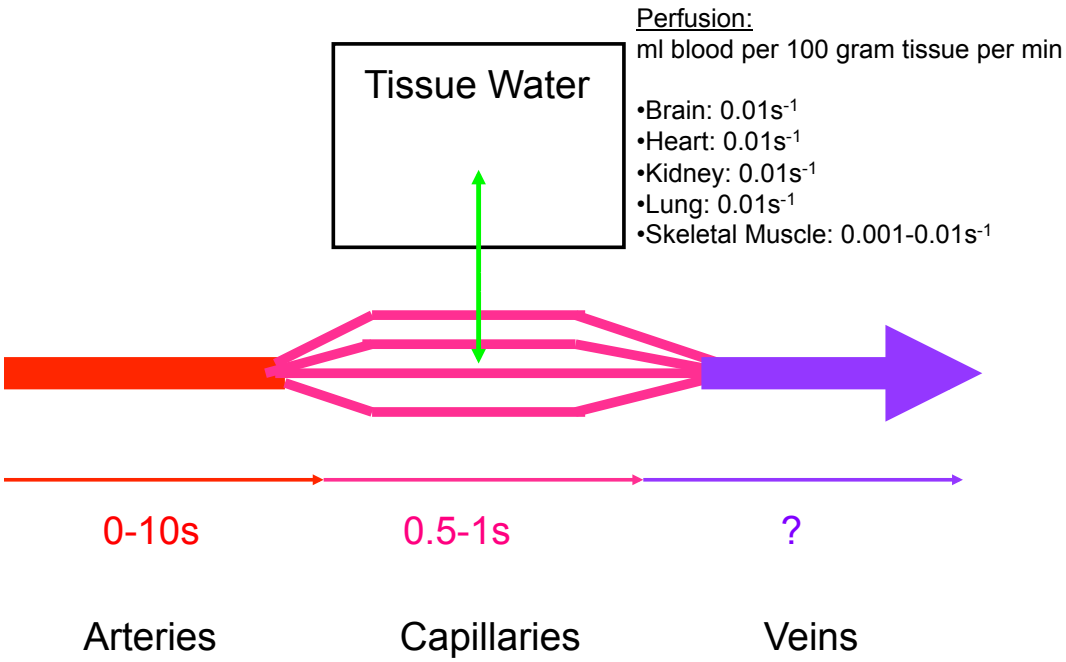
Arterial Spin Labeling



ASL Signal = Control - Tag ∝ CBF

Tissue Signal subtracted out.

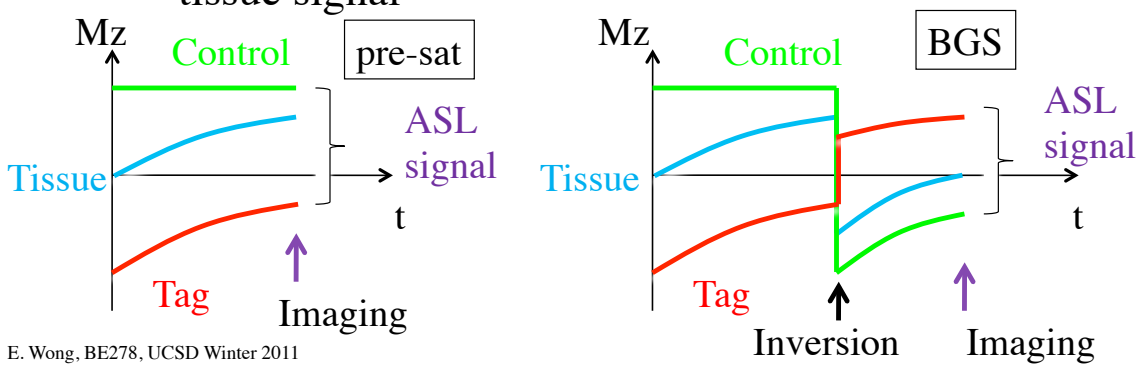
Blood Water Dynamics



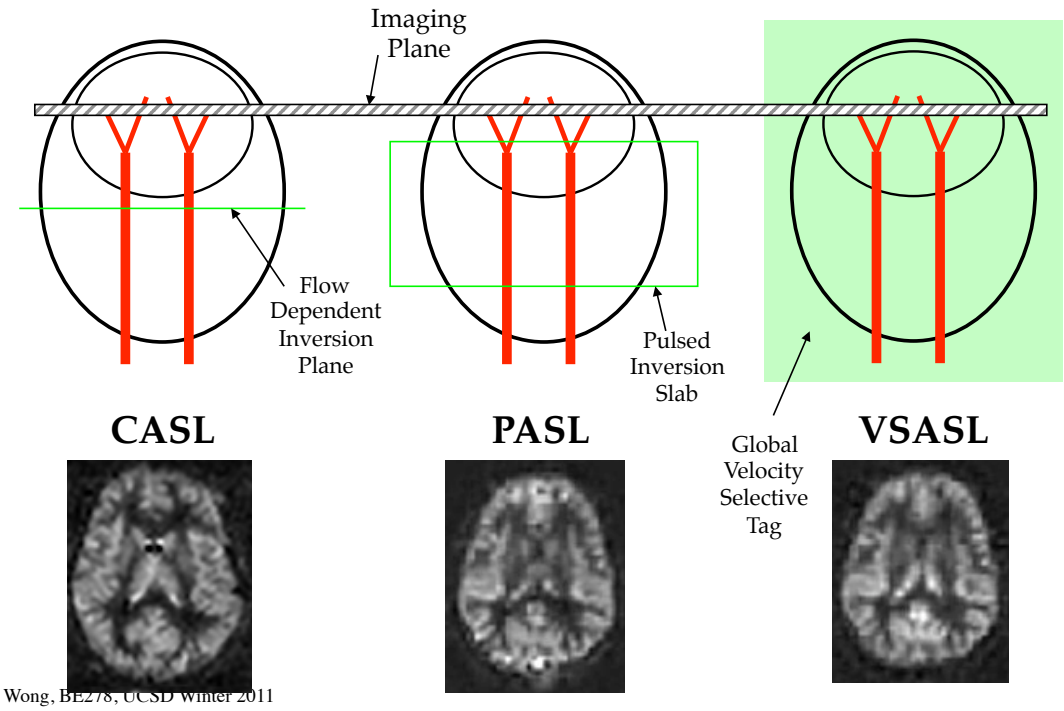
Dealing with Tissue Signal

- Pre-saturation (pre-sat):
  - Saturation on the imaging slab

- Back-Ground Suppression (BGS):
  - Globally applied inversion pulses to null tissue signal



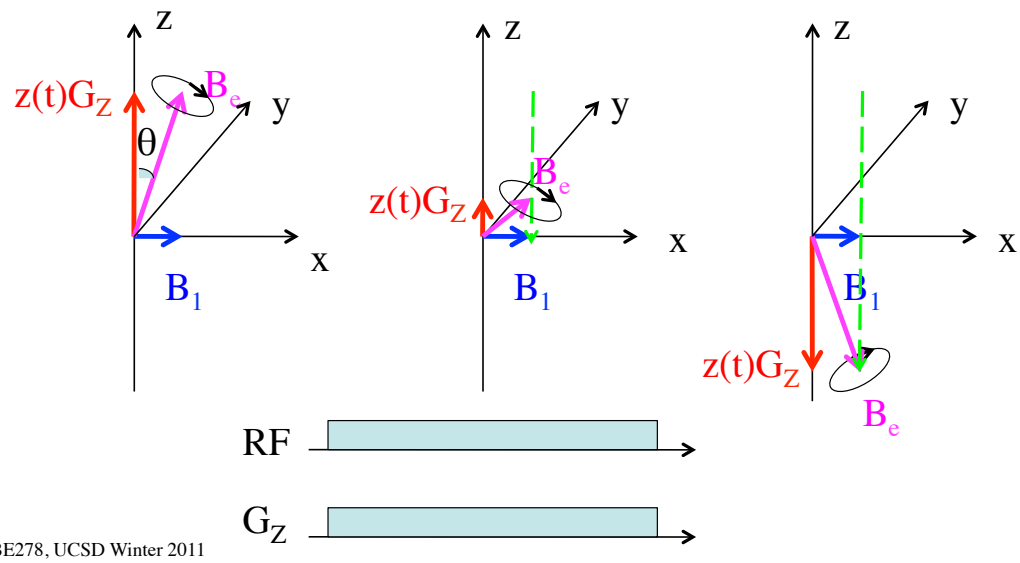
Types of ASL



CASL: Flow Driven Adiabatic Inversion

Effective field in frame that rotates at ω_L:

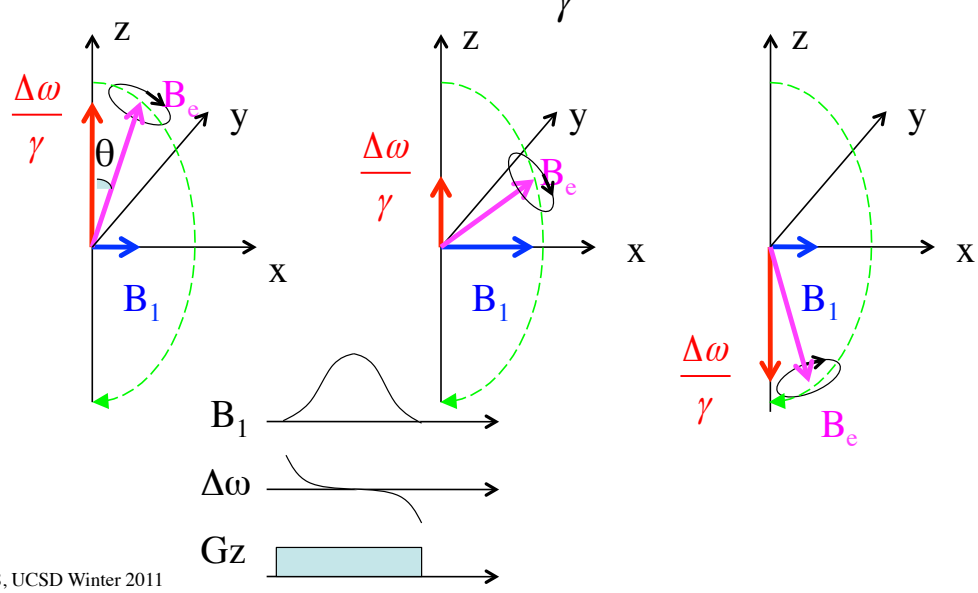
$$\vec{B}_e = B_1\hat{i} + z(t)G_Z\hat{k}$$



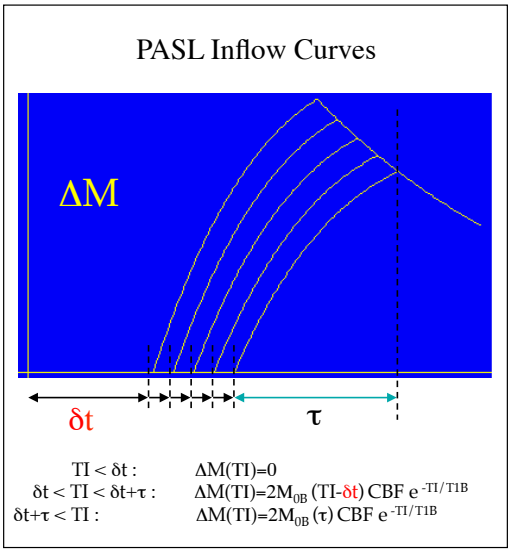
PASL: Pulsed Adiabatic Inversion

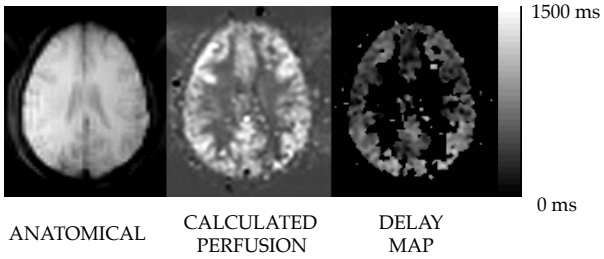
Effective field in frame that rotates with pulse:

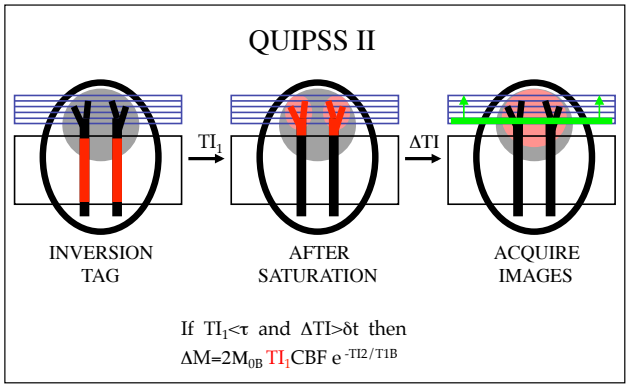
$$\vec{B}_e = B_1\hat{i} + \frac{\Delta\omega}{\gamma}\hat{k}$$



Transit Delay - PASL







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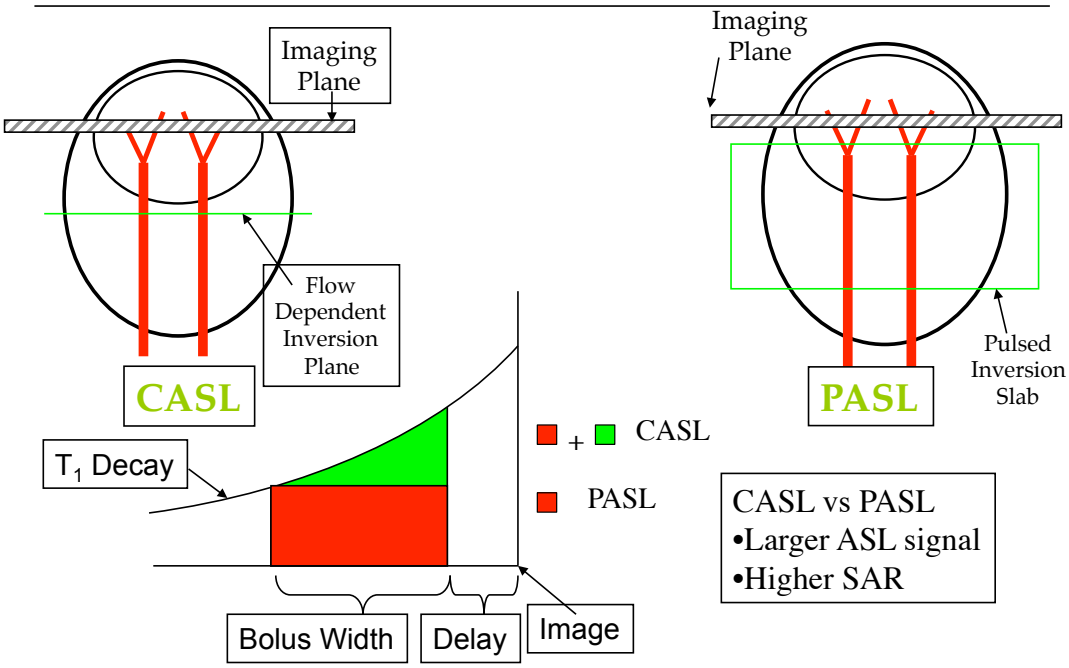
Continuous vs Pulsed ASL



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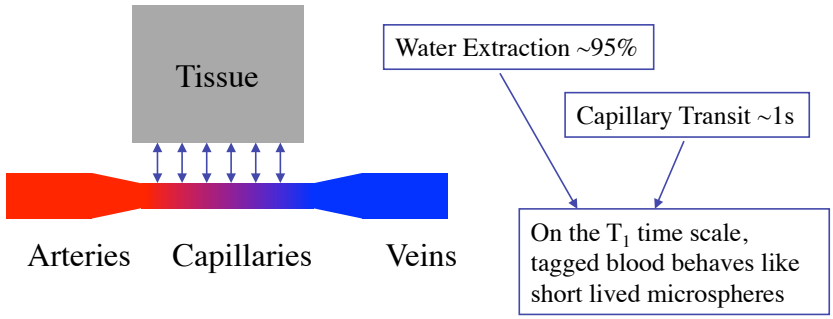
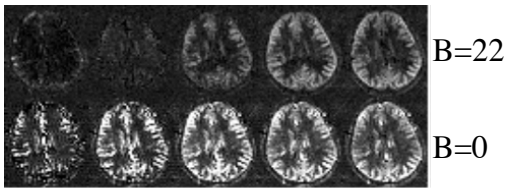
Water Exchange

Good…



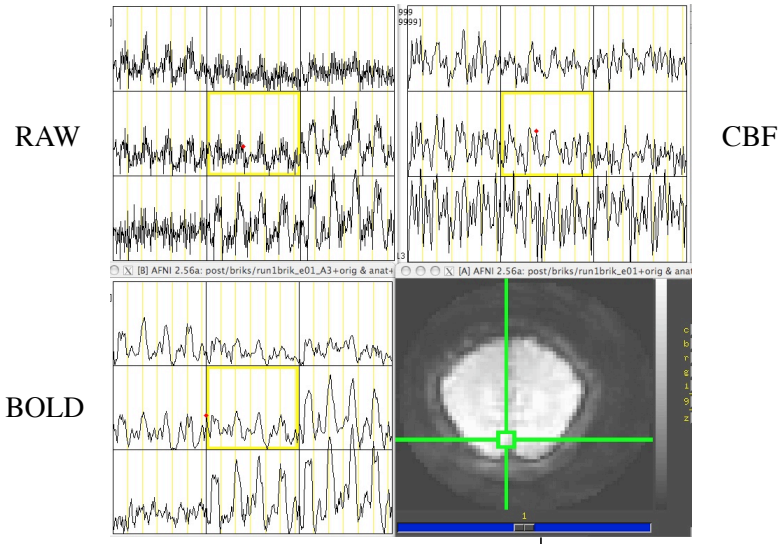
Not so good…



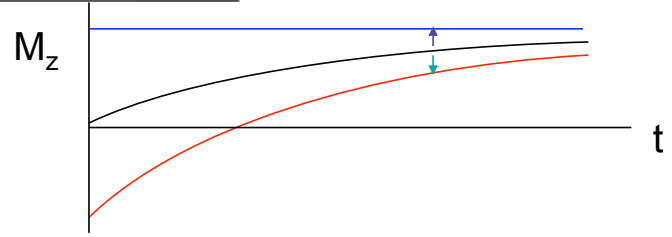
- T_1 shift changes relaxation rate of tag during TI
- T_2/T_2* shift changes ASL signal during image acquisition

Pic: http://www.freakygaming.com/gallery/game_art/heroes_of_might_and_magic_5/

CBF and BOLD Time Series



For Pulsed ASL with Presat:
Control - Tag = ASL Signal
Control + Tag = Tissue Signal

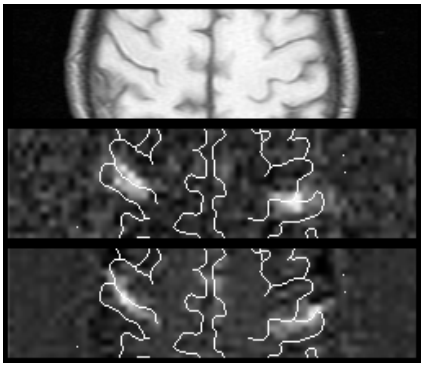


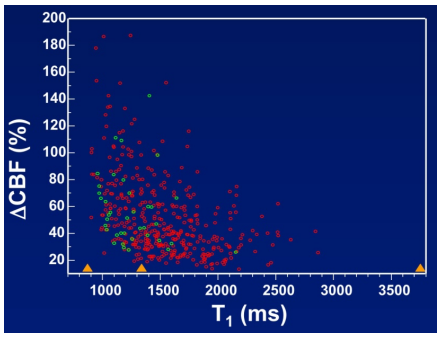
Simultaneous Flow and BOLD fMRI

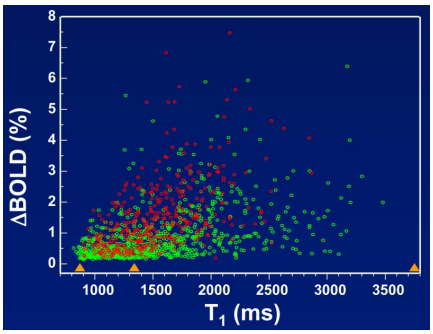
Anatomy

CBF Change

BOLD Change







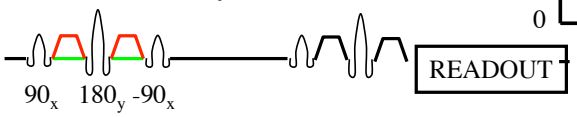
Transit Delays in Diagnostic ASL

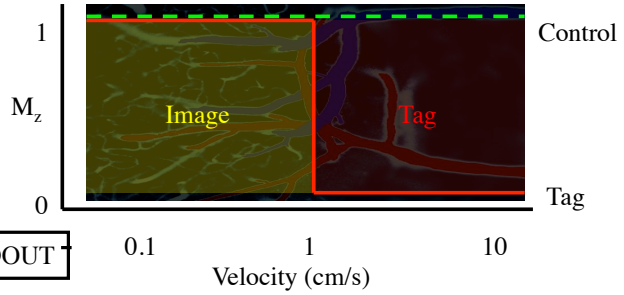
- Problem:
  - Long transit delays (delay >>T_1) limit the diagnostic potential of ASL in some disease states

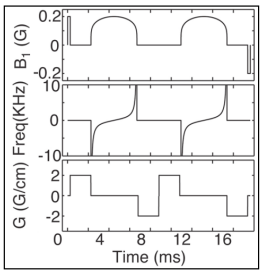
- Solution:
  - Apply tag pulses that are not spatially selective but velocity selective

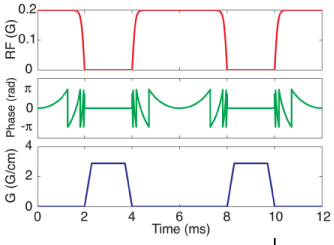
Velocity Selective ASL

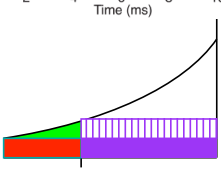
- Tagging based purely on velocity
- Tag has no spatial selectivity
- Transit delay eliminated

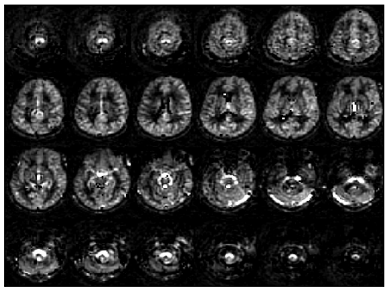






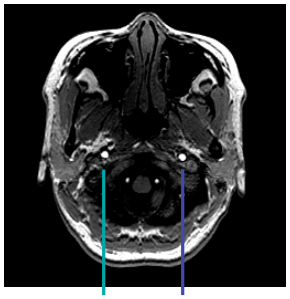


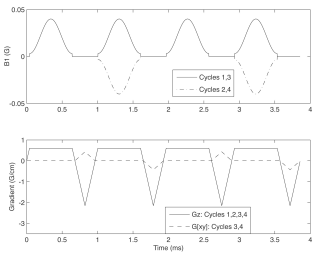


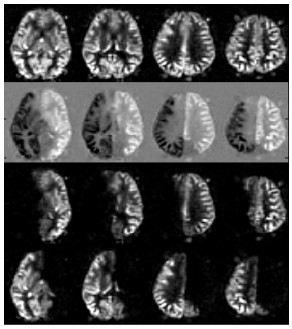


T_1=1.6s

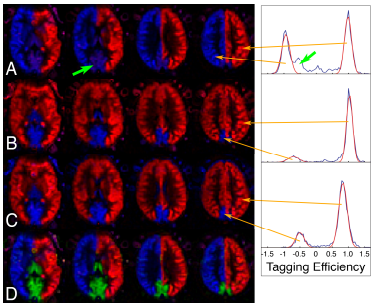
Vessel Encoded Pseudo-Continuous ASL

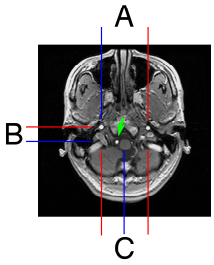




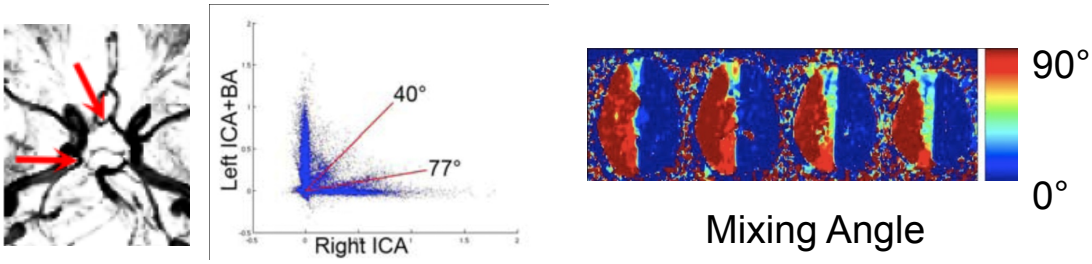


$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix} = \begin{bmatrix} -1 & 1 & -1 & 1 \\ 1 & -1 & -1 & 1 \\ -1 & -1 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} R \\ L \\ B \\ S \end{bmatrix}$$

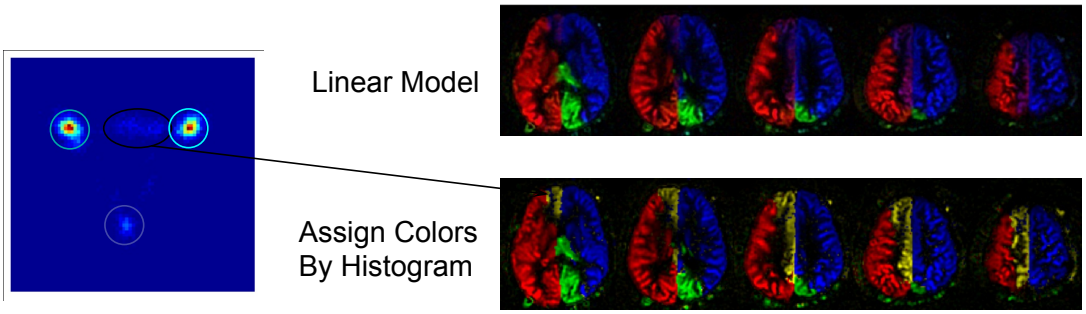




Vascular Mixing



Akash Kansagra



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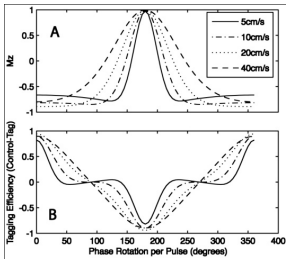
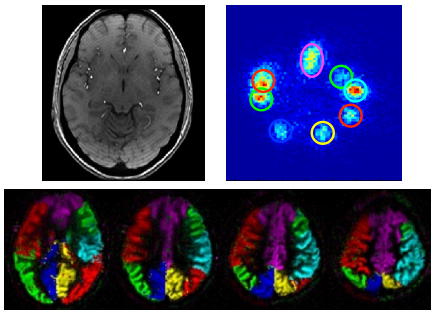
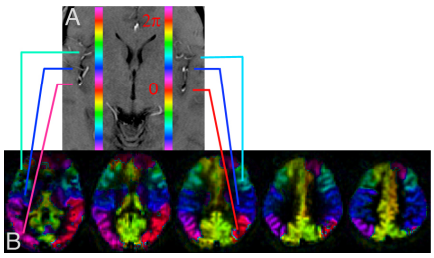
Vessel Encoded ASL

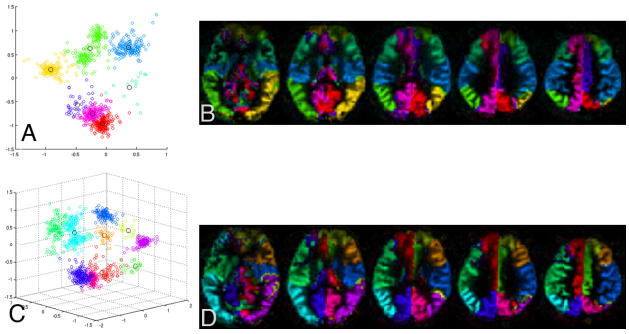
- Explicit identification of territories with probabilities
- Nonlinear encoding
- Vascular Source Imaging







sin/cos modulation



Multi-dimensional clustering

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