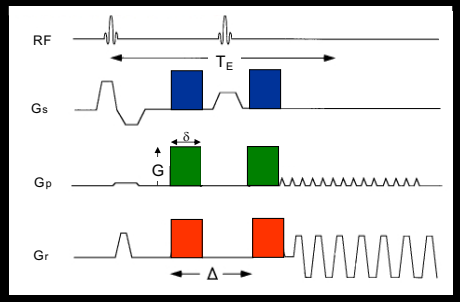


MEASURING DIFFUSION with MRI

MP/NTP 651

Fall 2020

1

Magnetic Resonance Imaging (MRI)

- Larmor Frequency

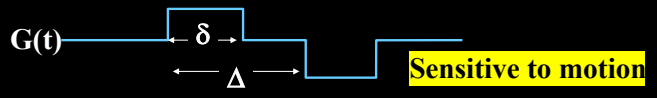
$$\omega=\gamma B_0$$

- Magnetic Field Gradient, G_x

$$\omega(x)=\gamma(B_0+G_x*x)$$

2

Diffusion Weighted (DW) MRI



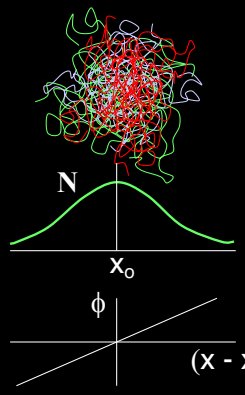
- Accumulated Phase

$$\phi=\gamma(x - x_o)G_x\delta$$

$$\omega(x)=\gamma(B_0+G_x*x)$$

3

DW-MRI II



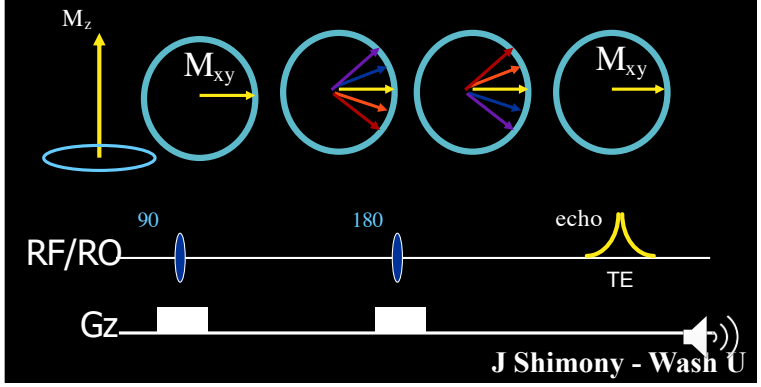
$$\phi_i=\gamma(x_i - x_o)G_x\delta$$

$$s = \sum_i s_i \, exp(-i\phi_i)$$

Attenuation!

4

Standard Spin Echo



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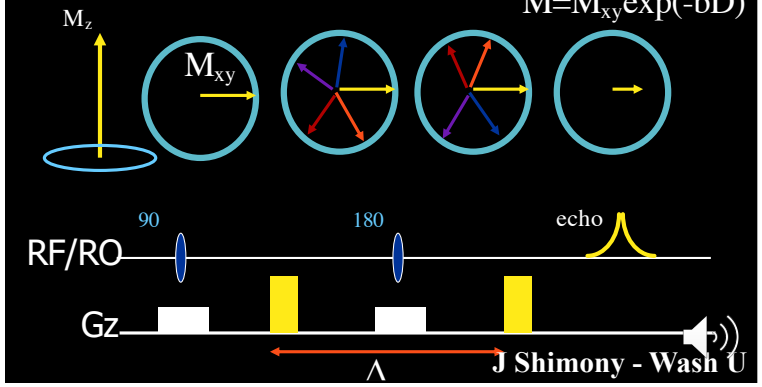
Diffusion Spin Echo



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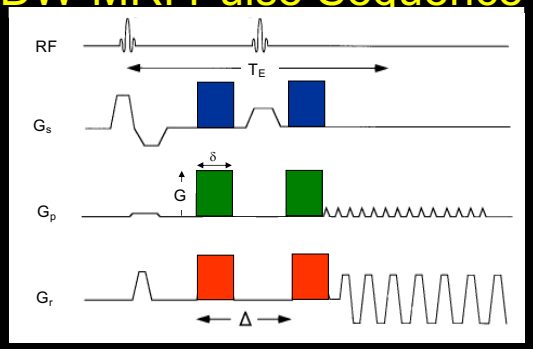
DW-MRI Pulse Sequence

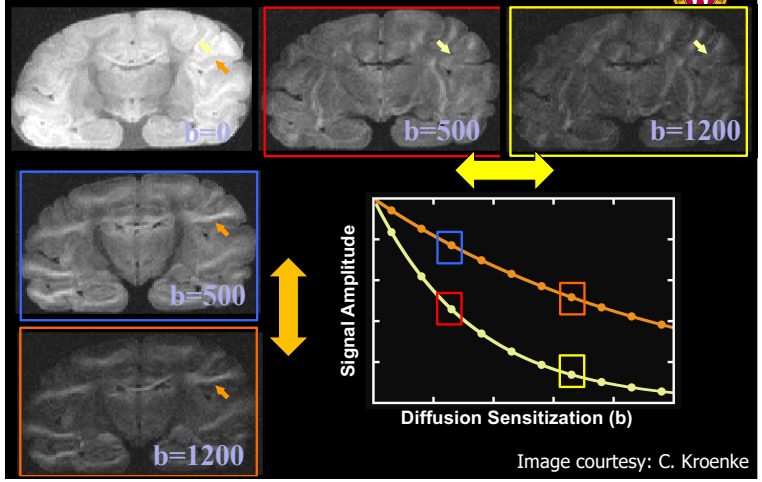


$S = S_o e^{-bD}$ $b = (\gamma\delta G)^2(\Delta - \delta/3)$

Pulsed-gradient, spin-echo, echo planar

7

Diffusion Anisotropy



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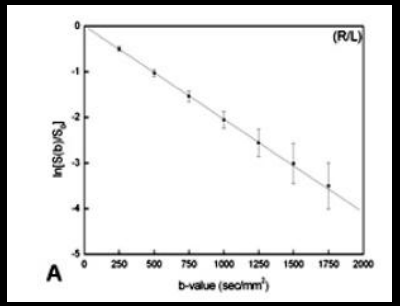
ln of Signal – Linear with b-value



Gianelli JACMP 2010

$$S_i = S_o e^{-b_i D}$$

$$D = (\ln S_o - \ln S_i) / b_i$$

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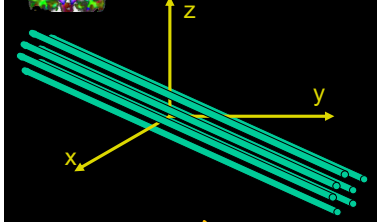
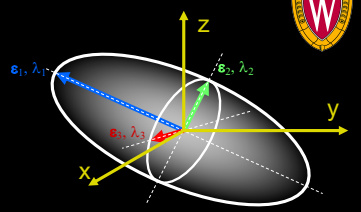
Diffusion Tensor





$$\mathbf{D} = \begin{pmatrix} D_{xx} & D_{xy} & D_{xz} \\ D_{yx} & D_{yy} & D_{yz} \\ D_{zx} & D_{zy} & D_{zz} \end{pmatrix}$$

$D_{ii} > 0$

$D_{ij} = D_{ji}$

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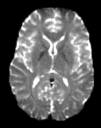
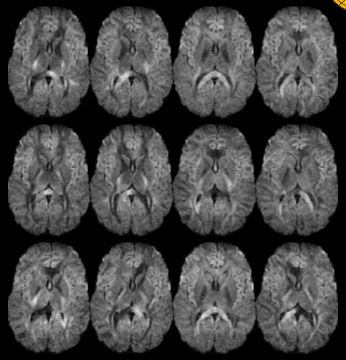
Diffusion Weighted Images



T2W Reference
S_o (b ~ 0 sec/mm²)



12 DW encoding directions
S_i (b=912 sec/mm²)

$$S_i = S_o \exp(-b \hat{g}_i^t \mathbf{D} \hat{g}_i)$$

$$b = \gamma^2 G^2 \delta^2 (\Delta - \delta / 3)$$

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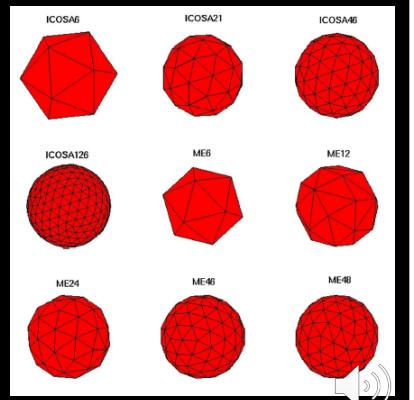
DTI – Encoding Considerations

- Single-shot EPI w/ DW gradients
- 6 or more encoding directions
  - More is better
    - 30 or more
  - Uniform sets
- b = 0, ~1000 sec/mm²



Hasan JMRI 2001

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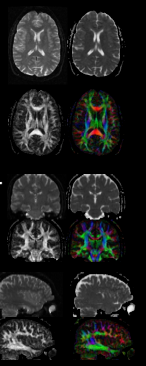
DTI – Protocol Parameters

- Field Strength:
  - Higher Field:
    - Better SNR (Alexander et al. 2006)
    - More distortion
- Diffusion-weighting: b-value:
  - ~1000 s/mm^2
  - Higher (>2000 s/mm^2) interesting behavior
- Number of DWI Directions:
  - >30 total images at 3T
  - More directions are better
    - High Angular Resolution
  - 4-8 reference b=0 images
- T2 Weighted (TR>4s); TE = minimum (60-100ms)



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DTI – Protocol Parameters

- Voxel dimensions: Δx, Δy, Δz (1.5-2.5 mm)
  - Smaller - reduces partial volume averaging
  - Smaller – lower SNR
- Matrix: Nx x Ny
  - 96x96 – 128x128
  - (FOVx = Δx * Nx)

$$SNR = k\Delta x\Delta y\Delta z\sqrt{N_x N_y}$$
$$= k\Delta z\sqrt{\Delta x\Delta y FOV_x FOV_y}$$

- Whole brain DTI:
  - Research ~ 2mm isotropic, >55 images (8-10 minutes)
  - Clinical ~ 3 mm isotropic, 24 images (3-4 min)

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