

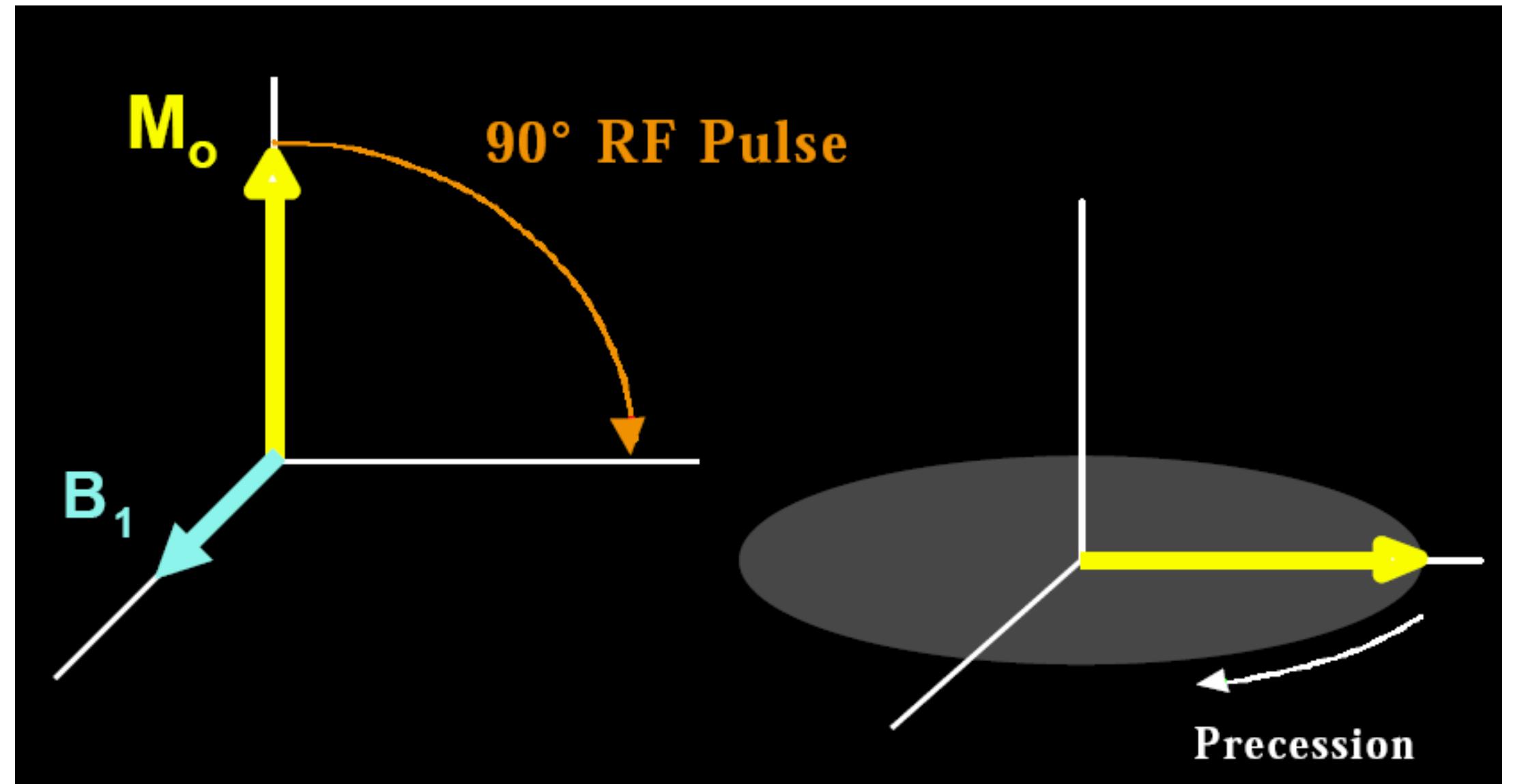
Module 17: Diffusion Tensor Imaging

Arnold Bakker

Department of Psychiatry and Behavioral Sciences
Division of Psychiatric Neuroimaging
Johns Hopkins University School of Medicine

Diffusion Tensor Imaging

- Excitation of a volume requires pulse frequency known as **Larmor Frequency**
- Larmor Frequency depends on gyromagnetic ratio of particle
- Hydrogen is most commonly used:
 - Unpaired proton
 - Abundant in form of water and fat



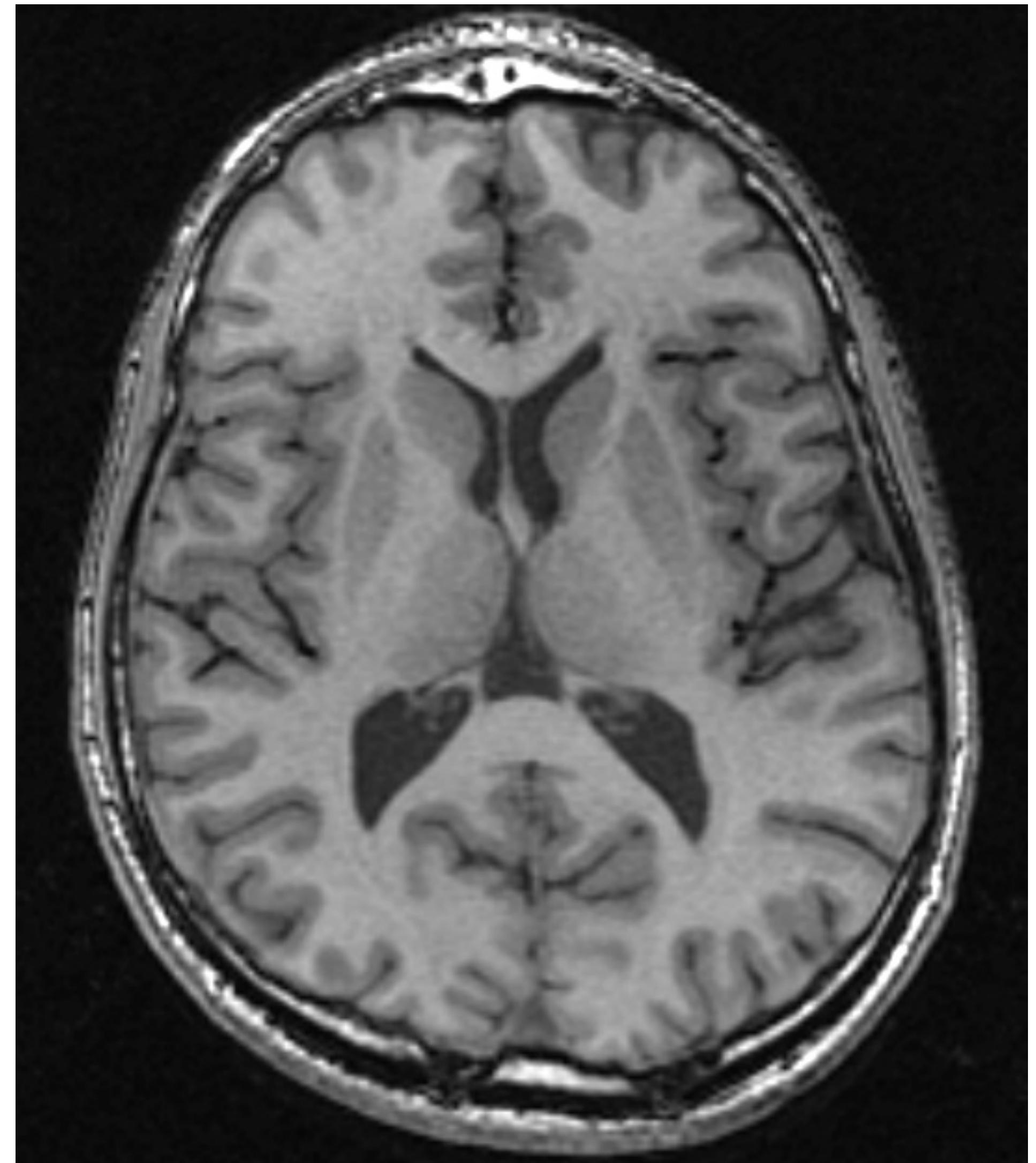
$$\omega_0 = \gamma B_0$$

↓ ↓ ↓
Larmor Frequency in MHz Gyromagnetic ratio Strength Mag. Field

Nucleus or Particle	Gyromagnetic Ratio (γ) in MHz/Tesla
^1H	42.58
^3He	-32.43
^{13}C	10.71
^{19}F	40.05
^{23}Na	11.26
^{31}P	17.24
electron	-27,204

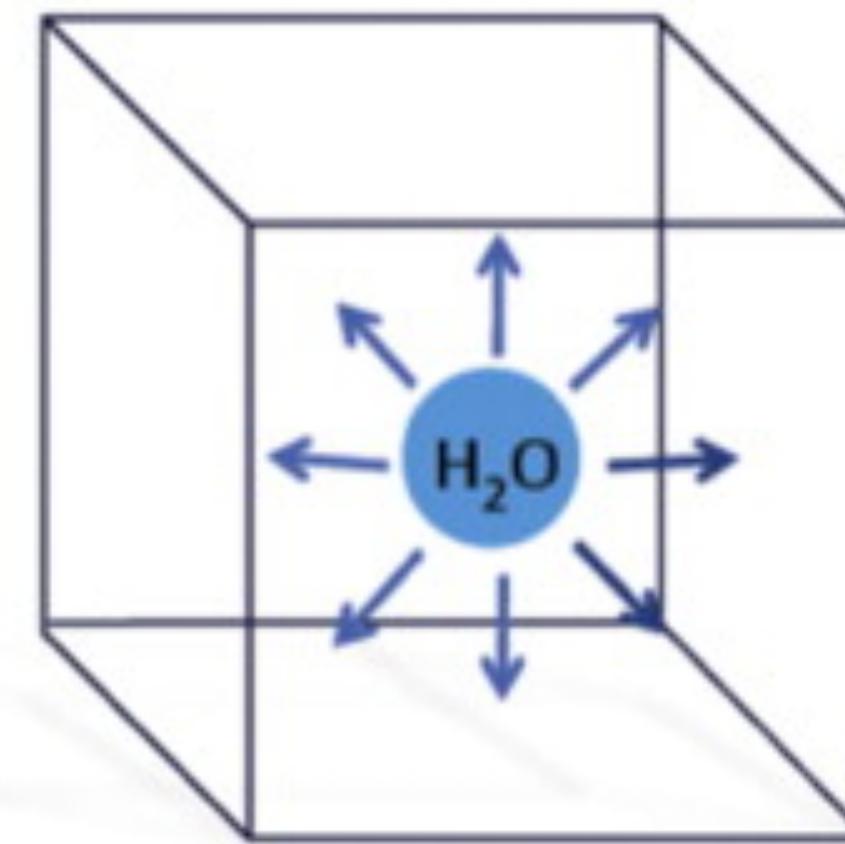
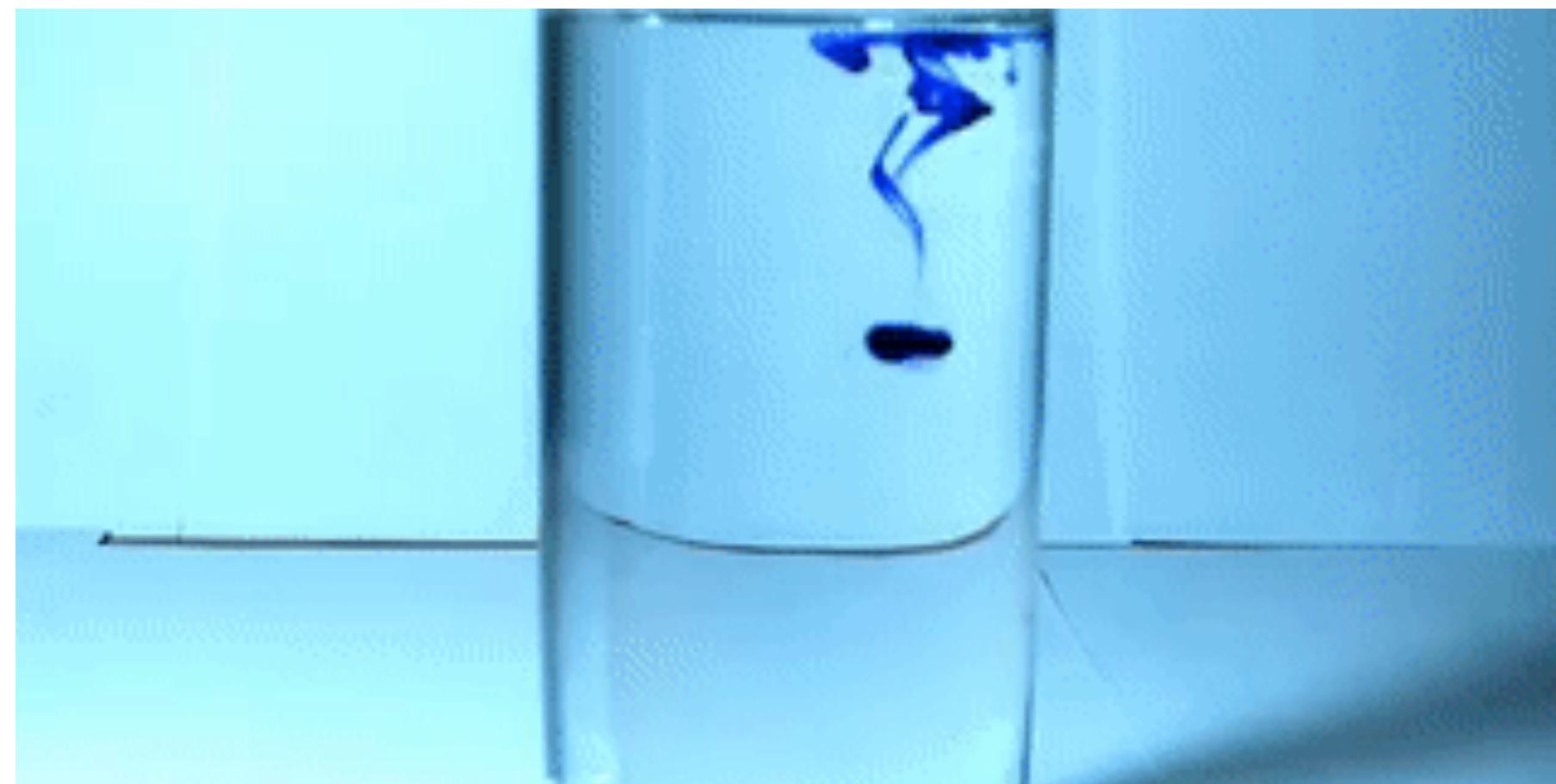
Diffusion Tensor Imaging

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- *Hydrogen is most commonly used:*
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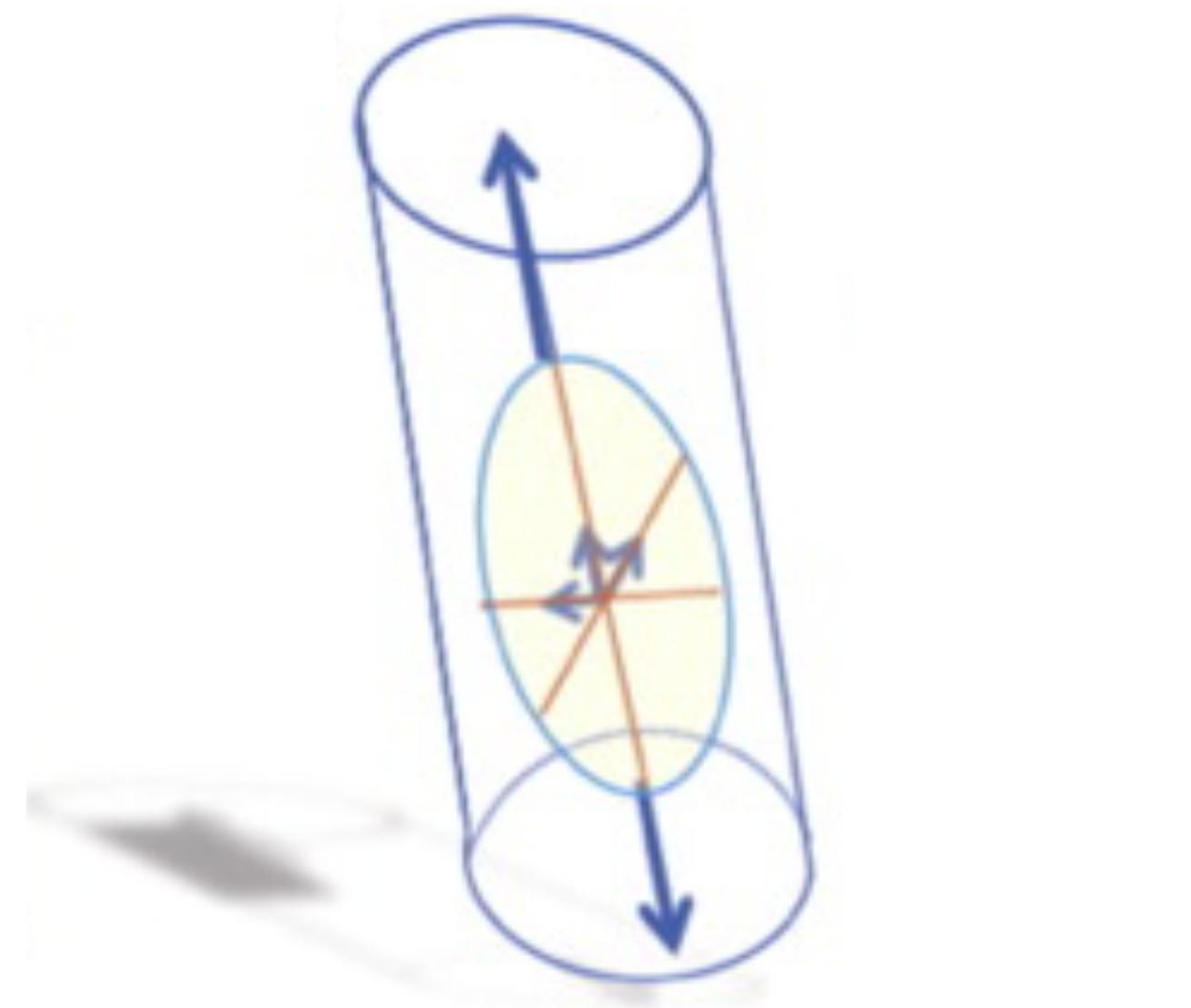


Diffusion Tensor Imaging

Water diffuses in tissue



Isotropic diffusion

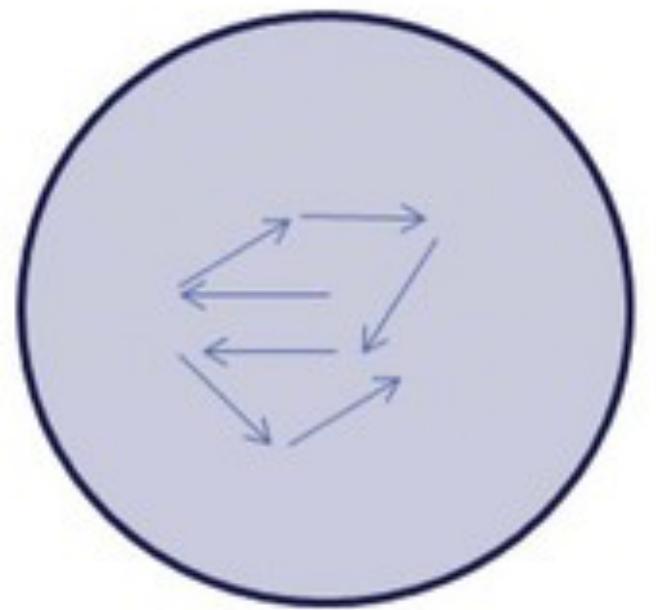


Anisotropic diffusion

Diffusion Tensor Imaging

Water diffuses in tissue

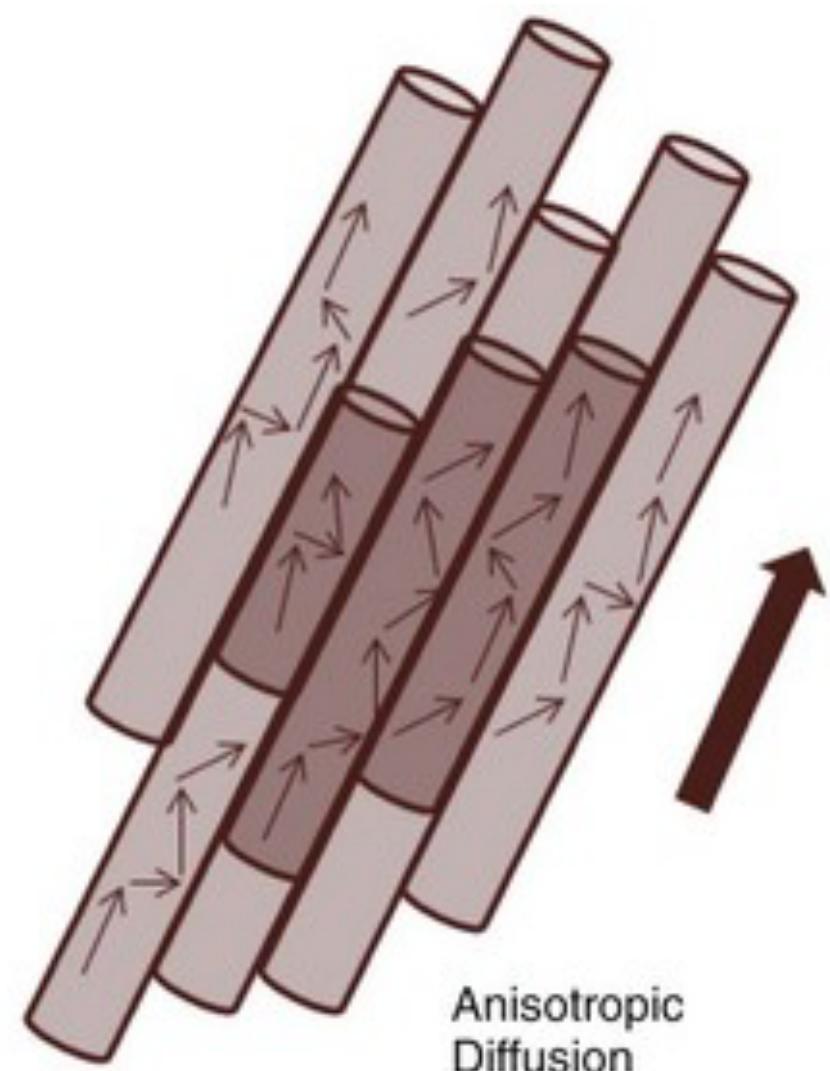
Unrestricted



Isotropic Diffusion
 $(\lambda_1 = \lambda_2 = \lambda_3)$

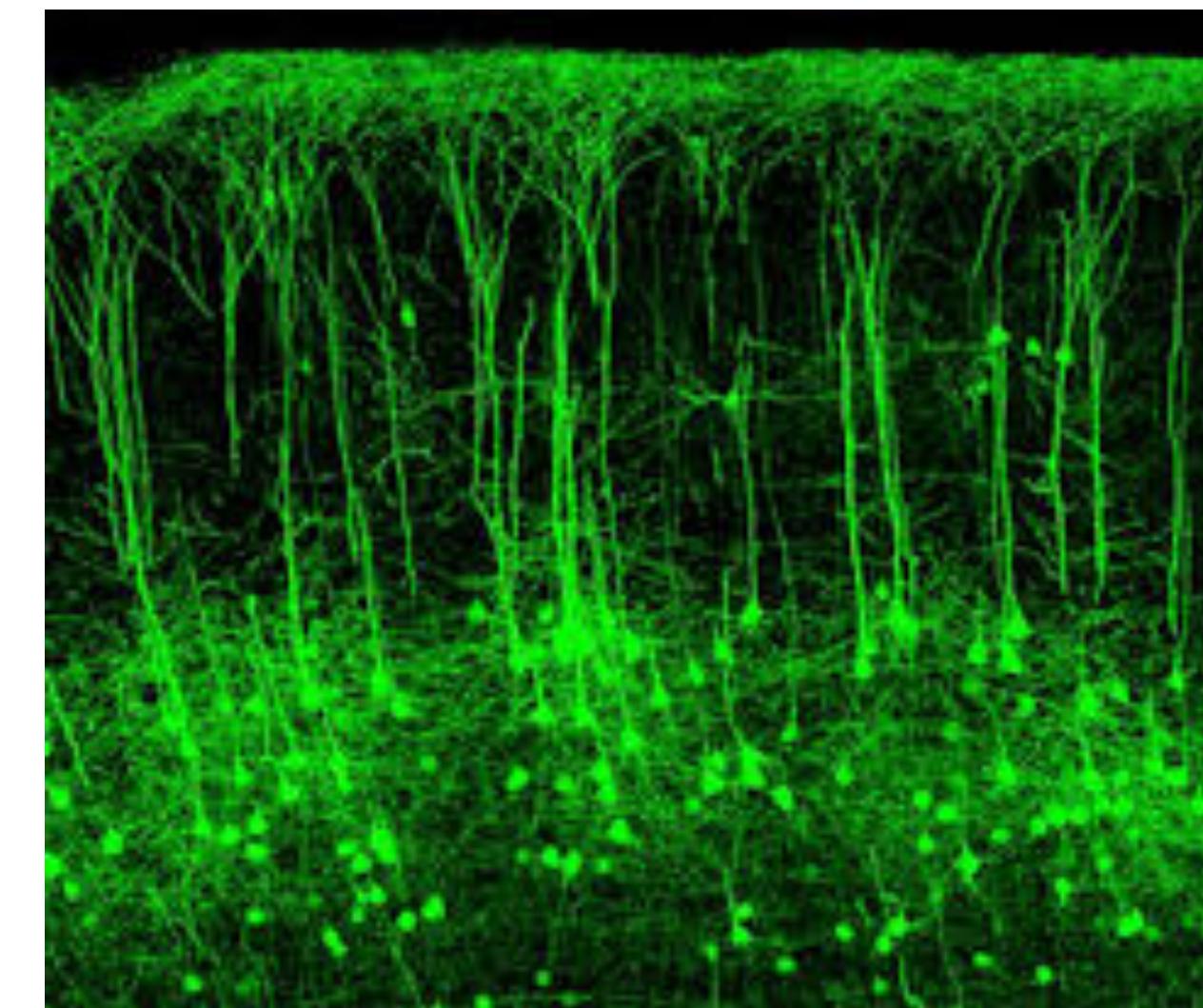
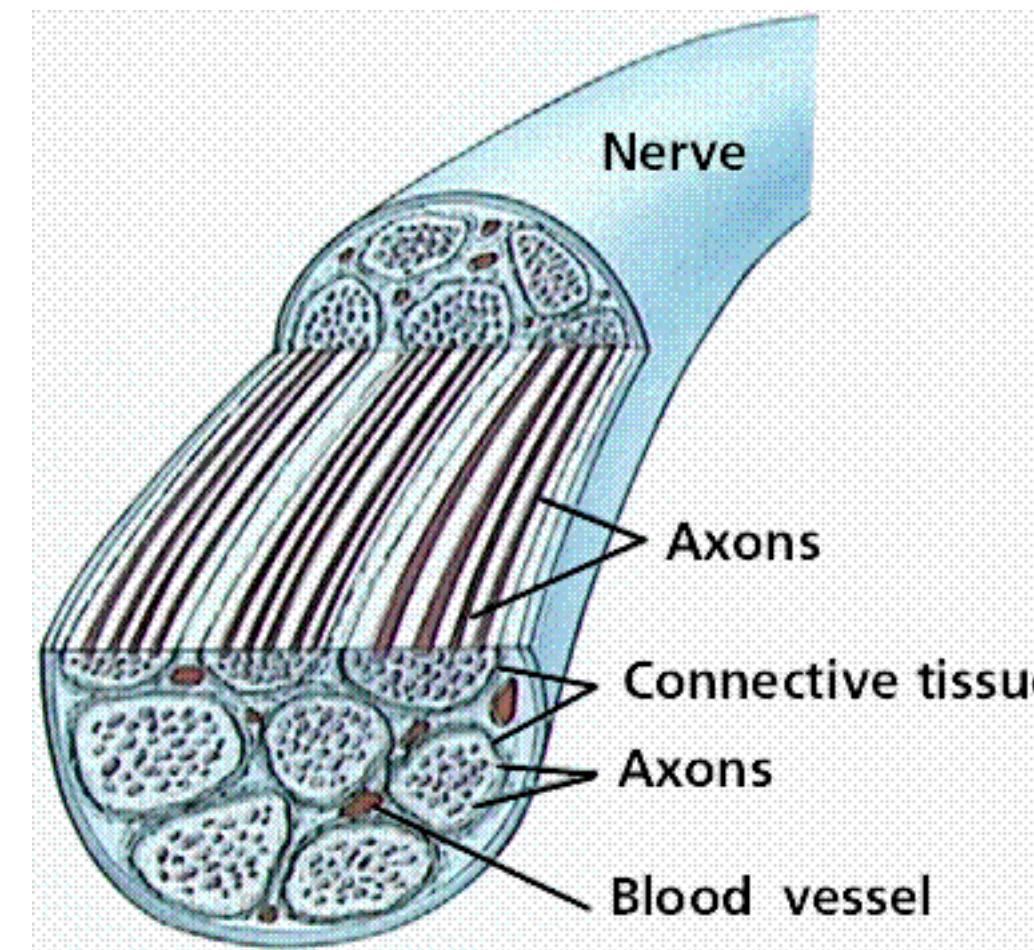
A

Restricted



B

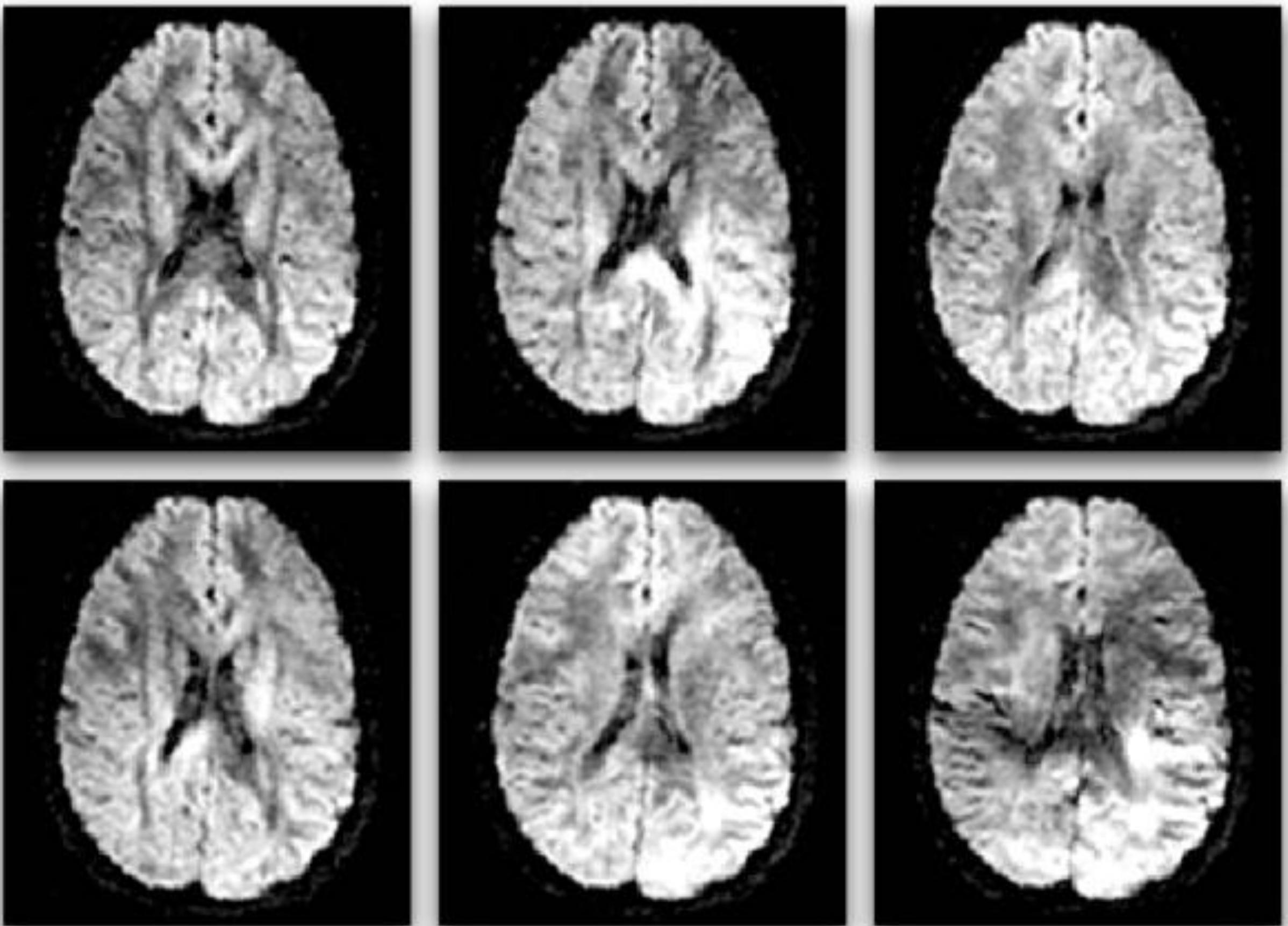
Anisotropic Diffusion



Diffusion Tensor Imaging

Diffusion tensor imaging employs gradient pulses for which the cumulative effect cancels out for stationary water molecules but causes a lack of signal for diffusing molecules appearing as darker voxels.

By creating images from multiple directions a three dimensional diffusion model can be estimated



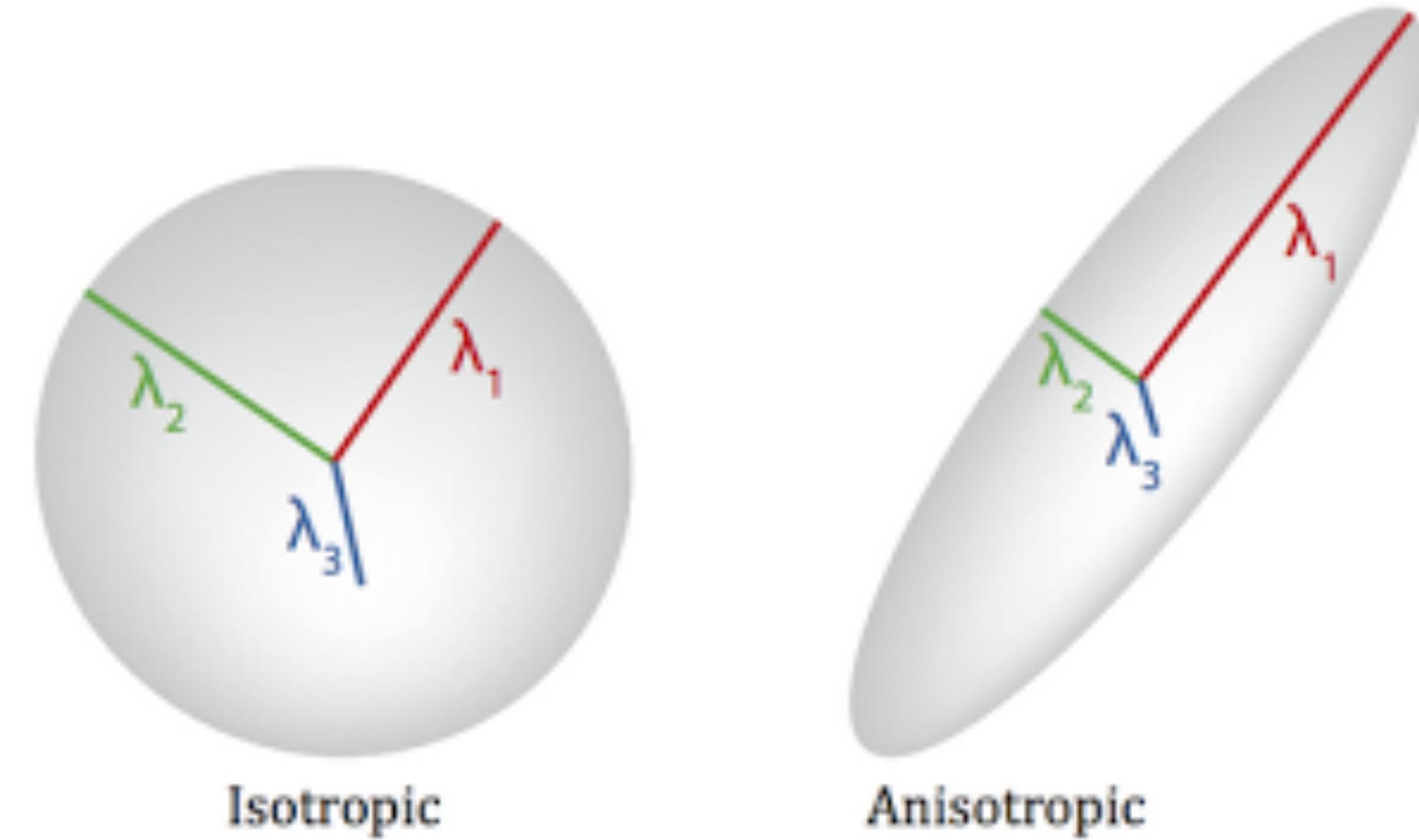
Diffusion Tensor Imaging

Diffusion Tensor

Displacement of molecules
modeled by:

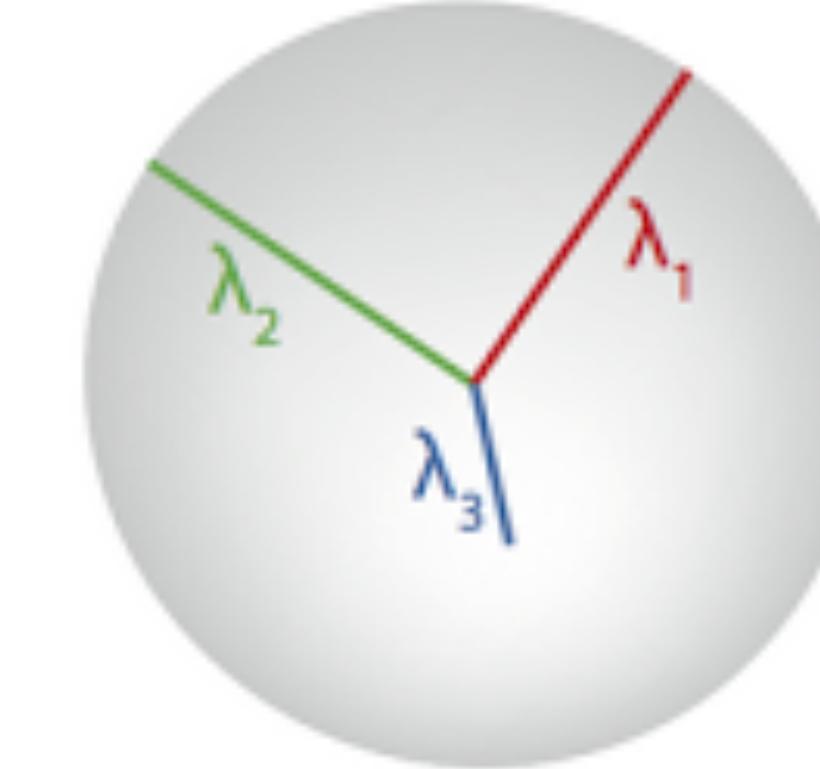
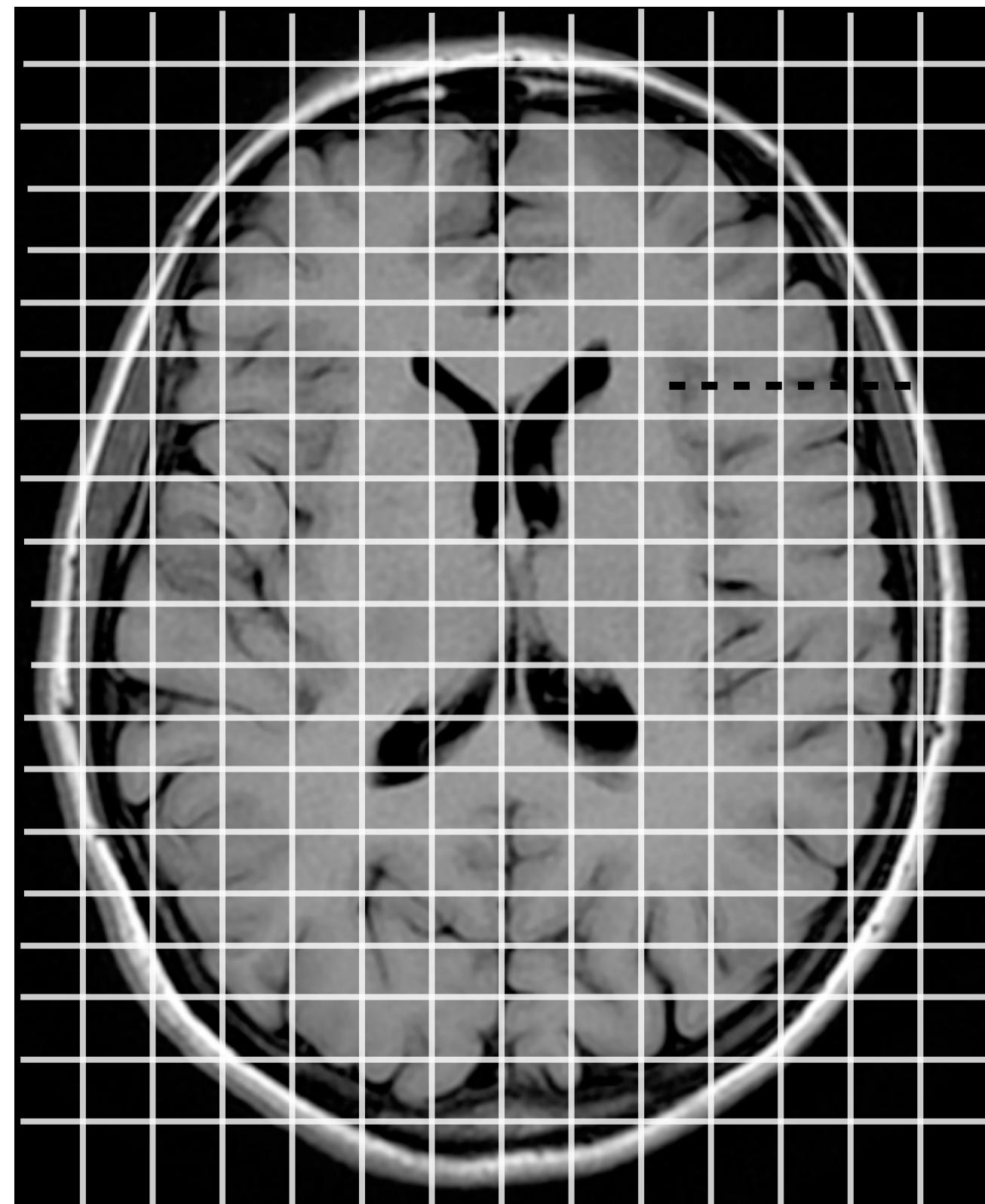
- 3 Eigenvectors
- 3 Eigenvalues

The major Eigenvector defines
direction of diffusion

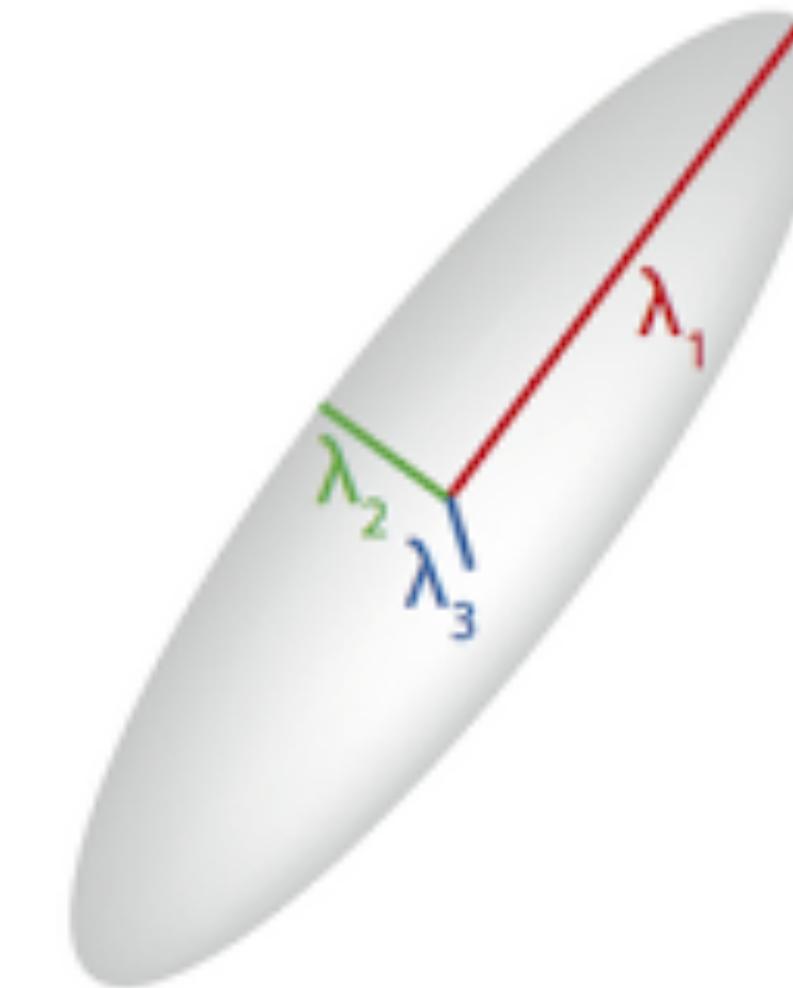


λ_1 = longitudinal (axial) diffusivity (AD)
 $(\lambda_2 + \lambda_3)/2$ = radial diffusivity (RD)
 $(\lambda_1 + \lambda_2 + \lambda_3)/3$ = mean diffusivity (MD)

Diffusion Tensor Imaging



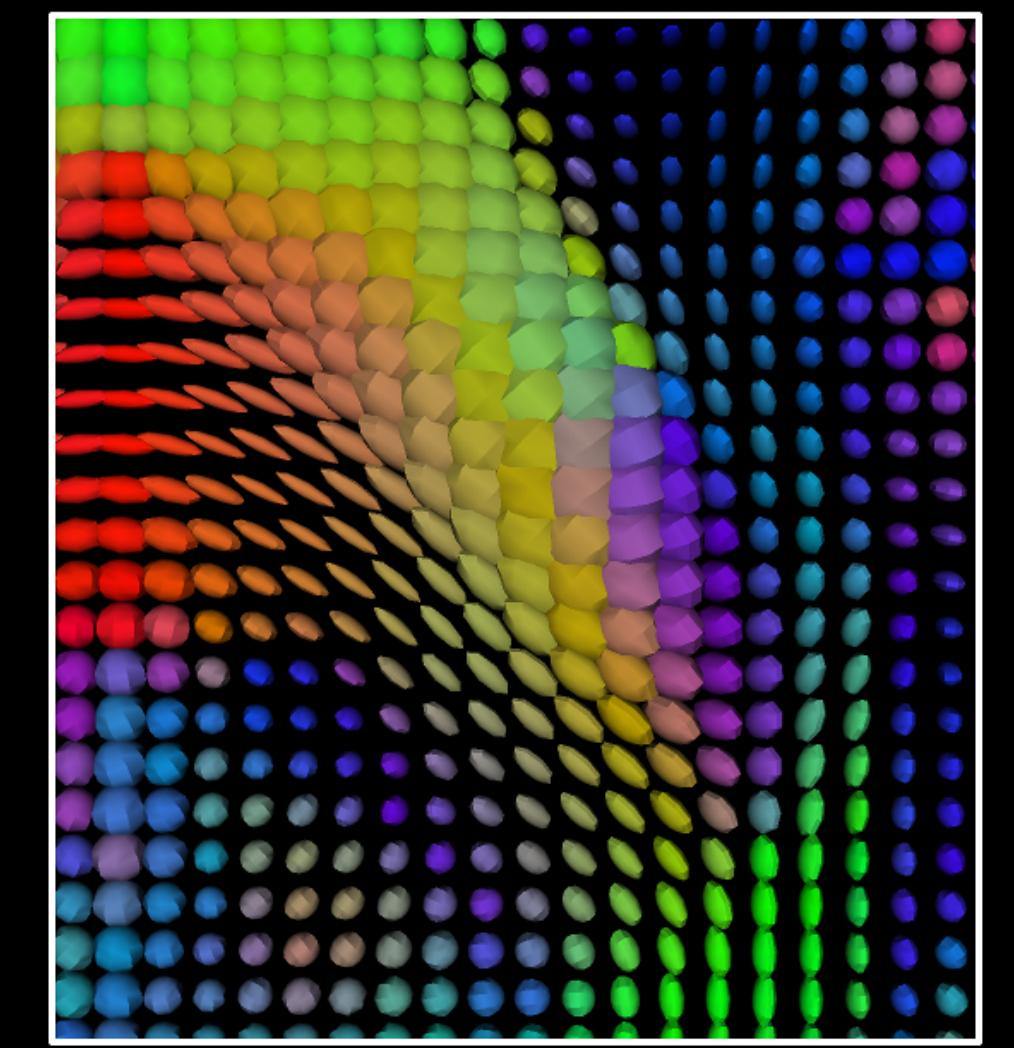
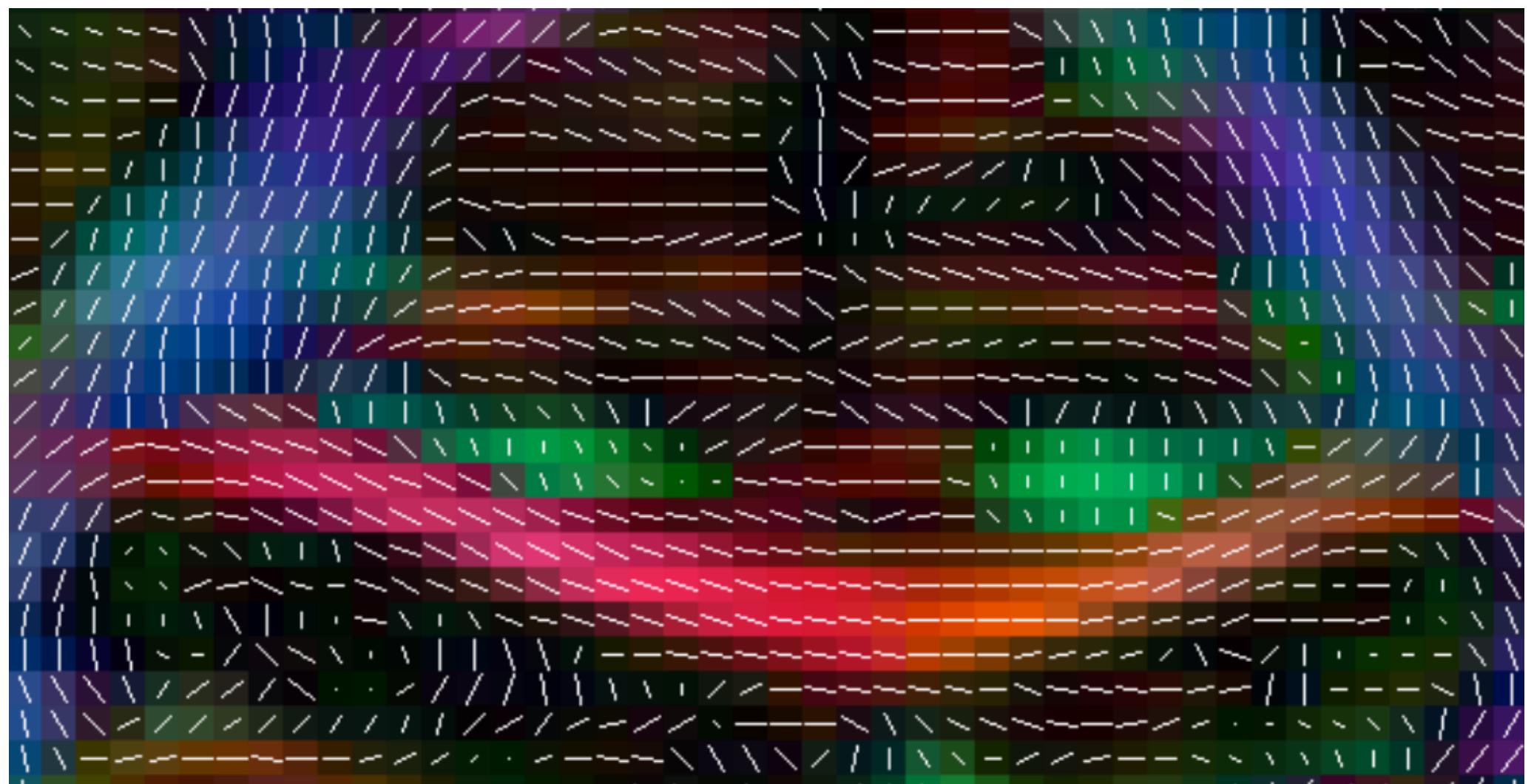
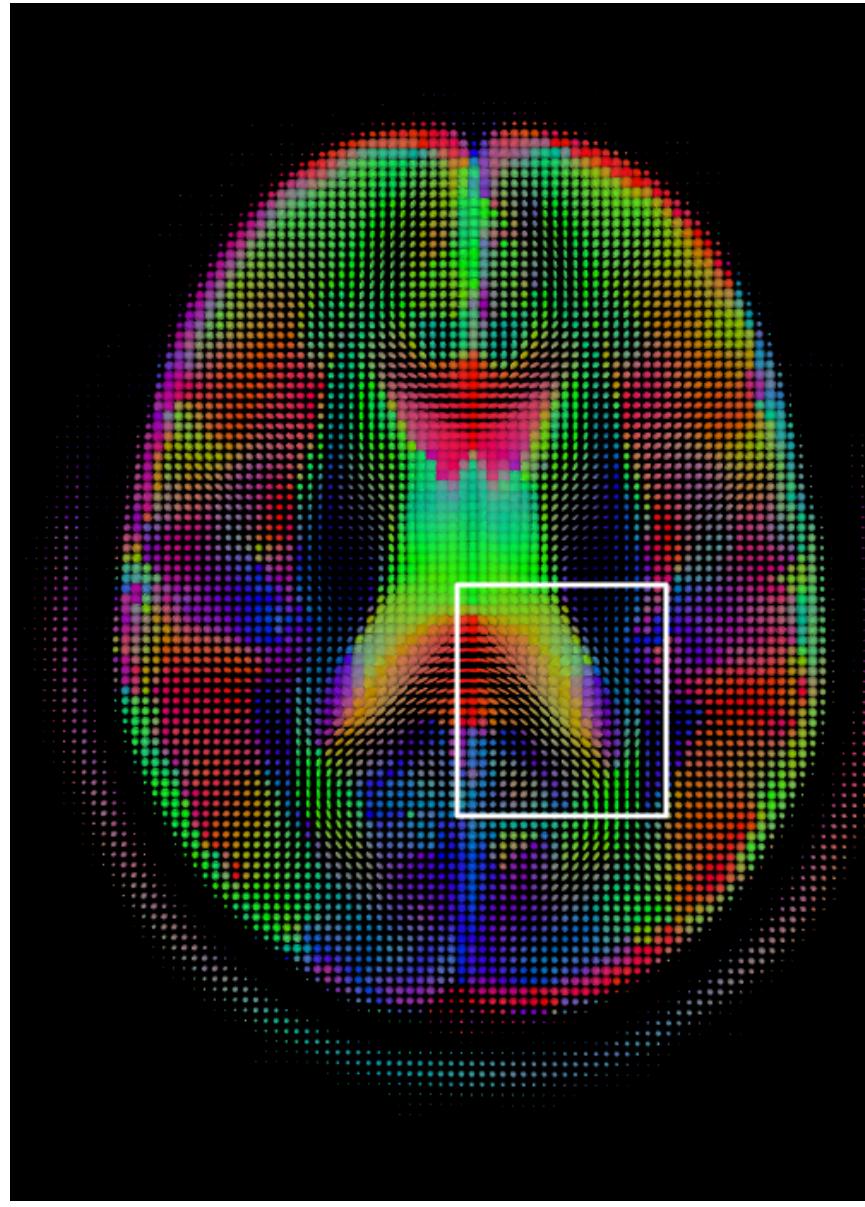
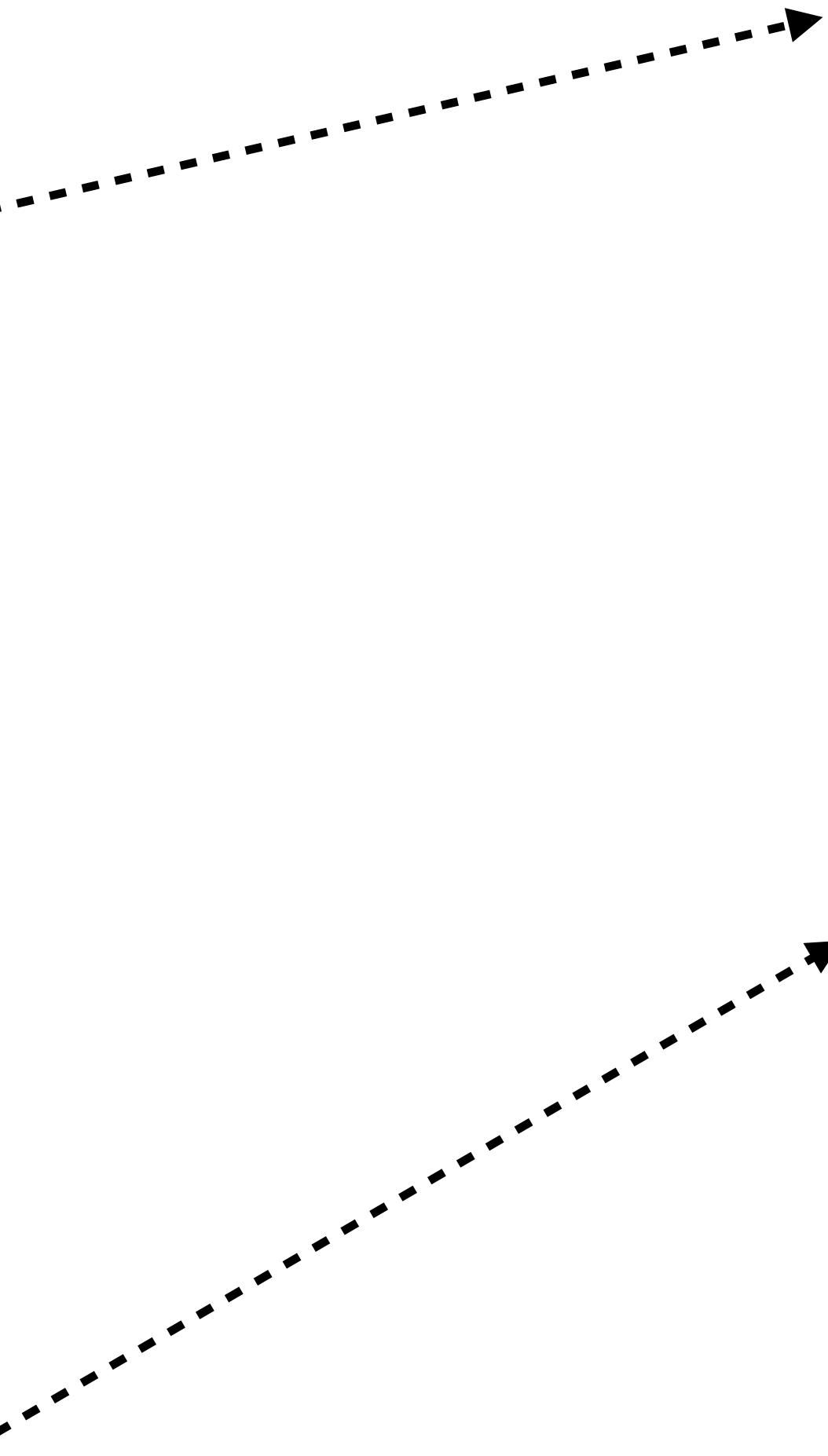
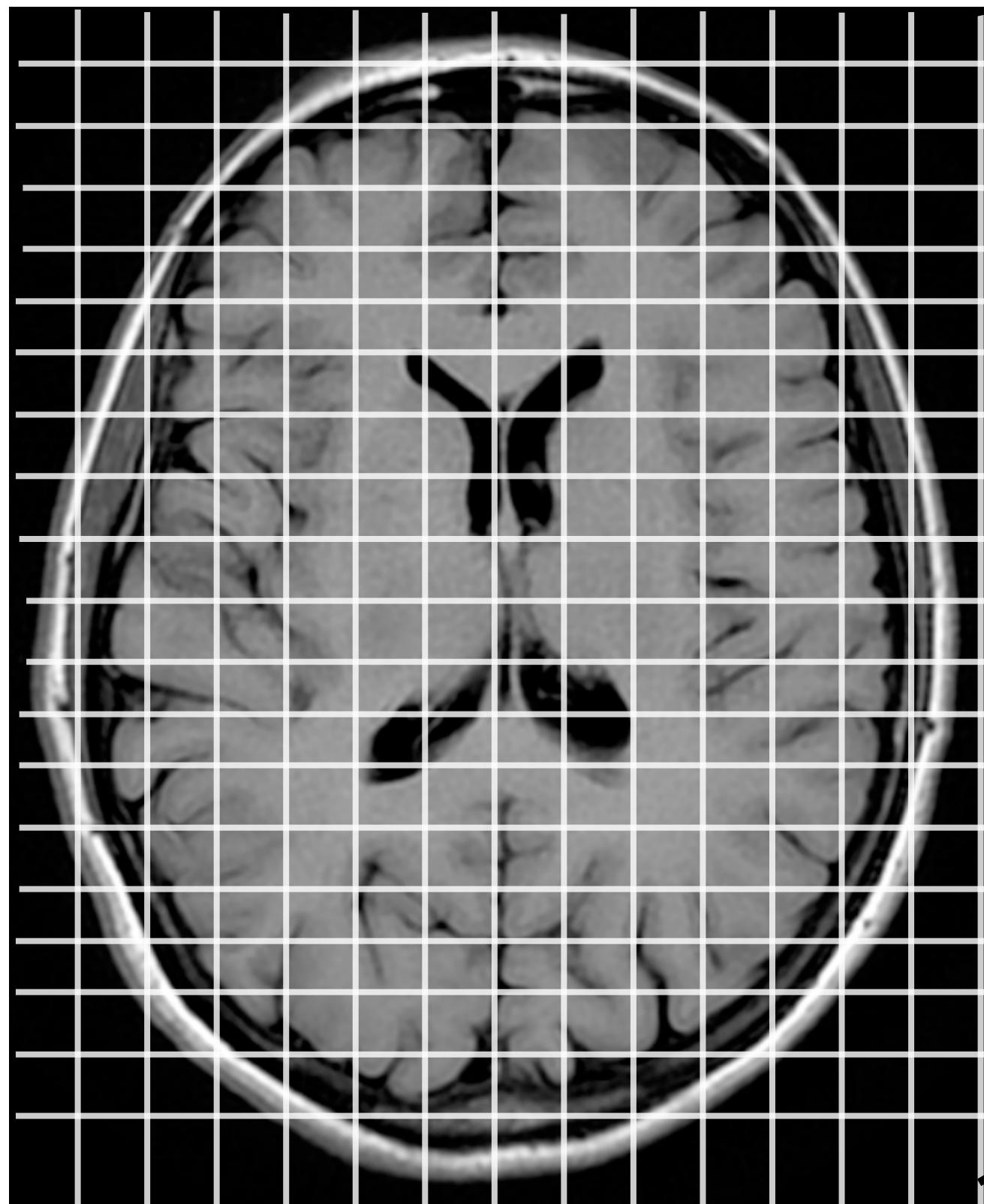
Isotropic



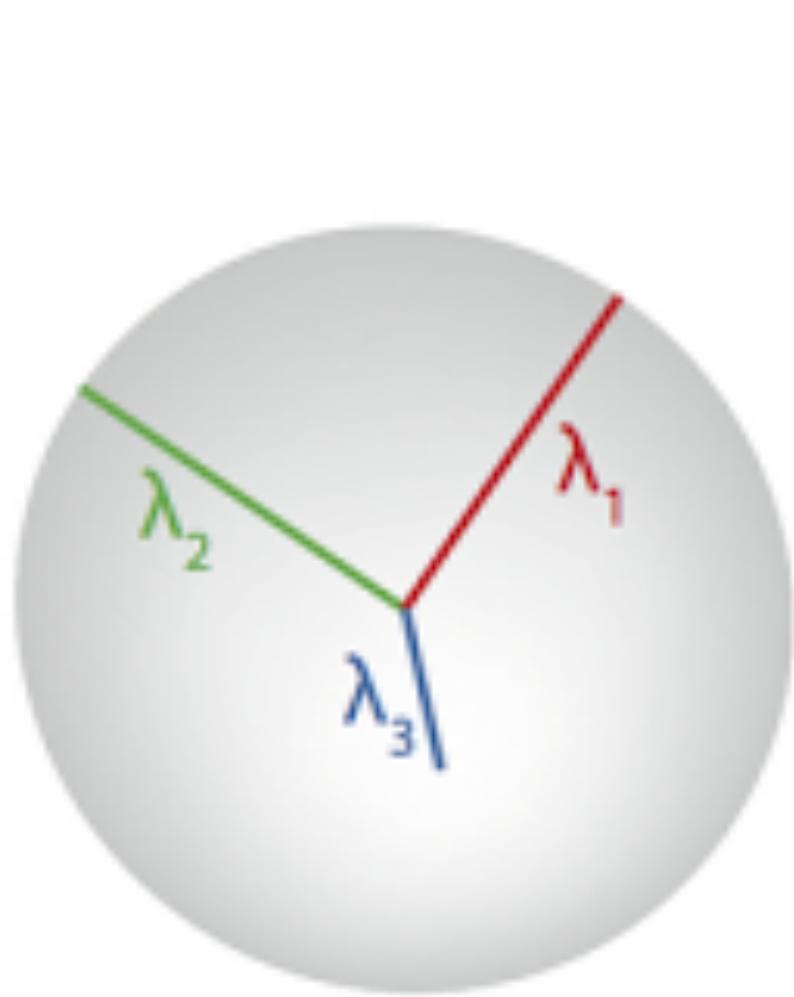
Anisotropic

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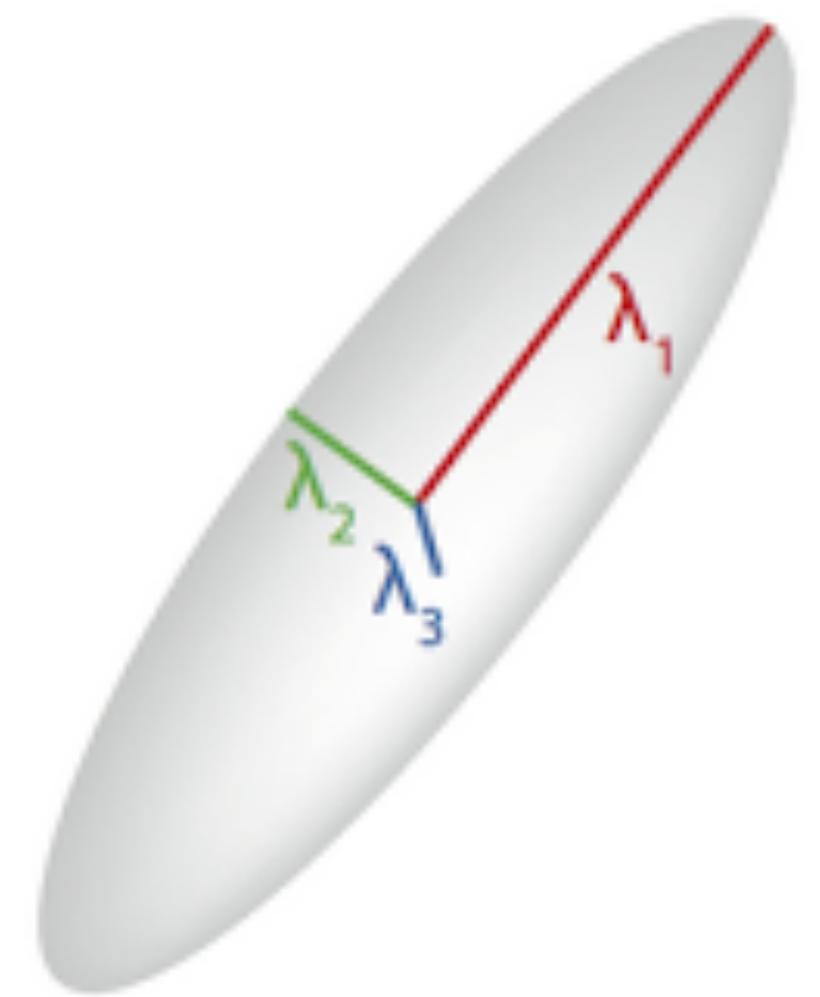
Diffusion Tensor Imaging



Diffusion Tensor Imaging

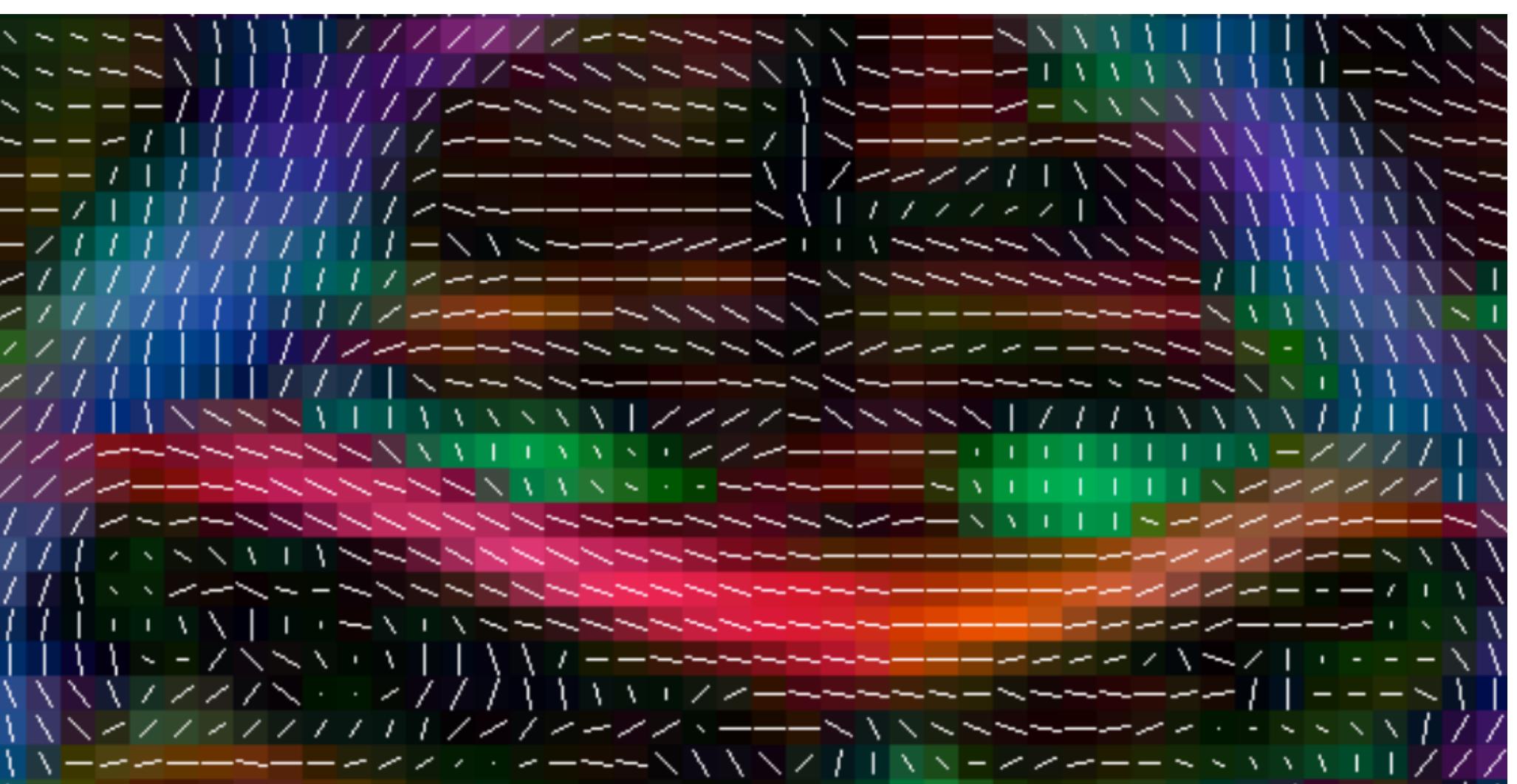
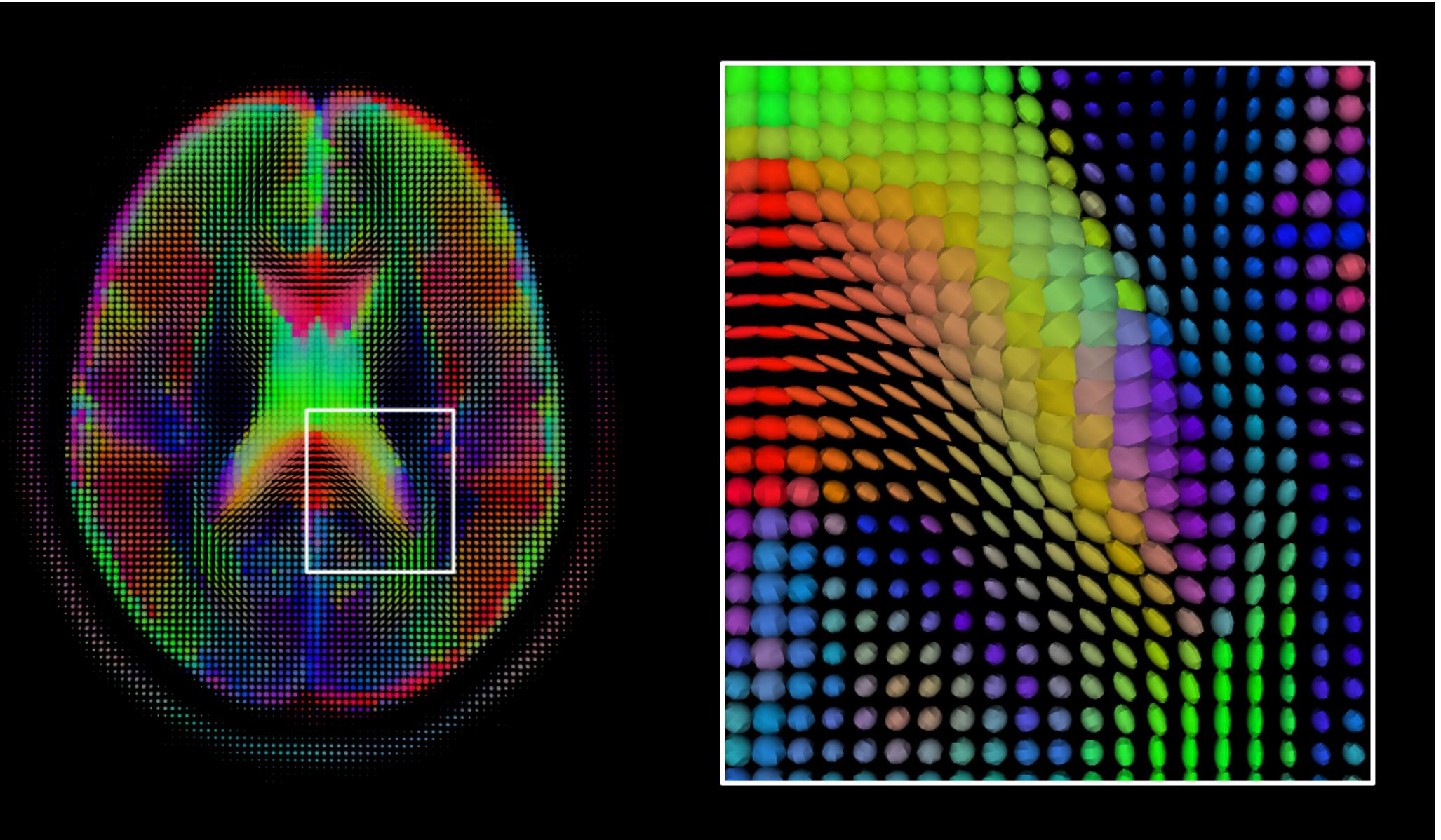


Isotropic



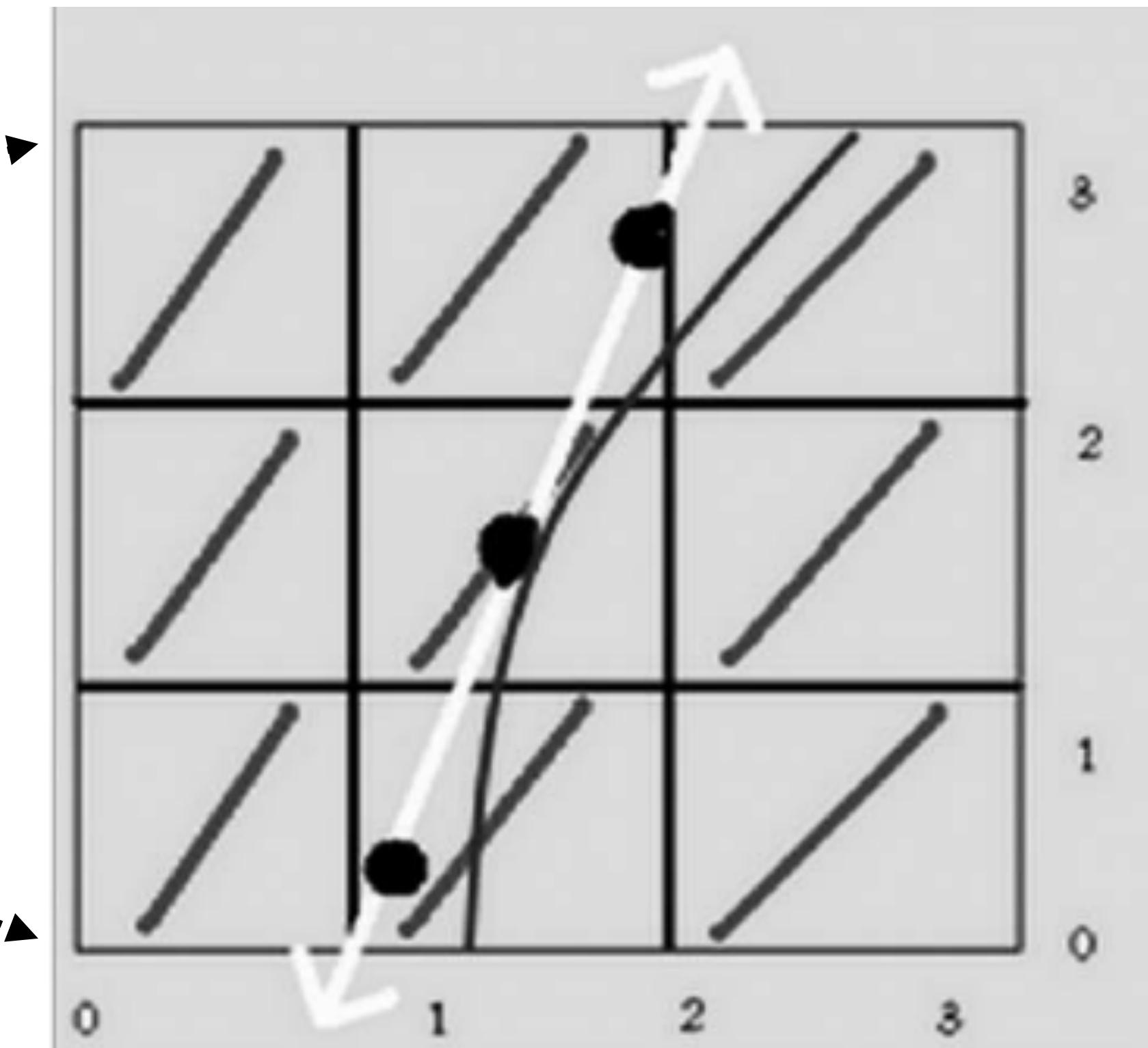
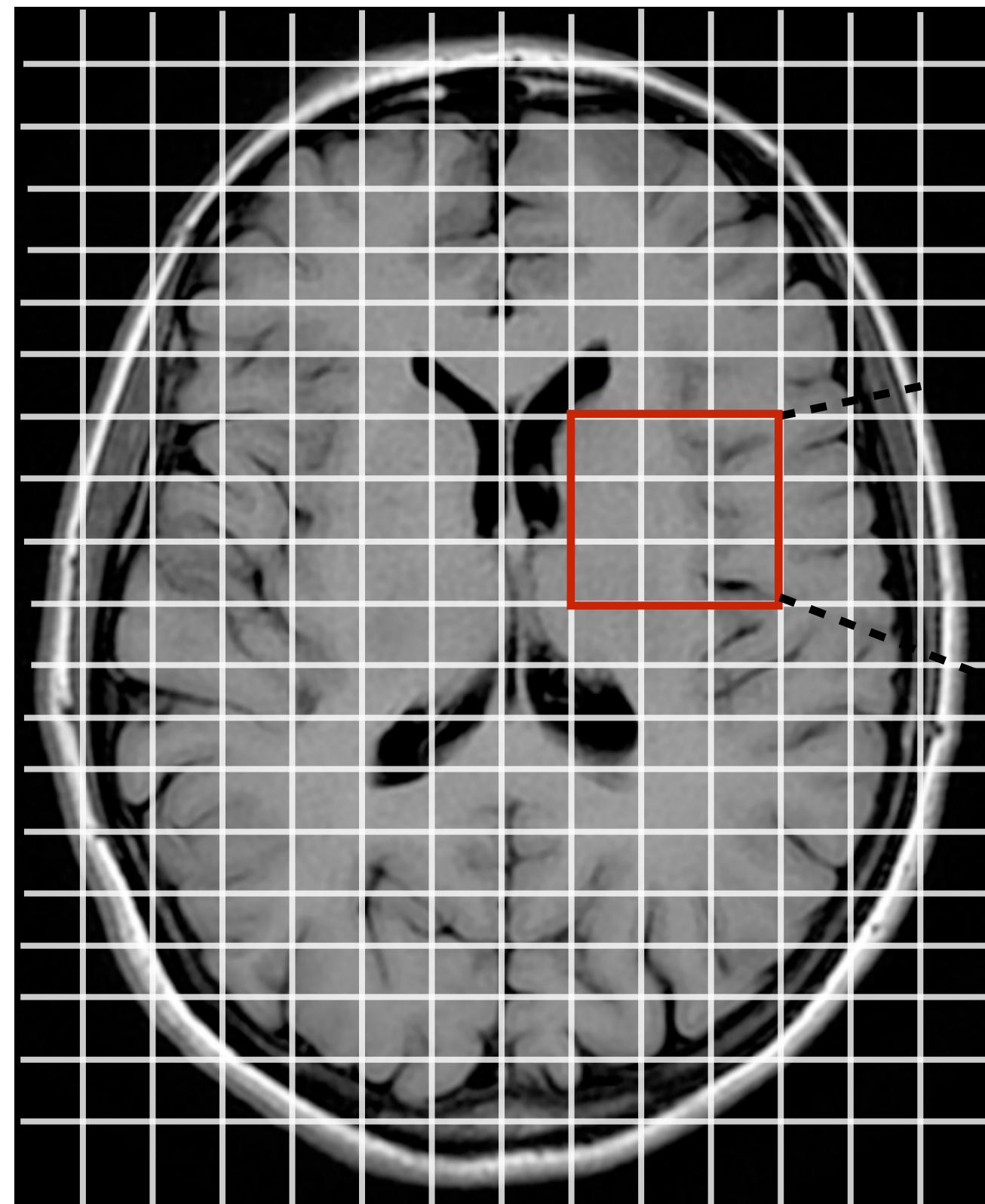
Anisotropic

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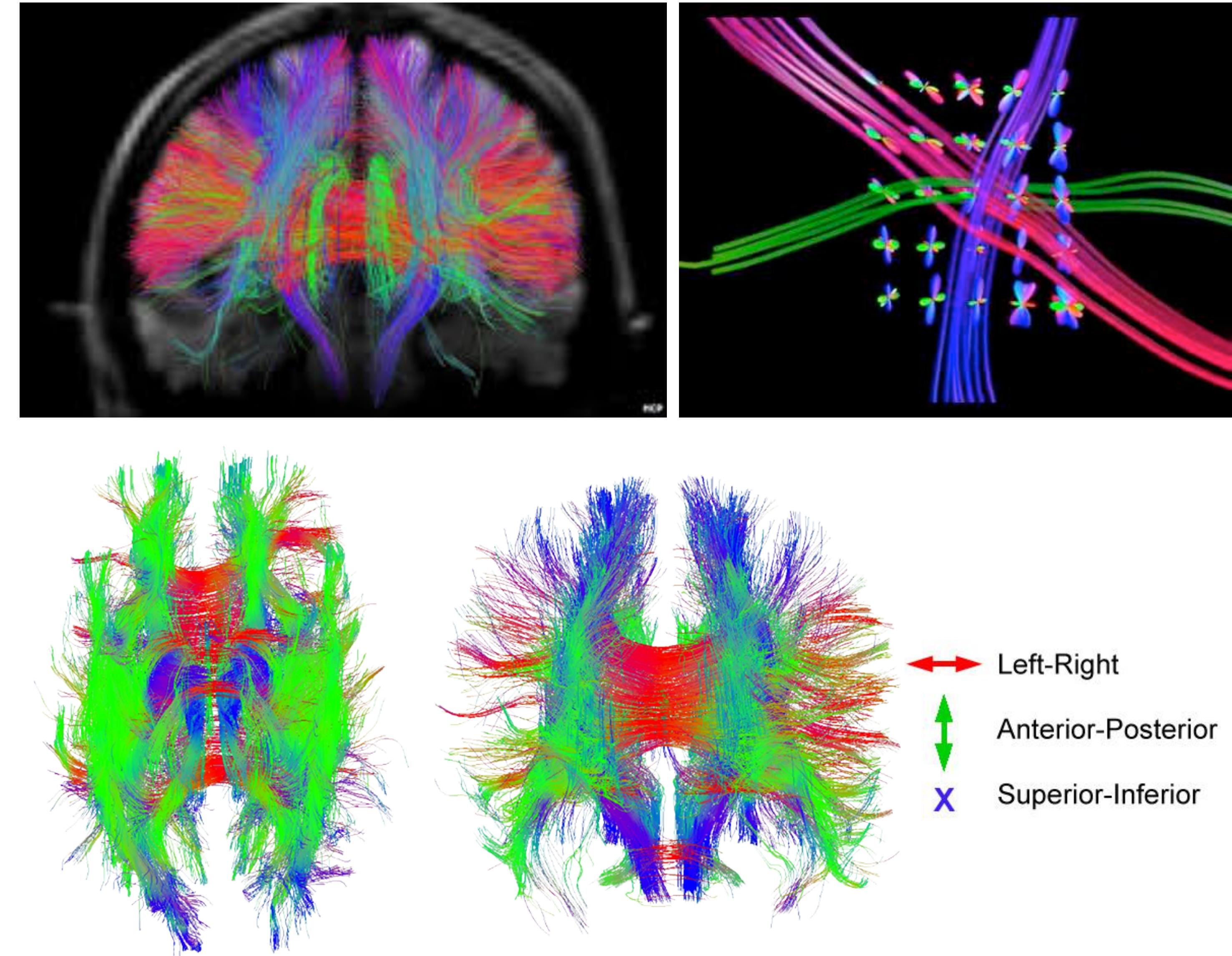
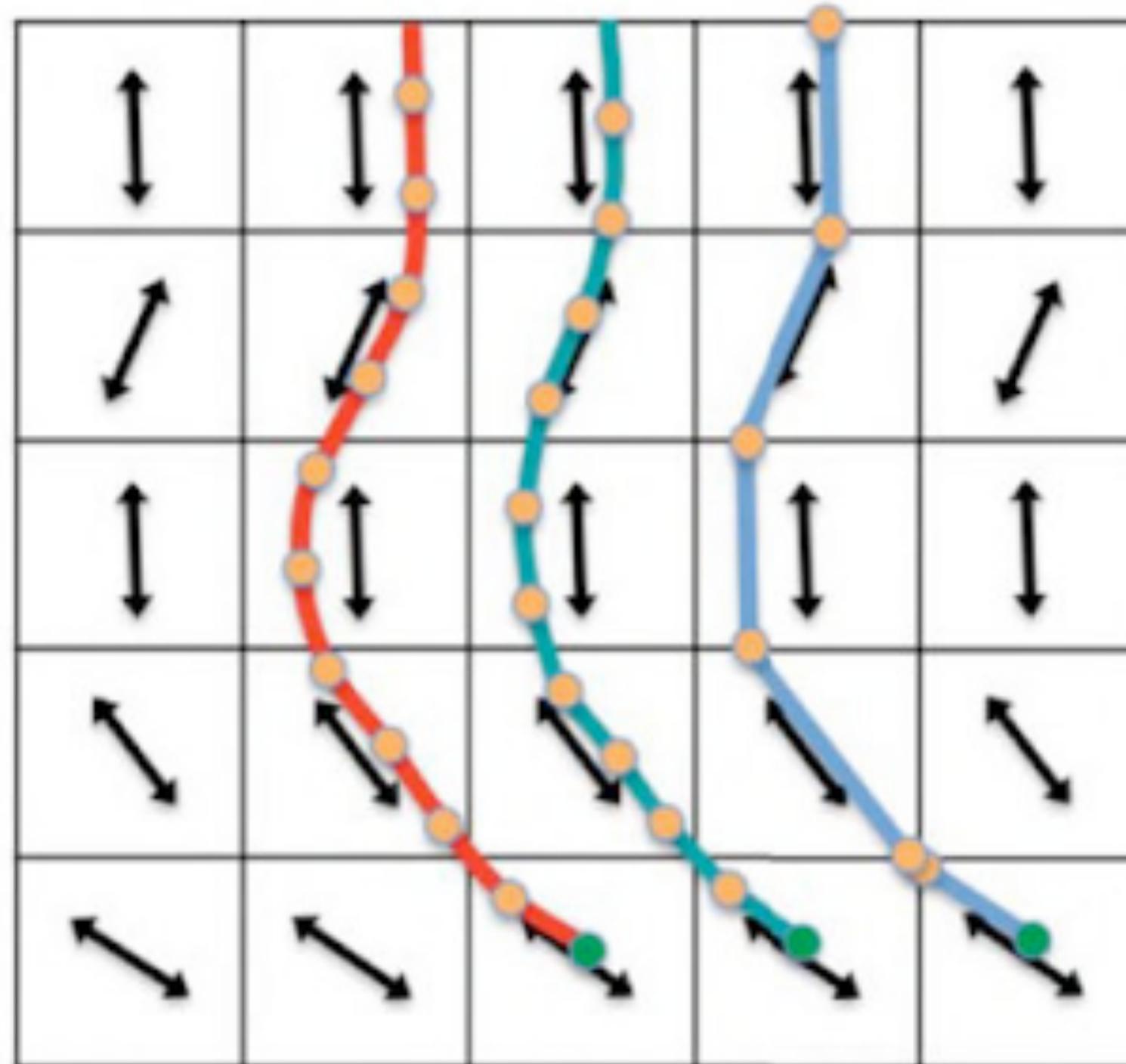
Diffusion Tensor Imaging

Probabilistic Fiber Tracking



Diffusion Tensor Imaging

Probabilistic Fiber Tracking



Diffusion Tensor Imaging

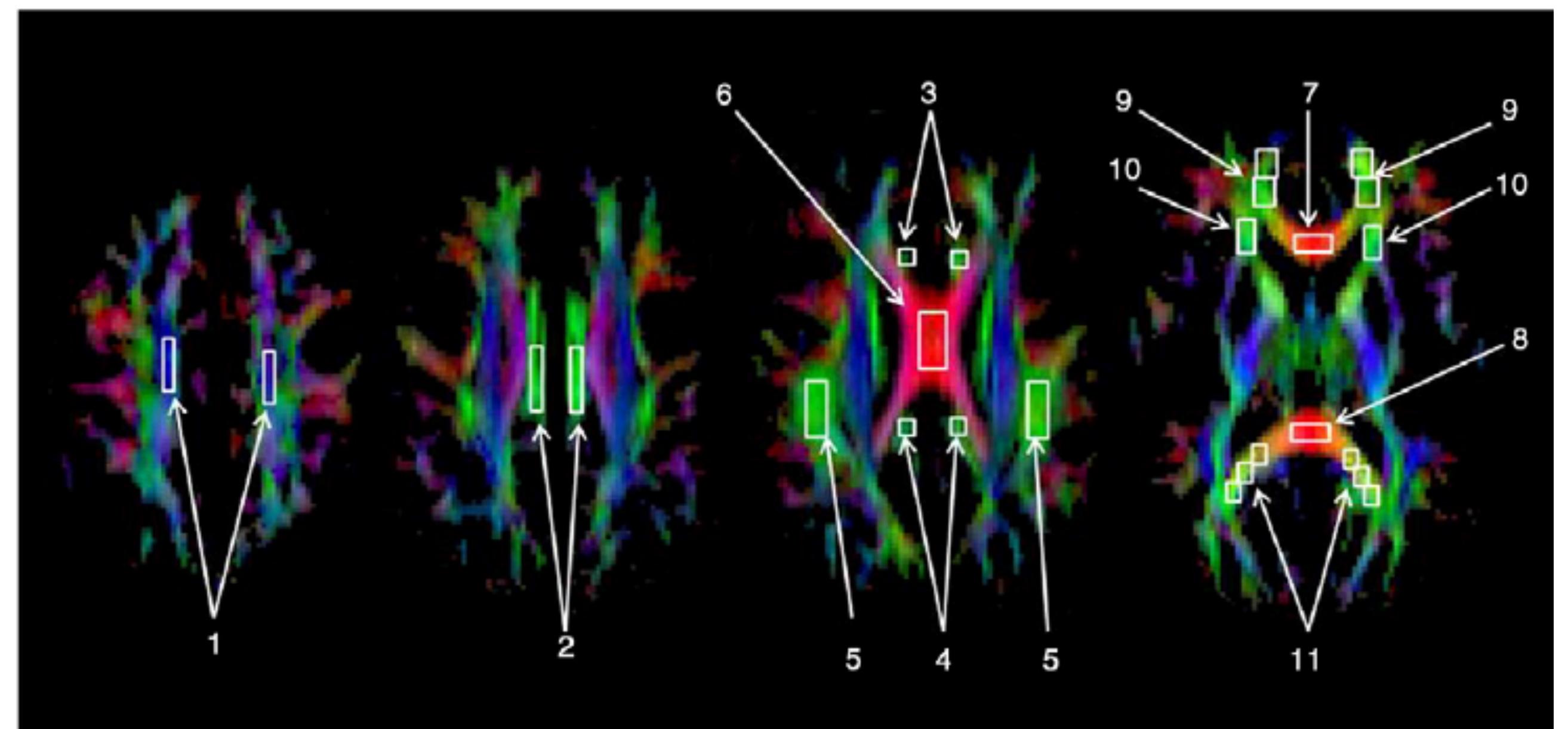
Studies of fractional anisotropy

Fractional measure of diffusivity.

- 0: Isotropic diffusion
- 1: Diffusion in only 1 direction

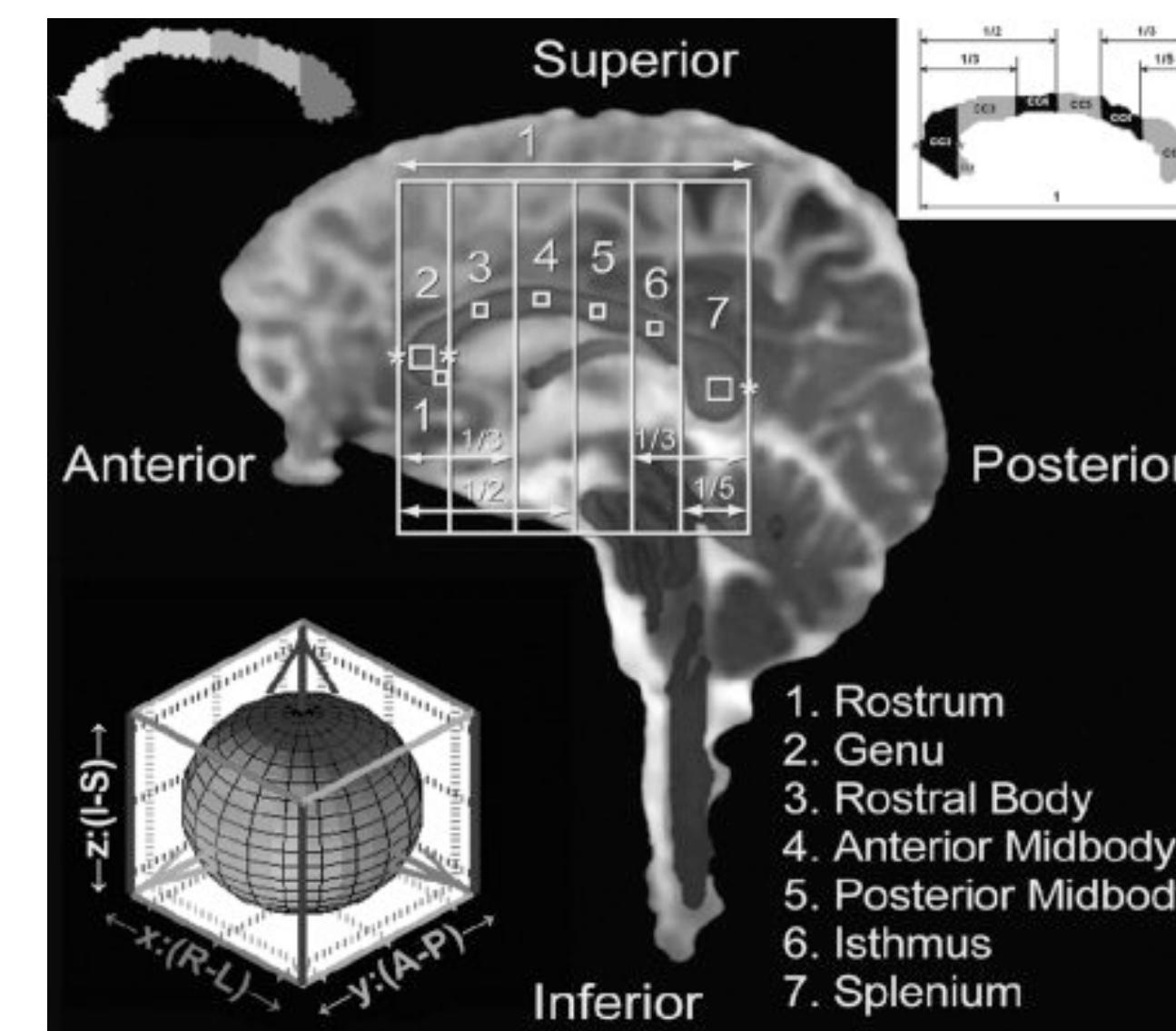
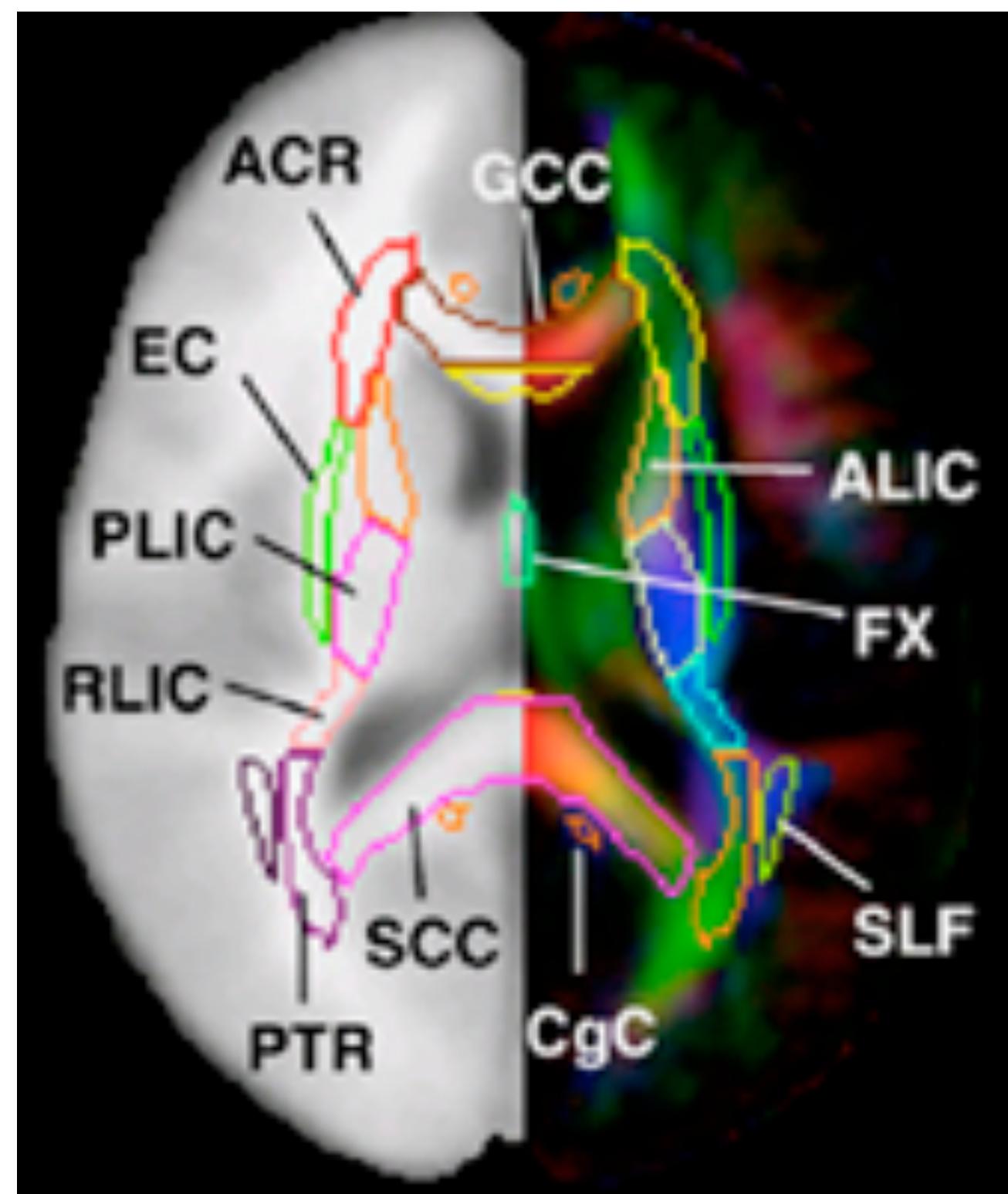
Measure of:

- Fiber density
- Brain connectivity
- White matter integrity



Diffusion Tensor Imaging

Group differences in FA



Original Research

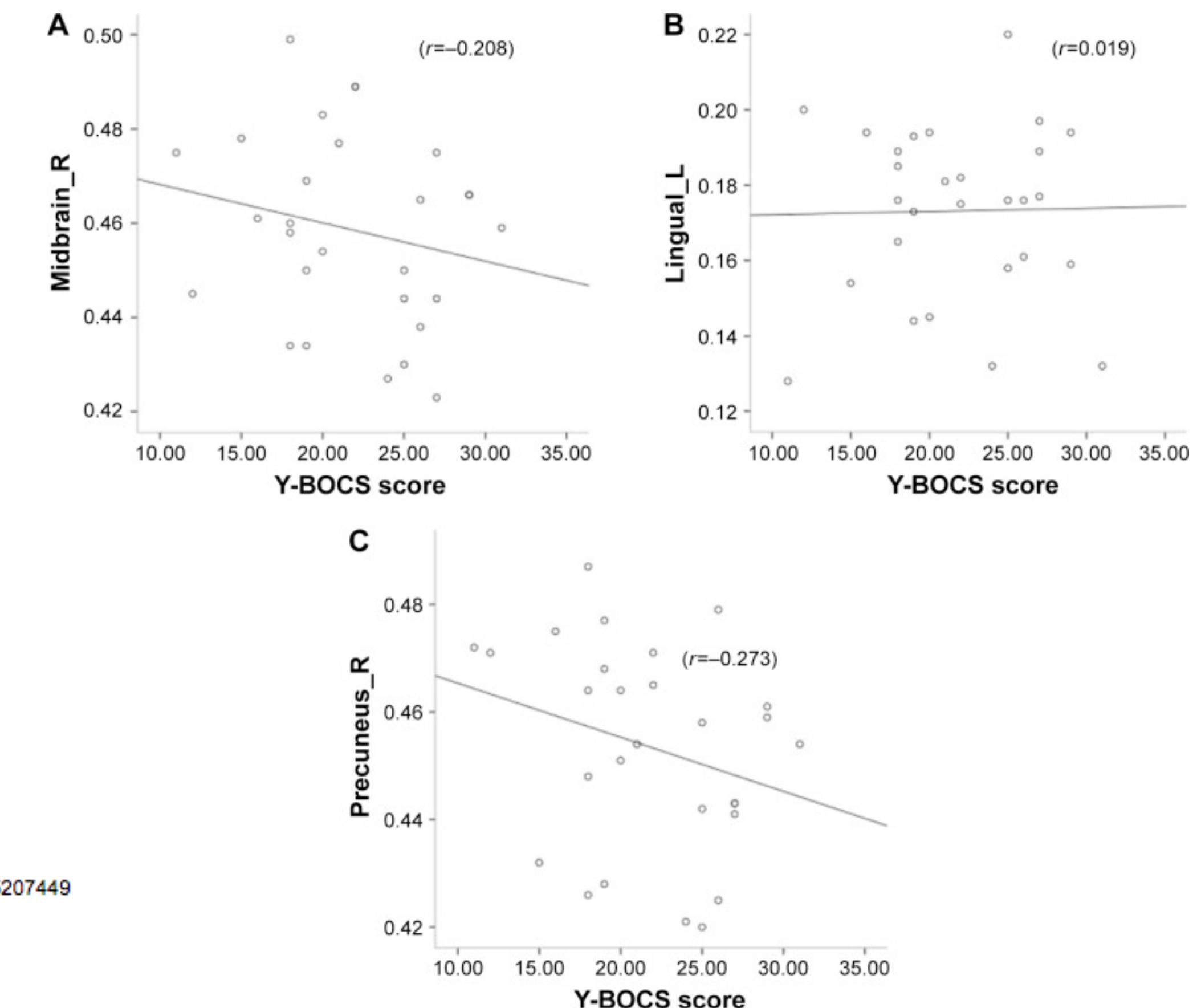
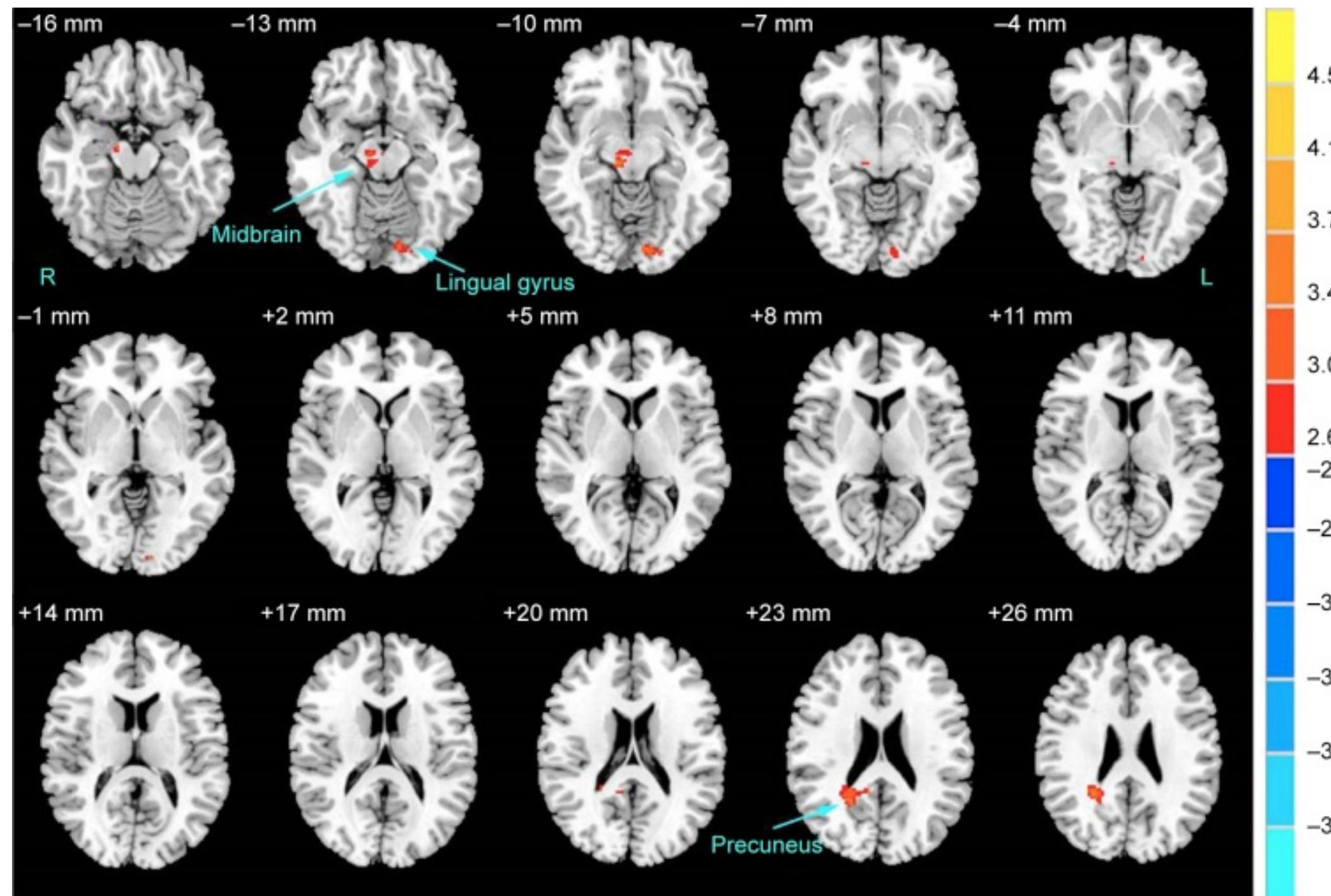
Diffusion tensor fractional anisotropy of the normal-appearing seven segments of the corpus callosum in healthy adults and relapsing-remitting multiple sclerosis patients[†]

Khader M. Hasan PhD✉, Rakesh K. Gupta MD, Rafael M. Santos MD, FRCS,



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Diffusion Tensor Imaging



Neuropsychiatr Dis Treat, 2017; 13: 69–76.

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PMCID: PMC5207449

Alterations of white matter fractional anisotropy in unmedicated obsessive-compulsive disorder

Jiong Tao,^{1,2} Xianglan Wang,² Zhiyong Zhong,^{1,2} Hongying Han,² Sha Liu,³ Shenglin Wen,⁴ Nianhong Guan,² and Lingjiang Li¹

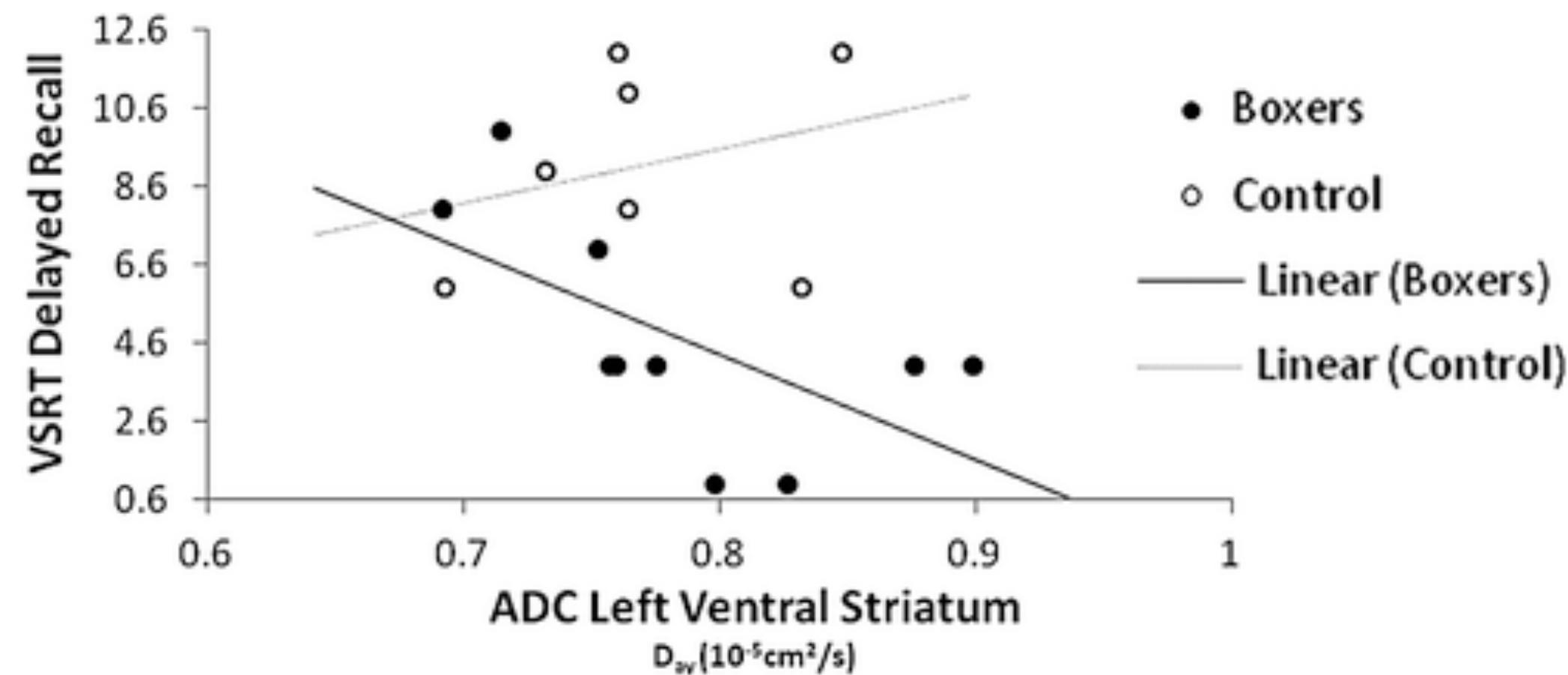
FA correlation with symptoms

Diffusion Tensor Imaging

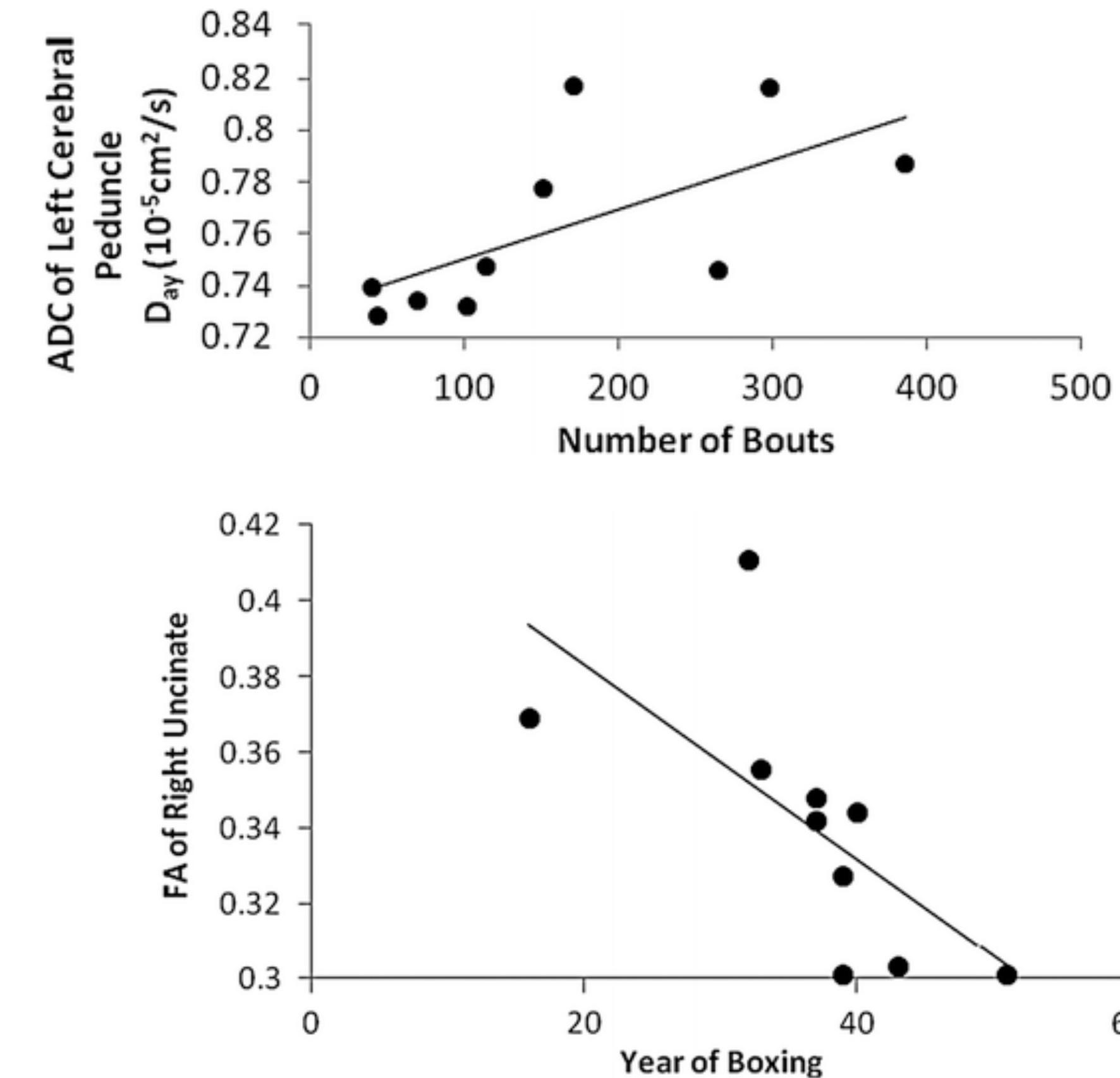
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DOI: 10.1089/neu.2015.4035

Chronic Effects of Boxing: Diffusion Tensor Imaging and Cognitive Findings

Elisabeth A. Wilde,^{1,2} Jill V. Hunter,² Xiaoqi Li,² Cristian Amador,³ Gerri Hanten,² Mary R. Newsome,^{1,2} Trevor C. Wu,⁴ Stephen R. McCauley,^{1,2} Gregory S. Vogt,¹ Zili David Chu,² Brian Biekman,² and Harvey S. Levin^{1,2}



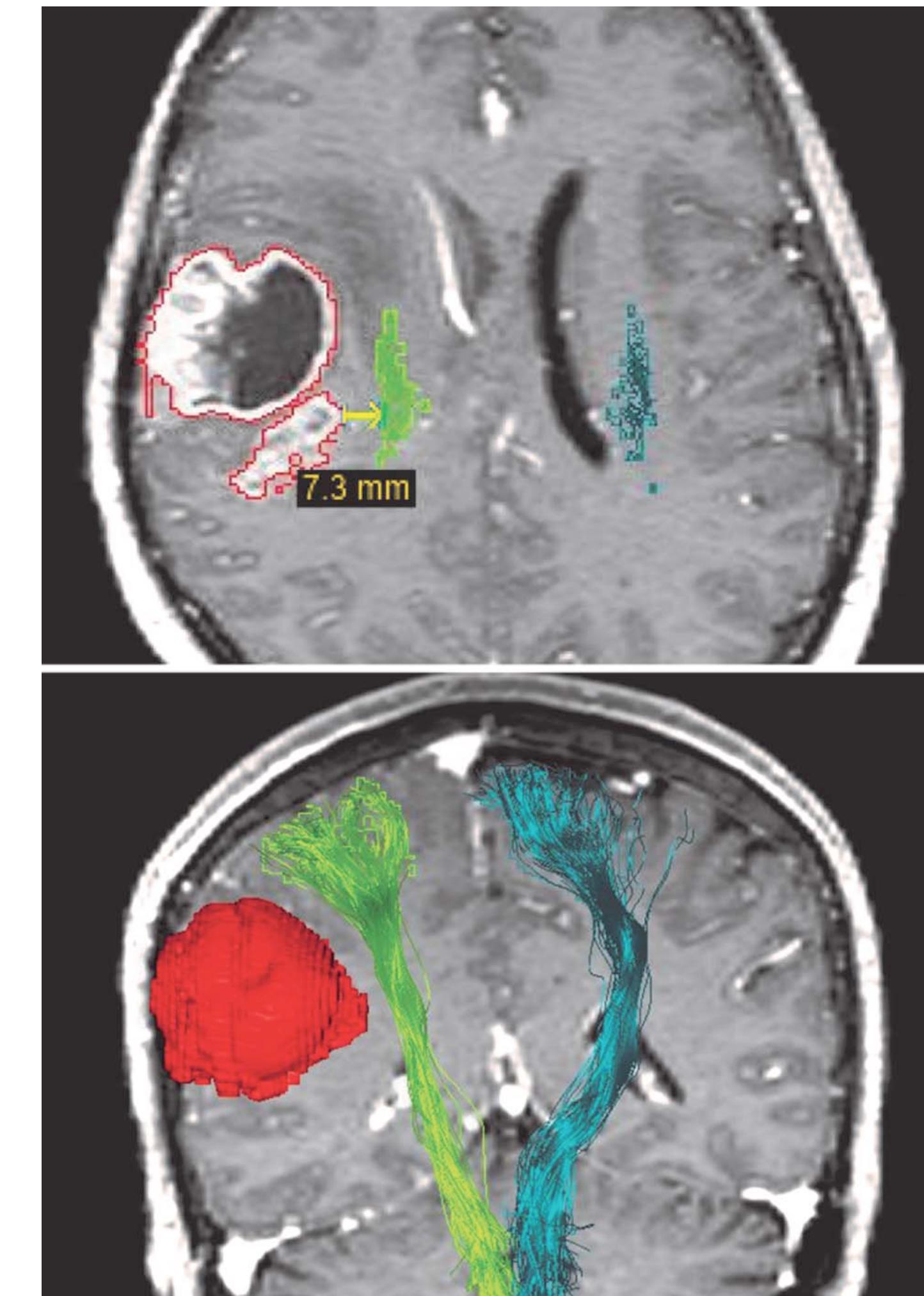
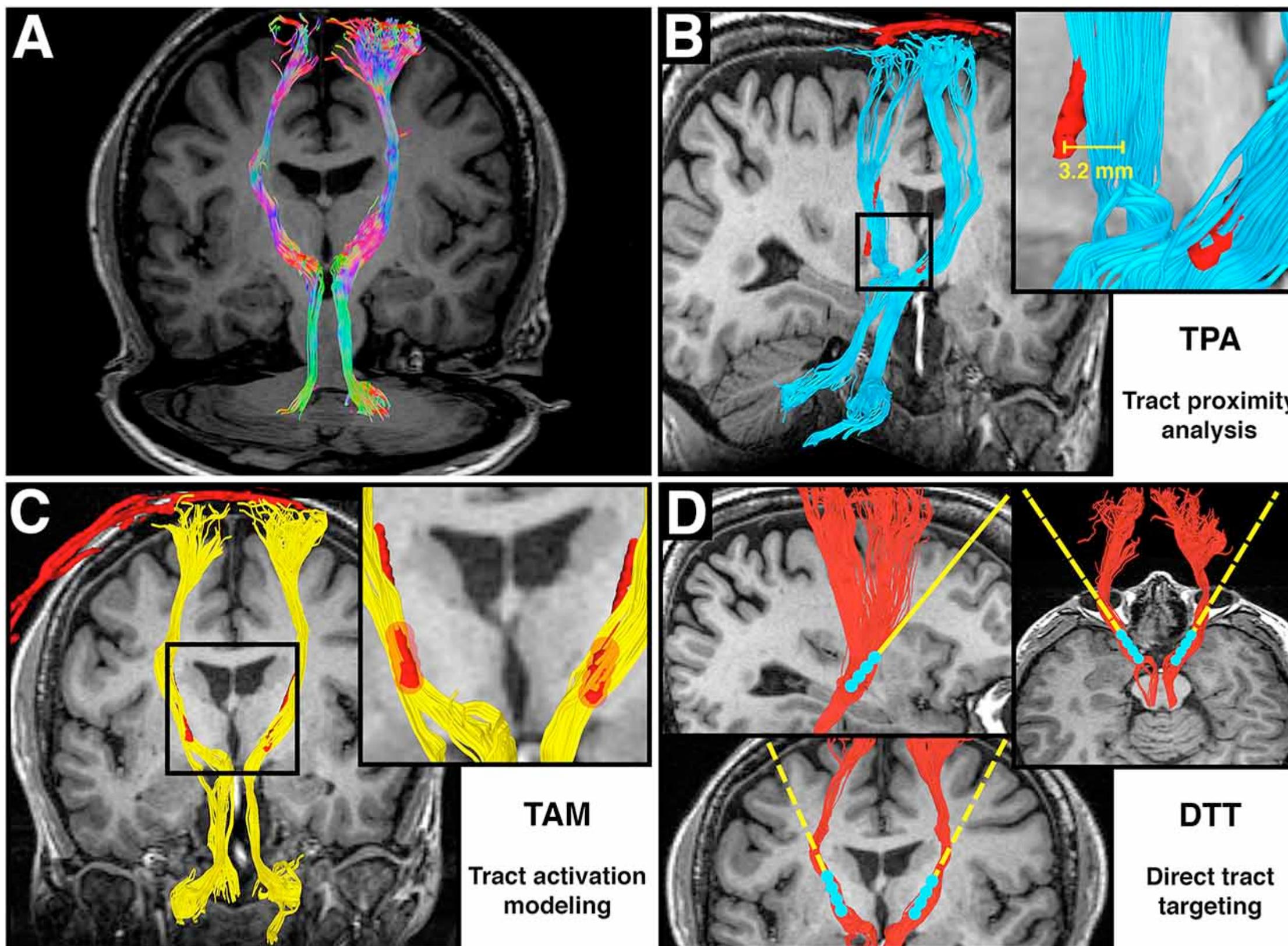
FA correlation with task performance



FA correlation with life events

Diffusion Tensor Imaging

DTI tractography in surgical planning



Diffusion Tractography in Deep Brain Stimulation Surgery: A Review

Diffusion Tensor Imaging

Studies in Diffusion Tensor Imaging

- Provides a measure of structural connectivity
- Provides a measure of structural organization
- Group comparisons
- Correlation with symptoms / events
- Correlation with cognitive performance

