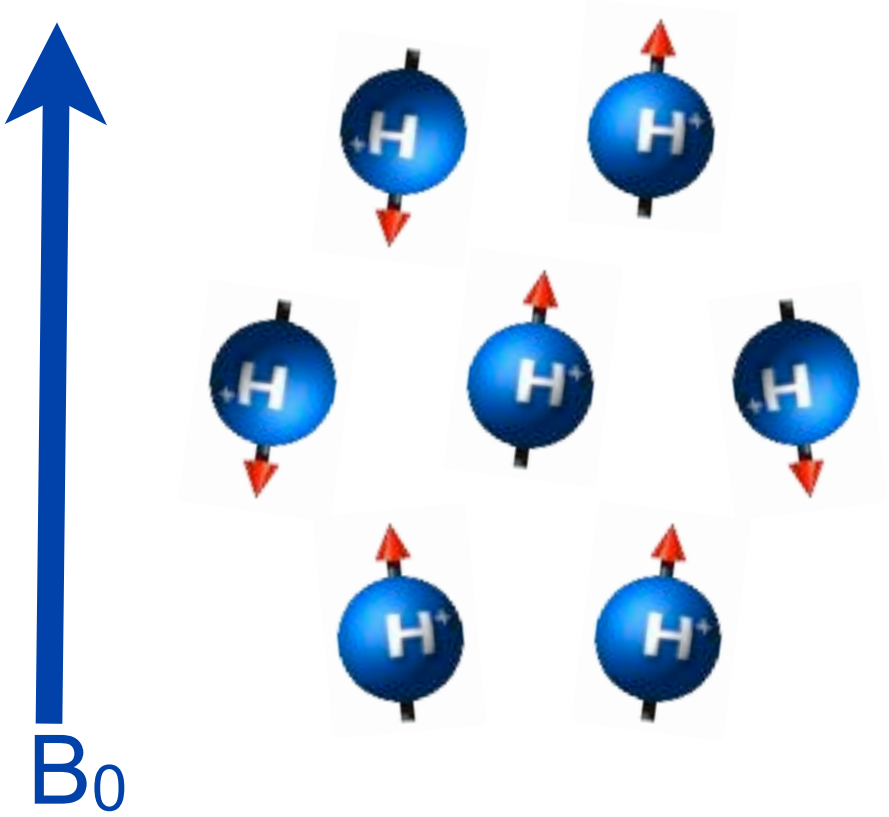
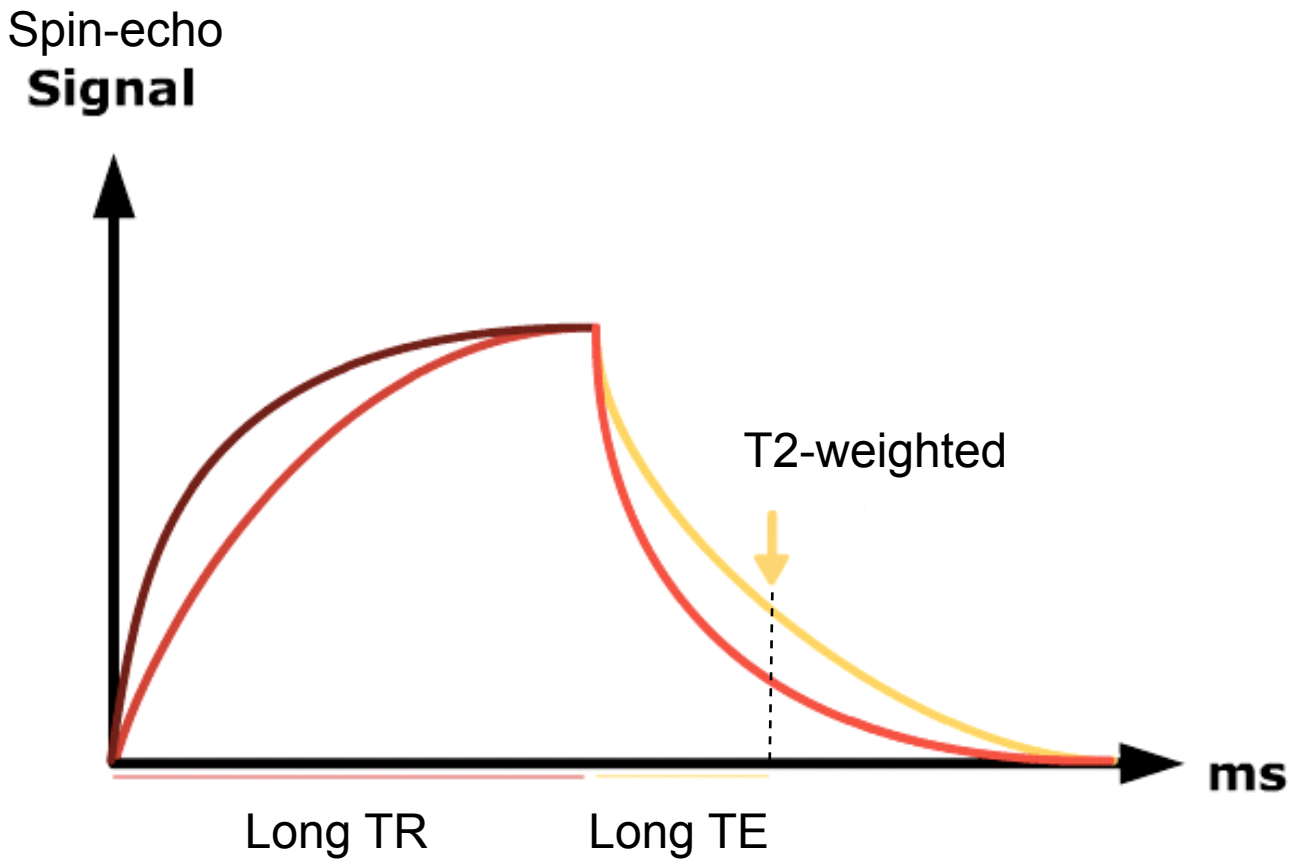
Introduction to Diffusion MR Imaging

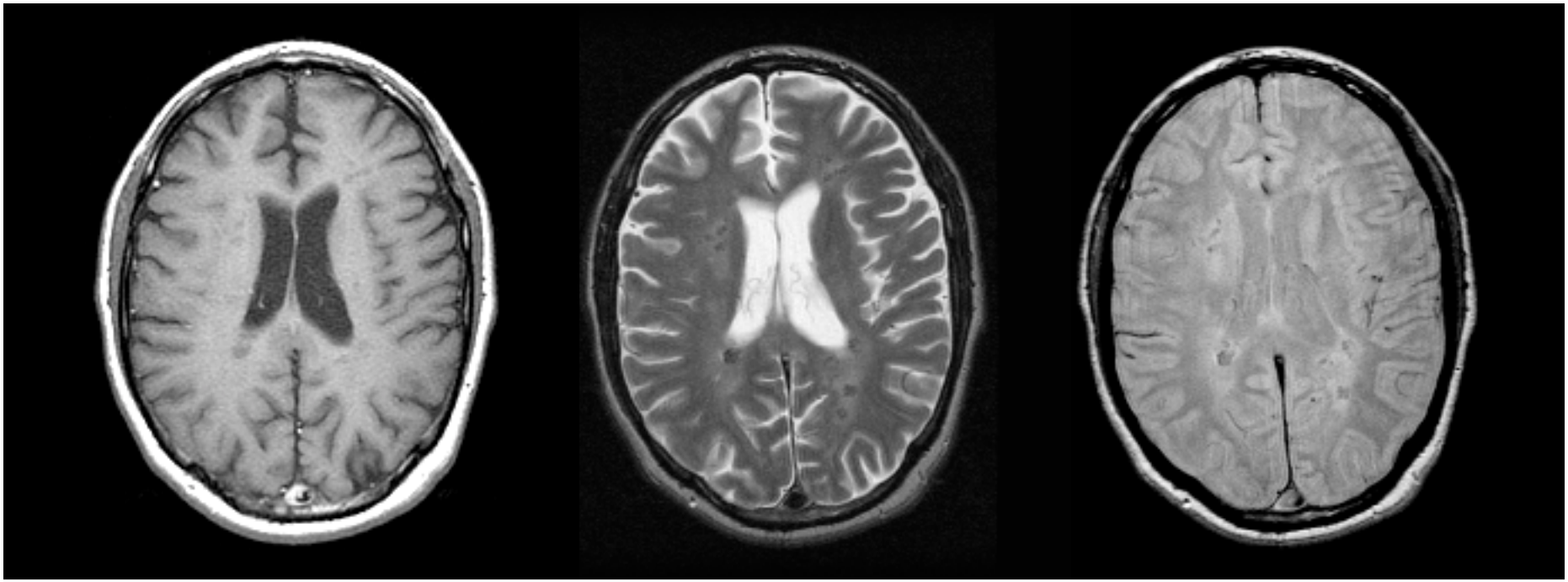
Tissue contrast



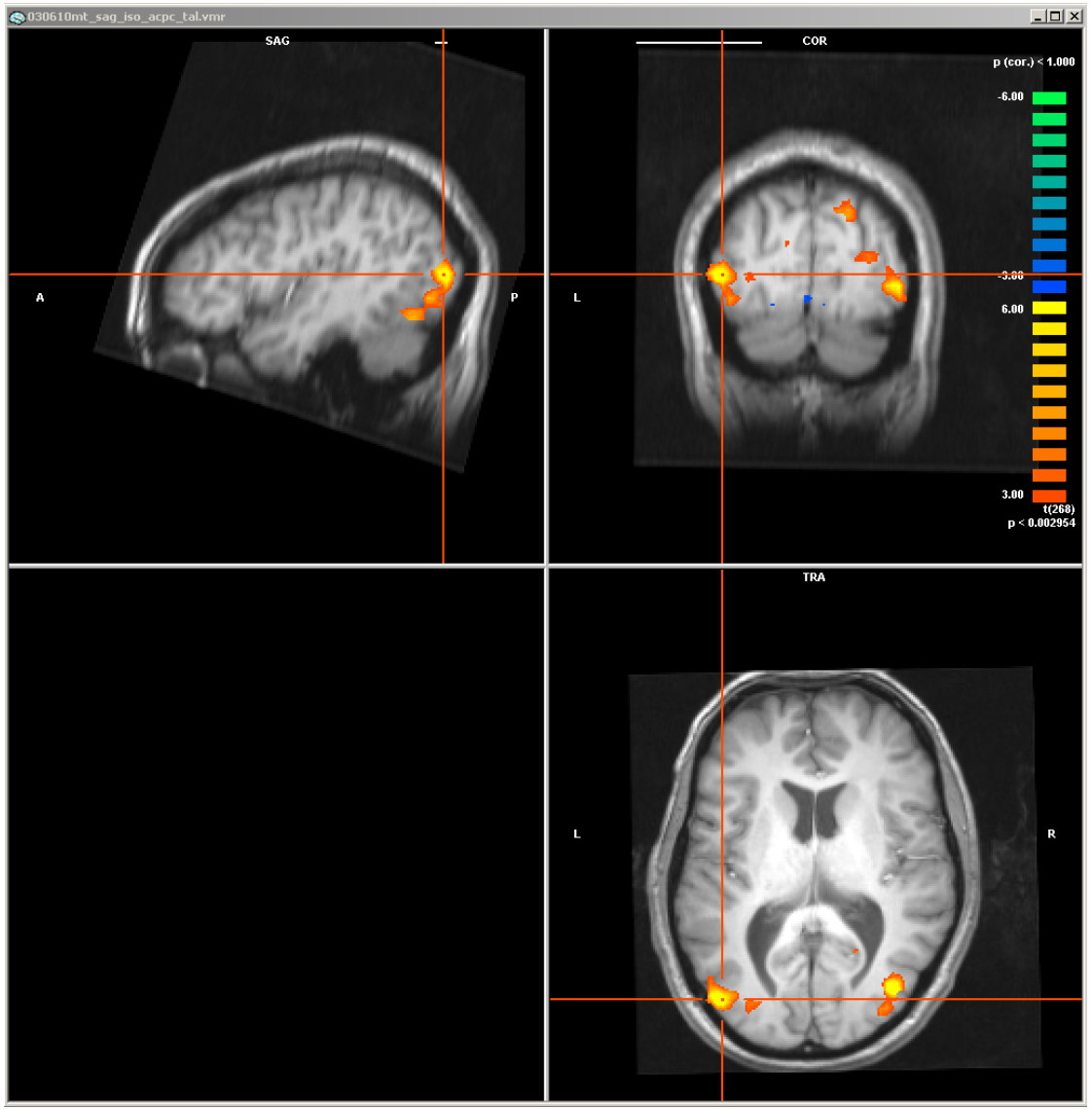
Tissue contrast



Tissue contrast

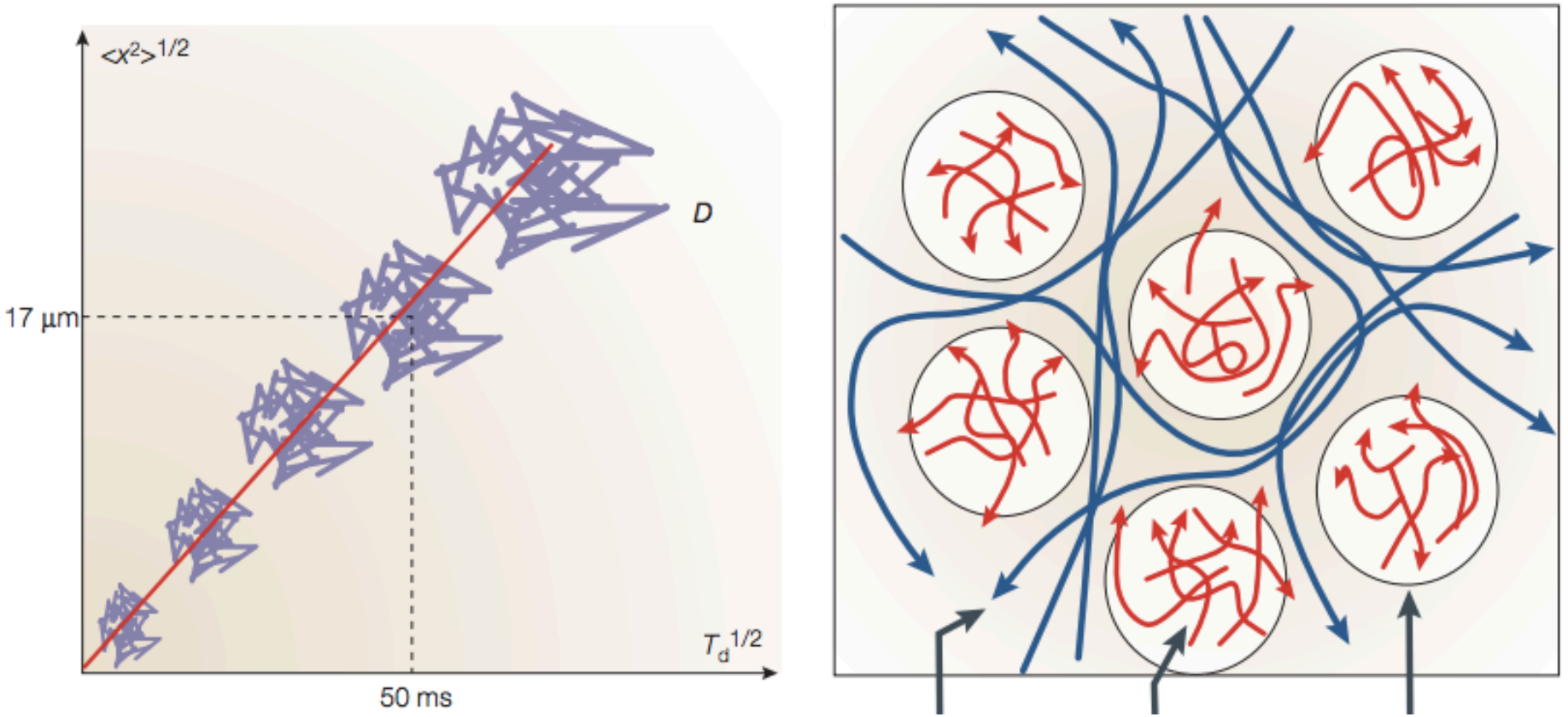


T1 T2 PD


030610mt_sag_iso_acpc_tal.vmr
SAG
A
P
COR
L
p (cor.) < 1.000
-6.00
-3.00
6.00
3.00
t(268)
p < 0.002954
TRA
L
R

BOLD fMRI

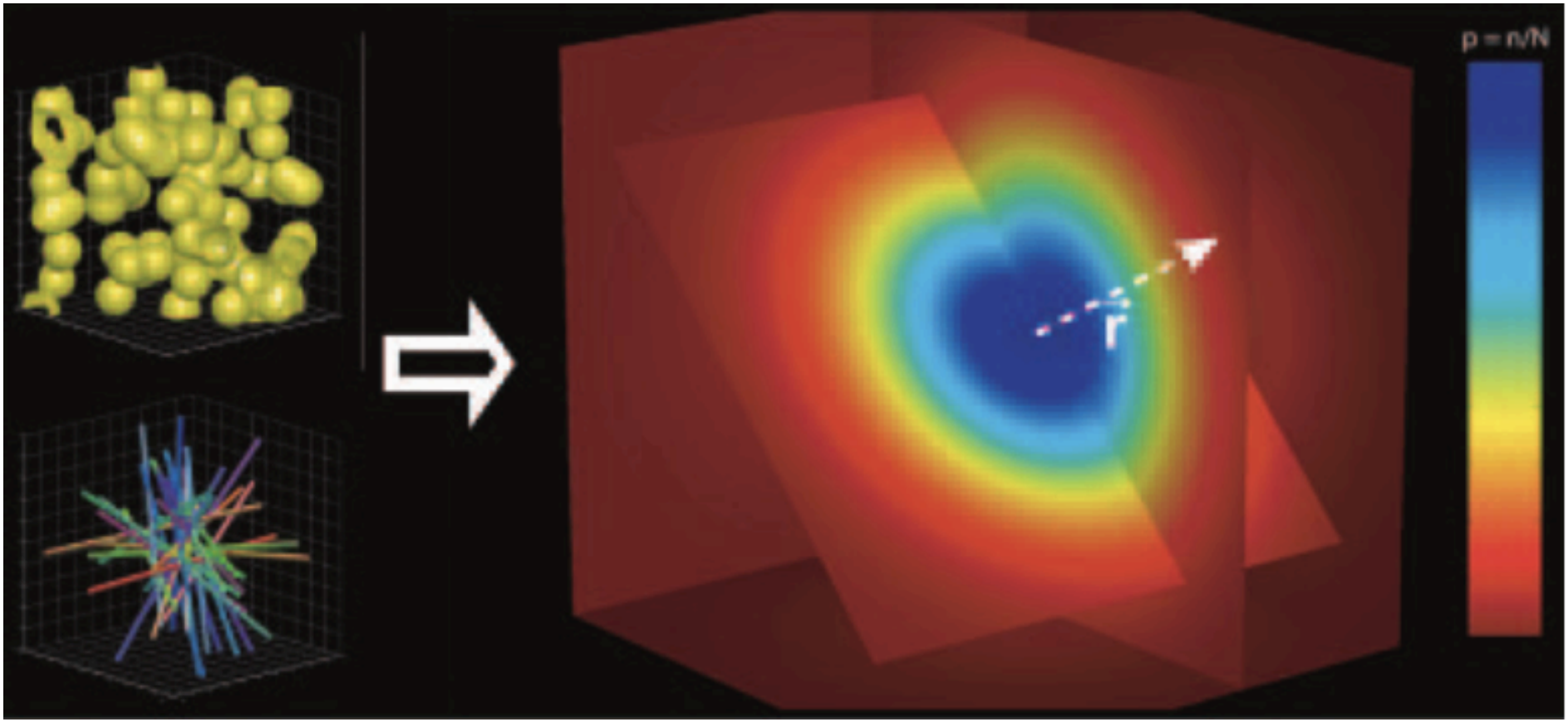
Diffusion In Tissue



Le Bihan D., Nat Rev Neurosc, 2003.

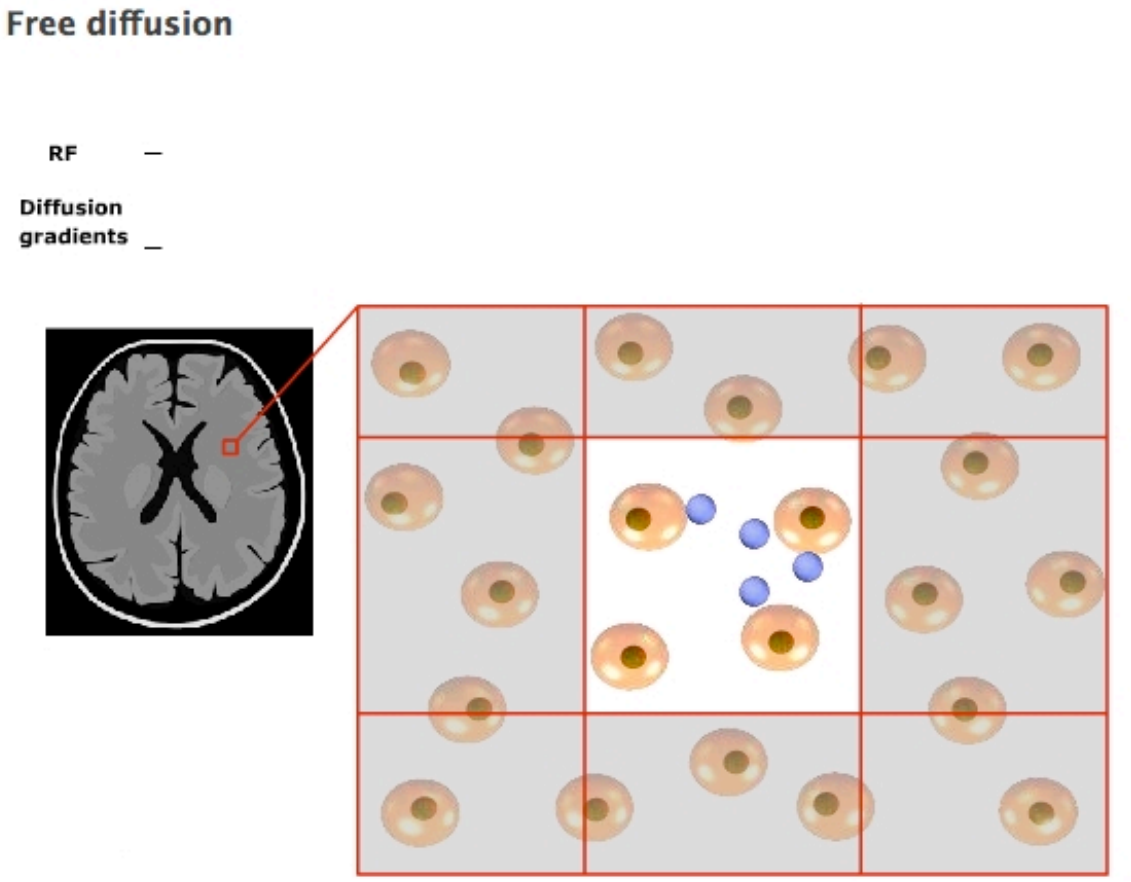
Diffusion coefficient of a water molecule is lower in tissue than in free water because of the presence of cellular structures that slow the water diffusion.

Assumption of isotropy

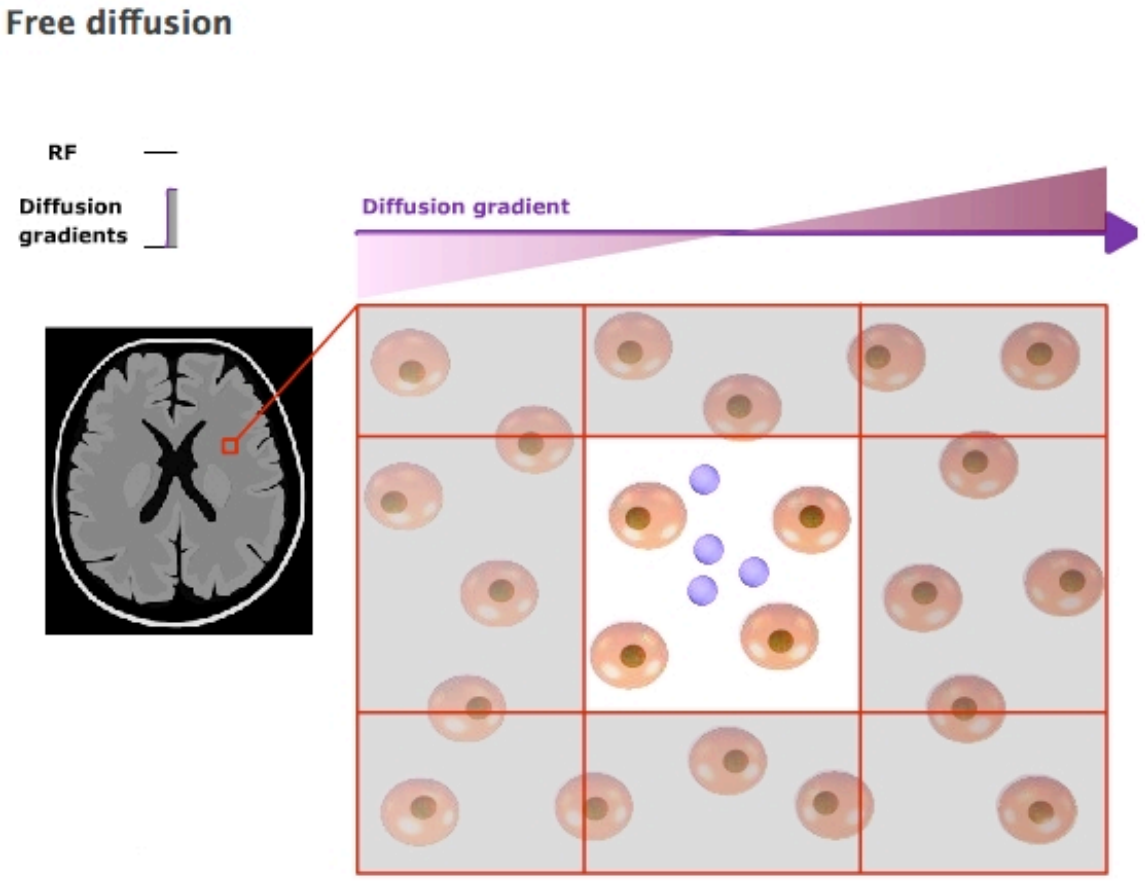


Hagmann P., et al. Radiographics (2006)

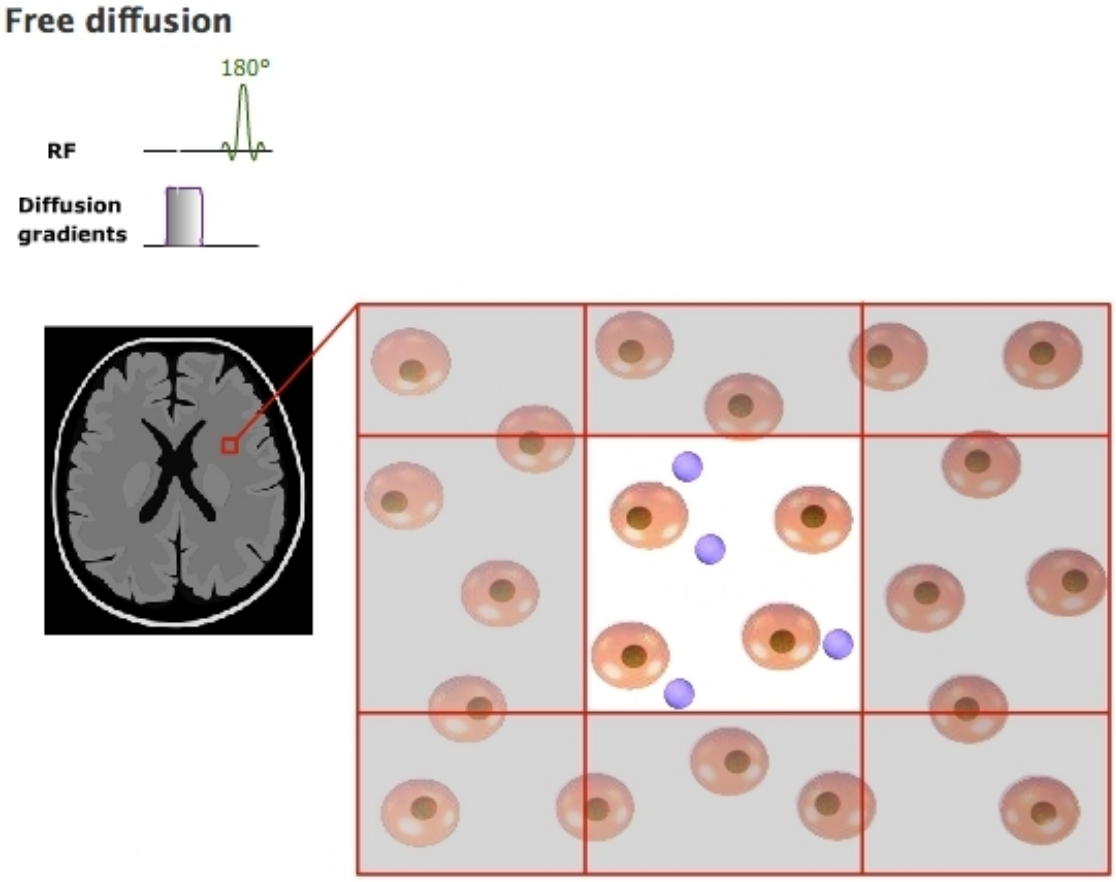
Diffusion-Weighted MRI Sequence



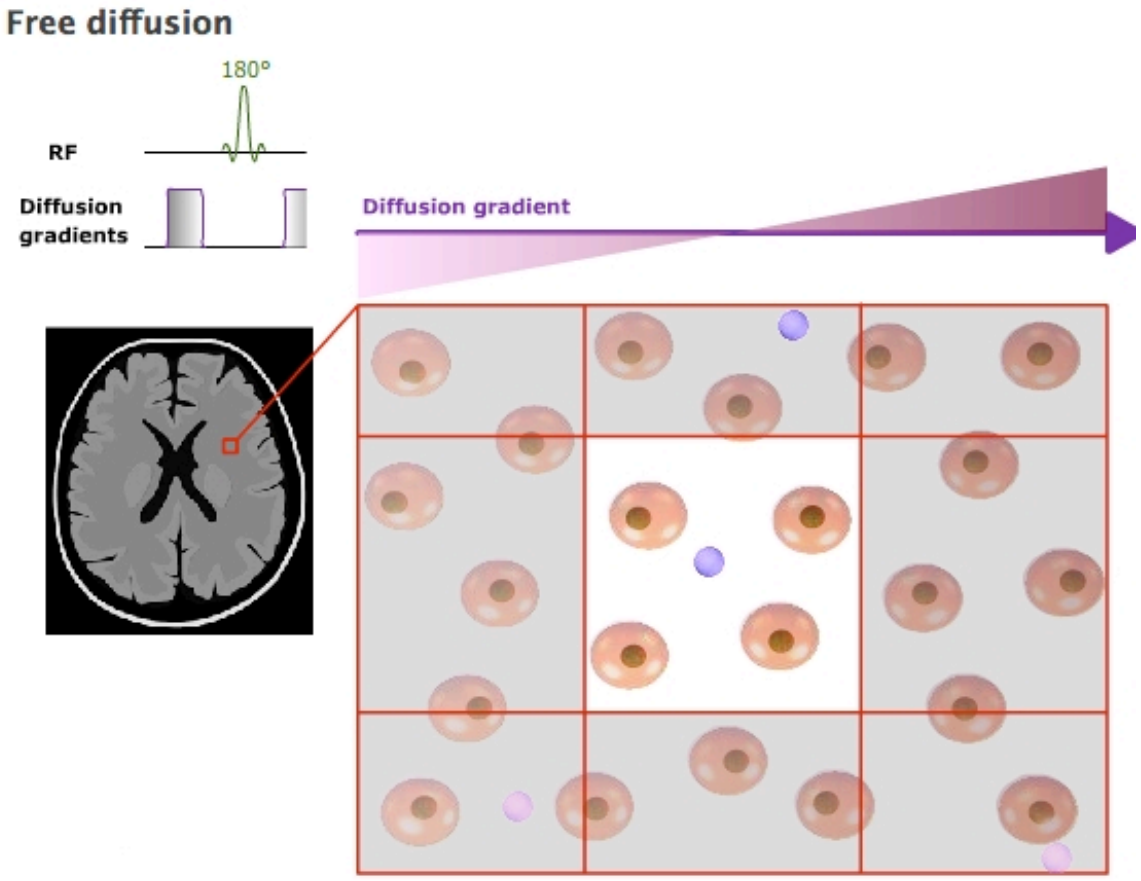
Diffusion-Weighted MRI Sequence



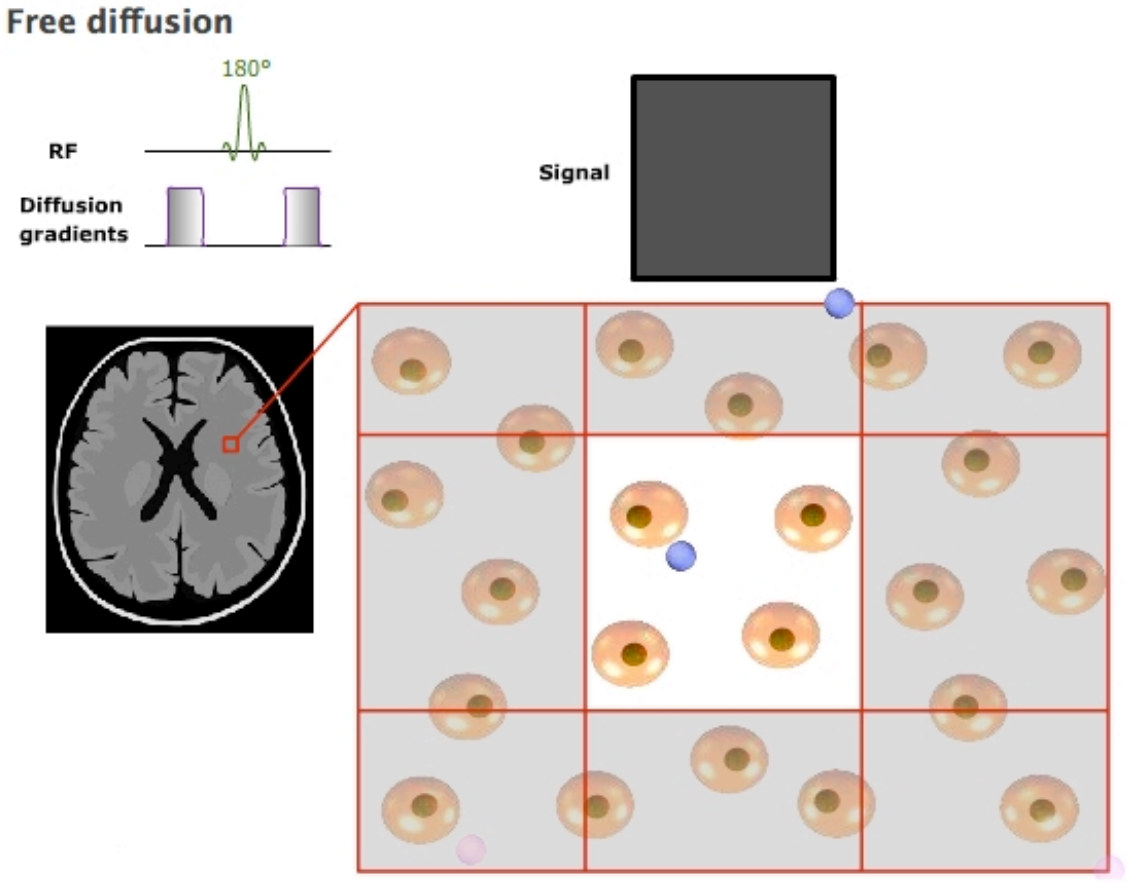
Diffusion-Weighted MRI Sequence



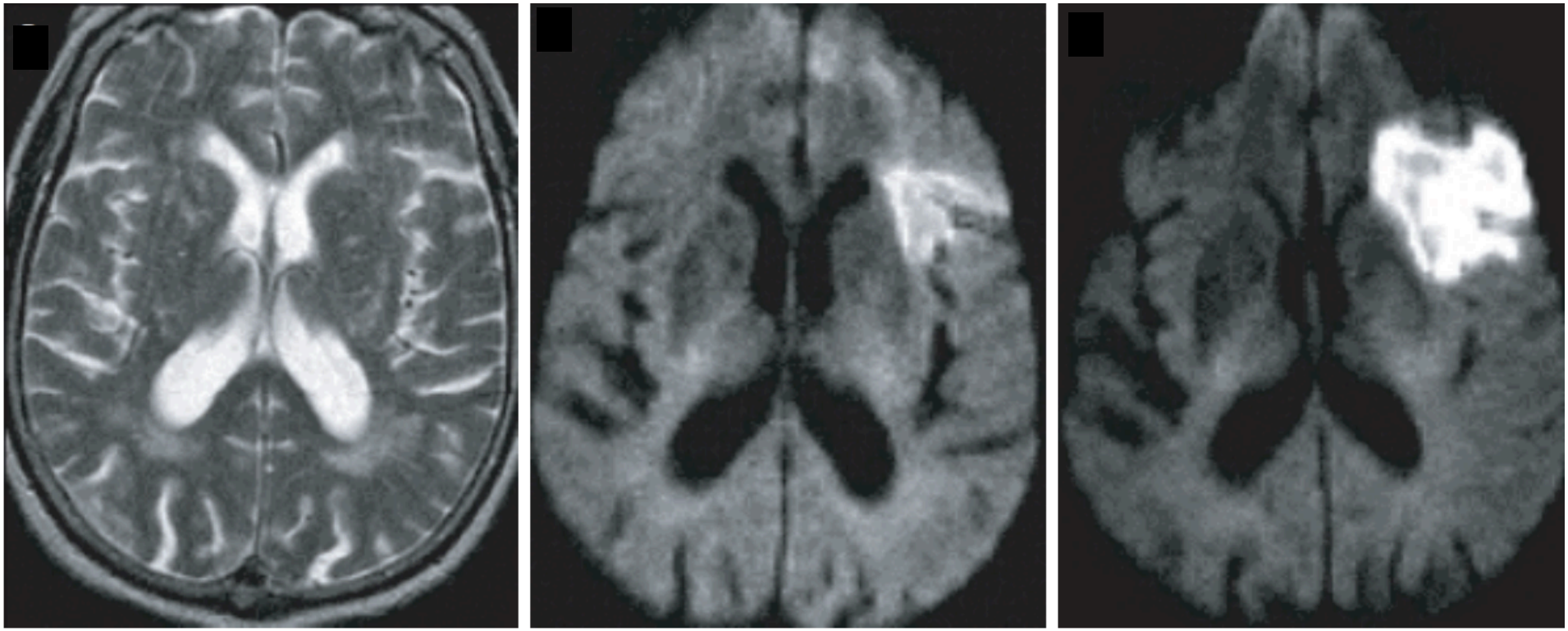
Diffusion-Weighted MRI Sequence



Diffusion-Weighted MRI Sequence



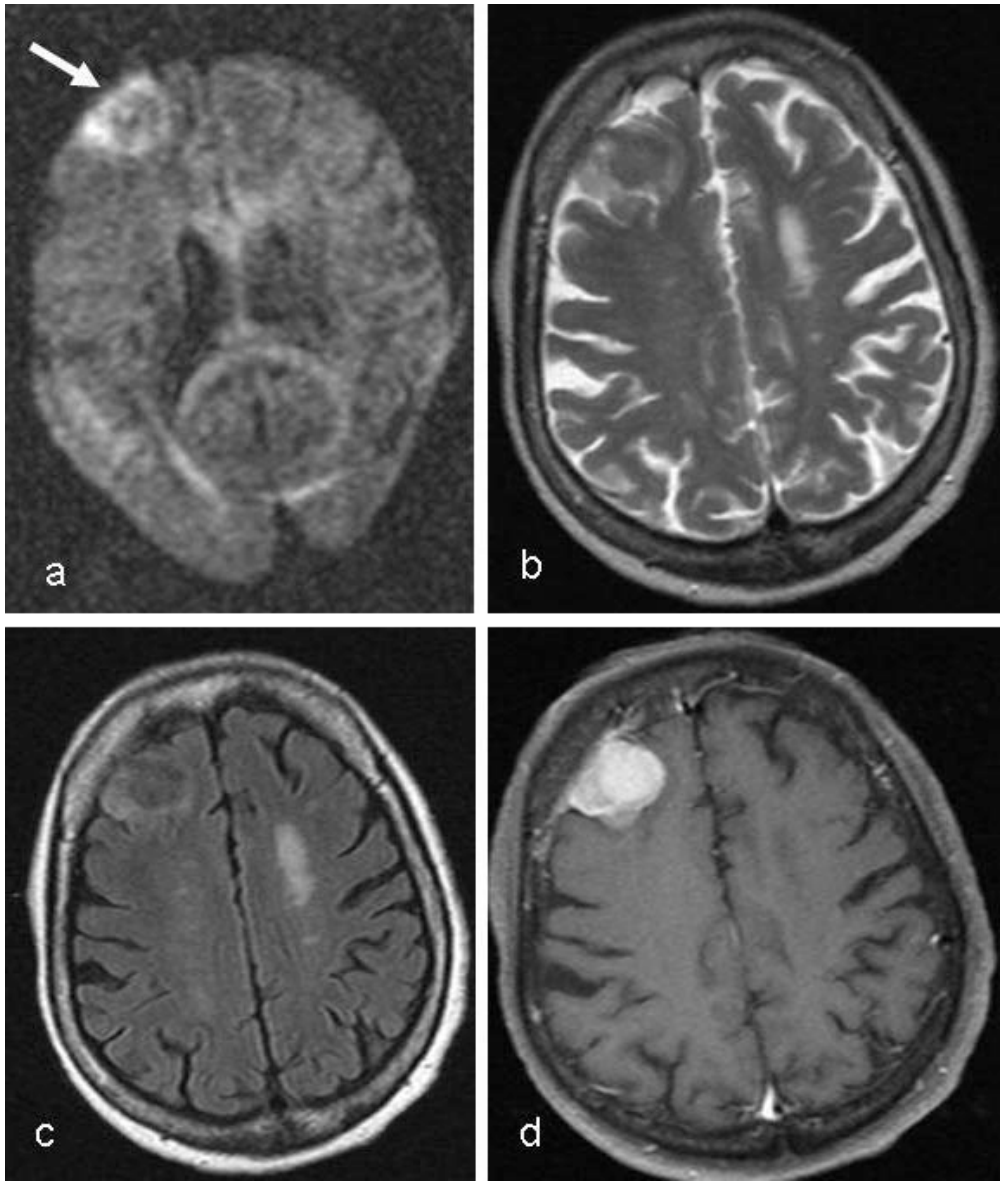
Diffusion MRI applications



Le Bihan D., Nat Rev Neurosc, 2003.

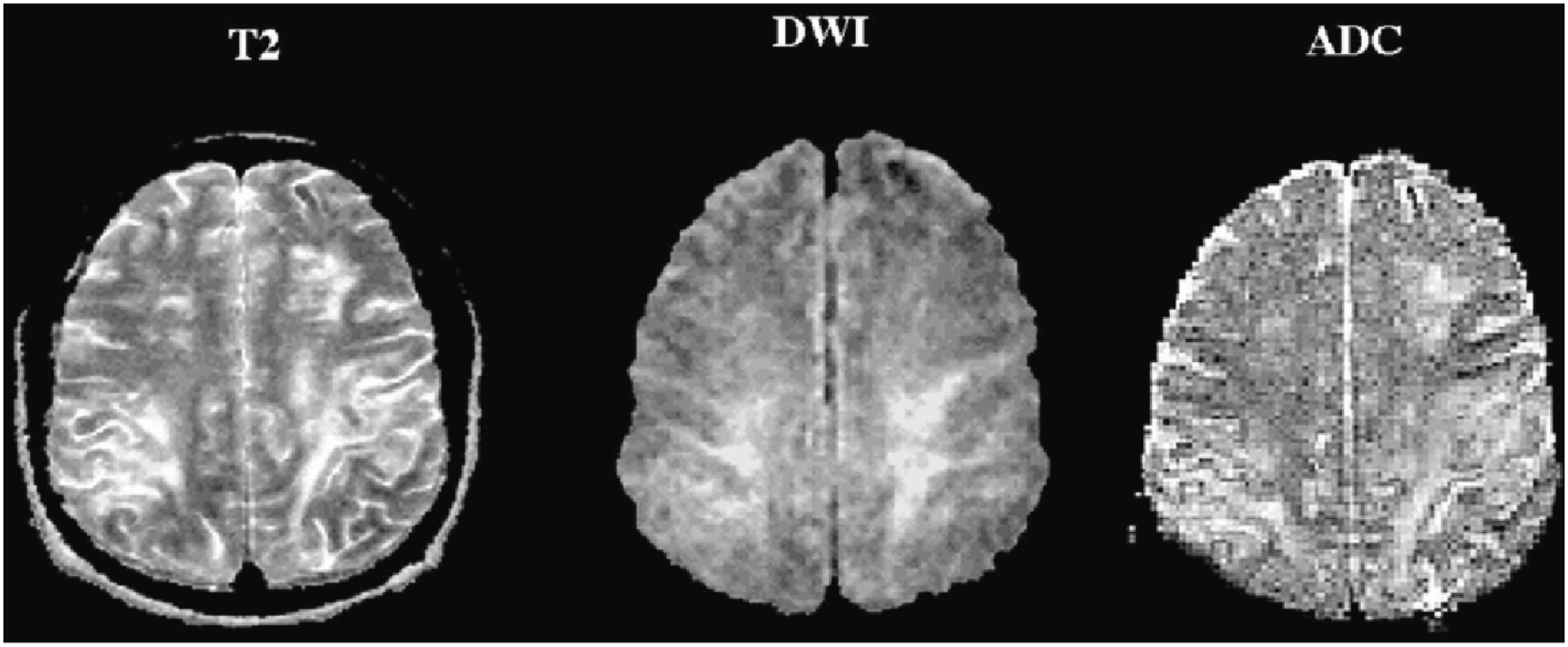
Acute ischaemia: T2w MRI, DW-MRI 3 hrs and 5 days after onset of aphasia

Diffusion MRI applications



Meningioma

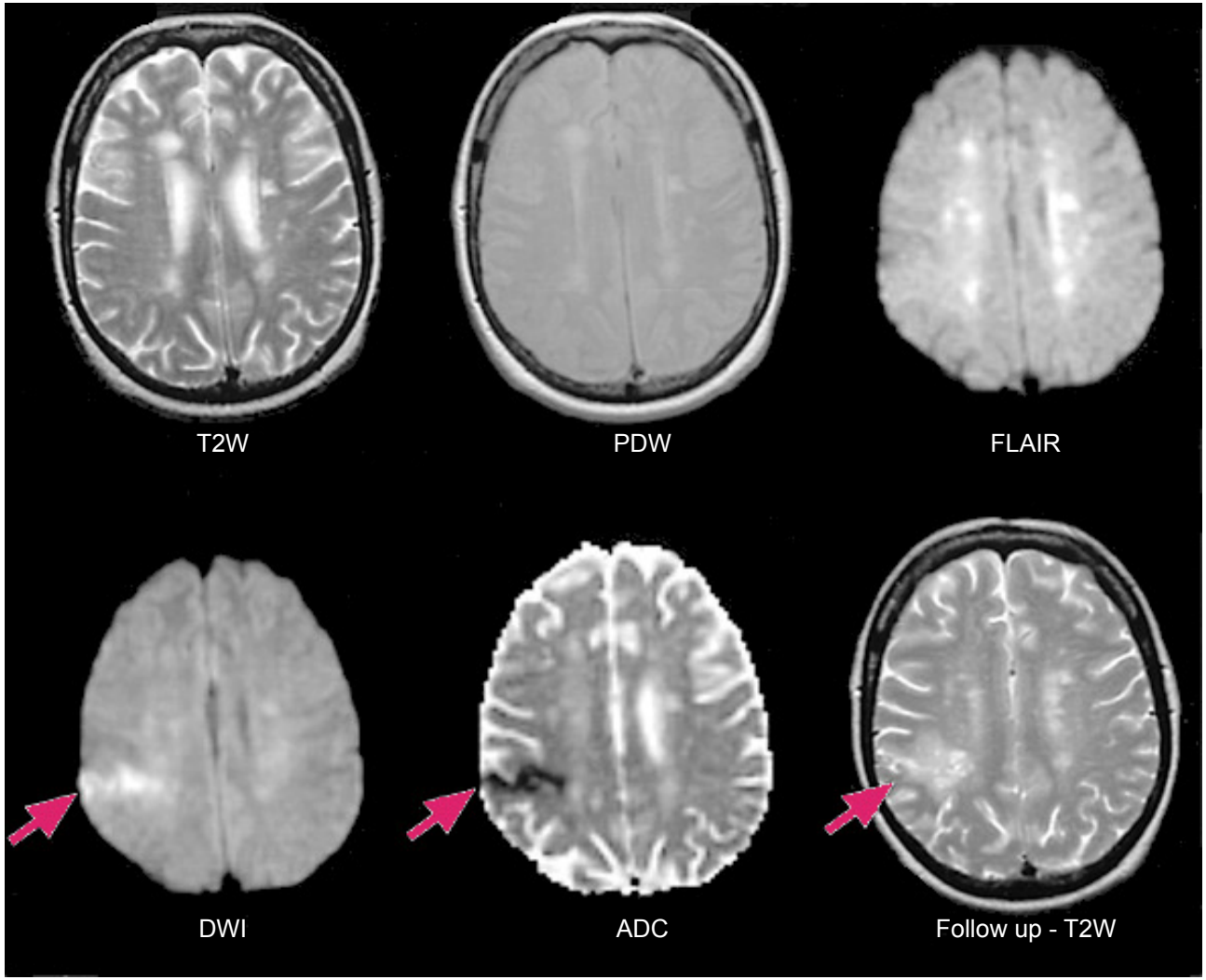
Diffusion MRI applications



Schaeferr PR., Journal of the Neurological Sciences (2001)

Vasogenic edema

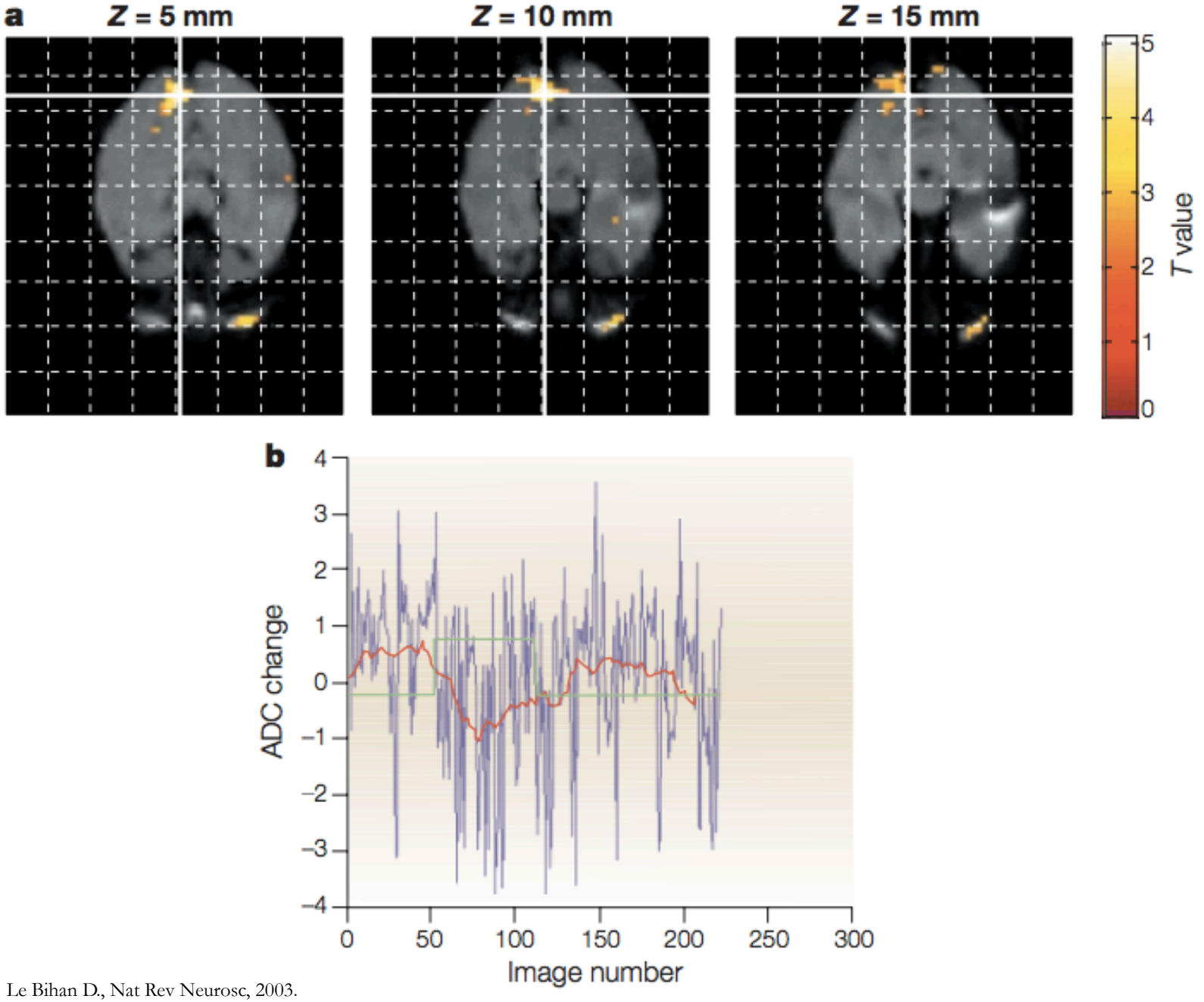
Diffusion MRI applications



Lansberg MG, et al. Arch Neurol. (2000)

65-year-old woman 7 hours after the acute onset of left arm discoordination

Diffusion MRI applications

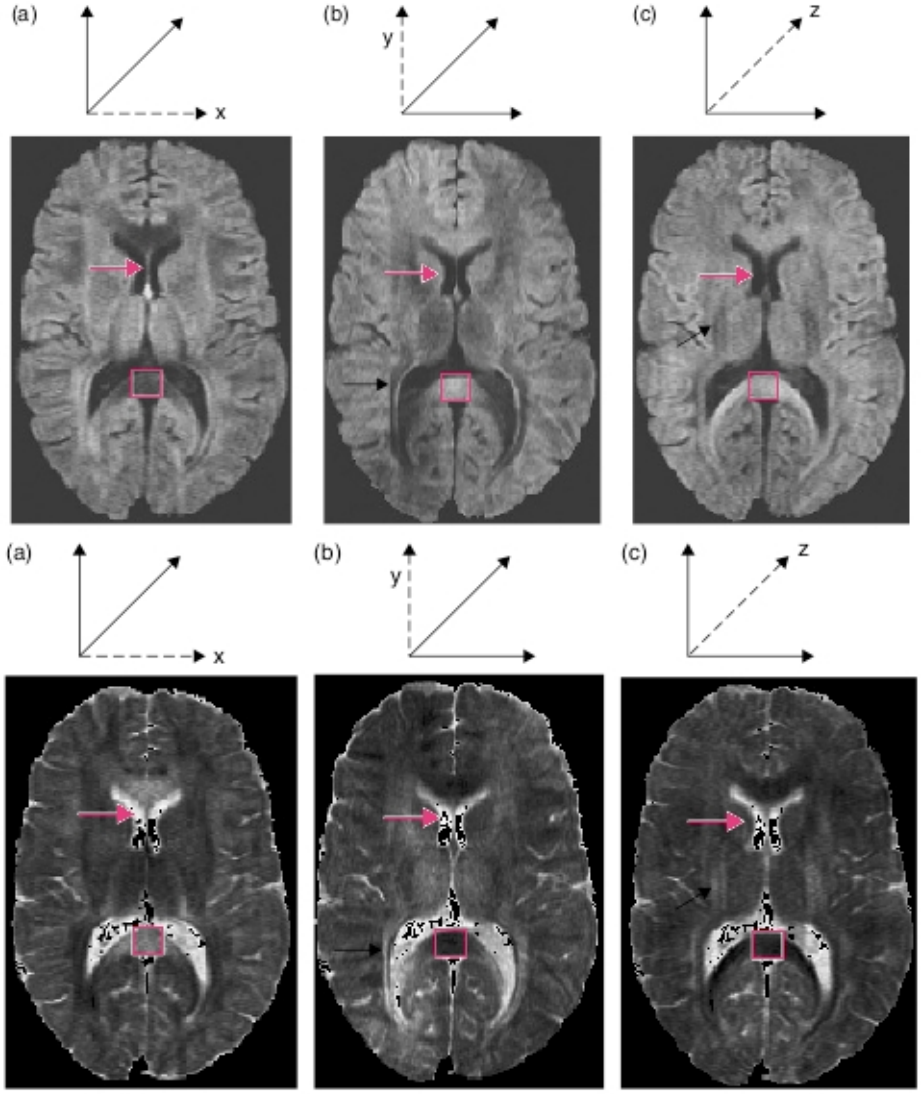


Le Bihan D., Nat Rev Neurosc, 2003.

Diffusion-Weighted MRI Limitations

DWI signal

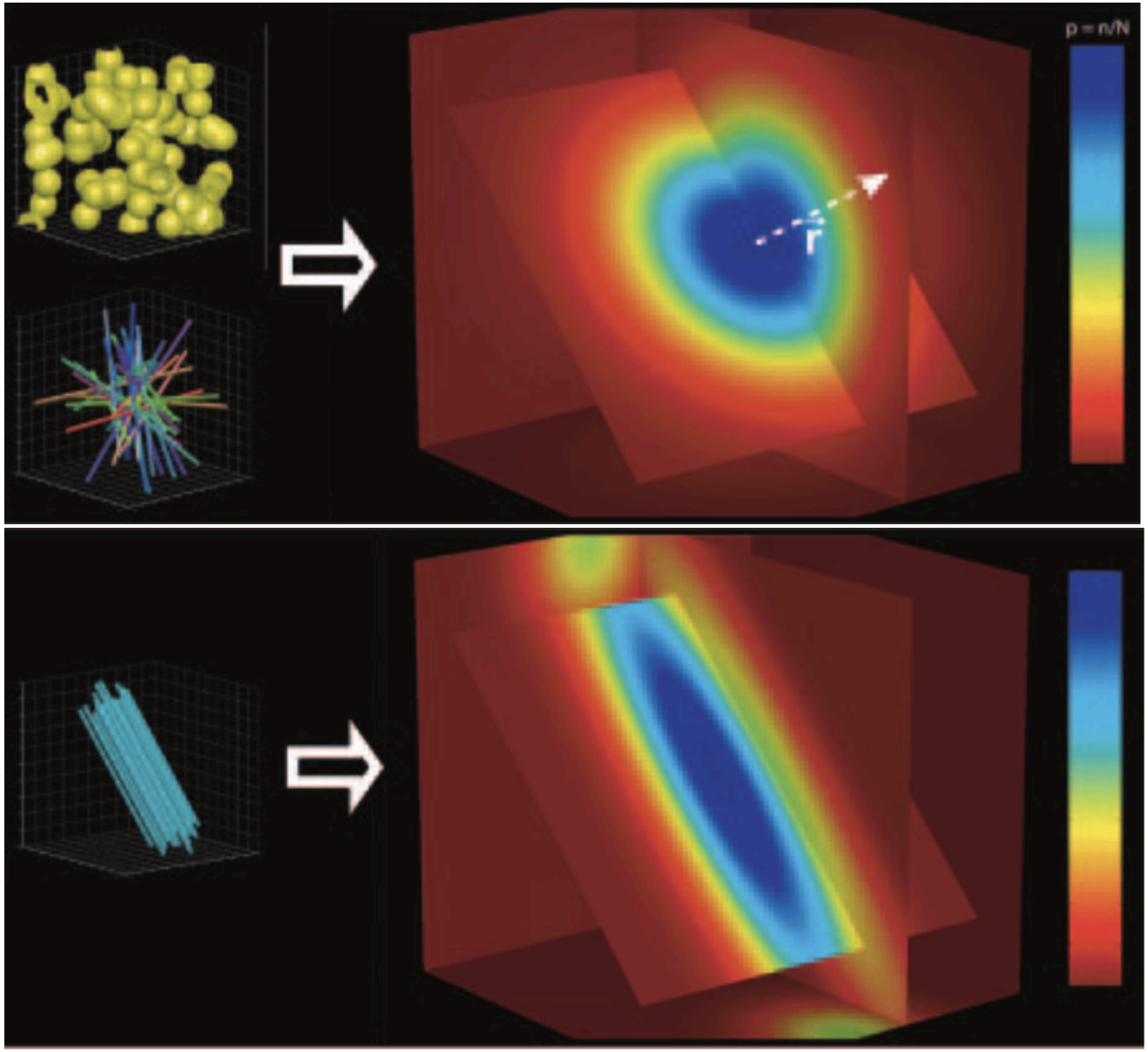
ADC



Paul Toft, Quantitative MRI of the brain. John Wiley & Sons Ltd (2003)

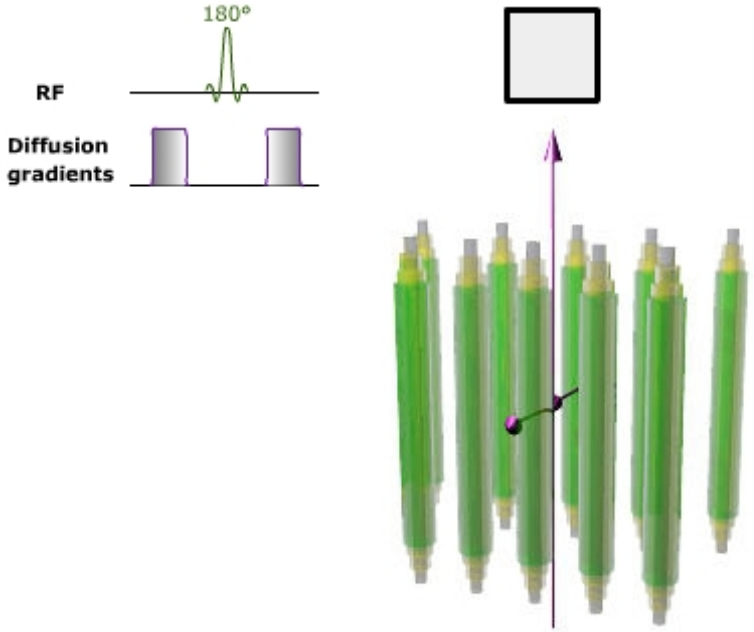
The main drawback of DWI is that the results depend on the direction of the applied gradients

Apparent Diffusion Component (ADC) MRI Limitations

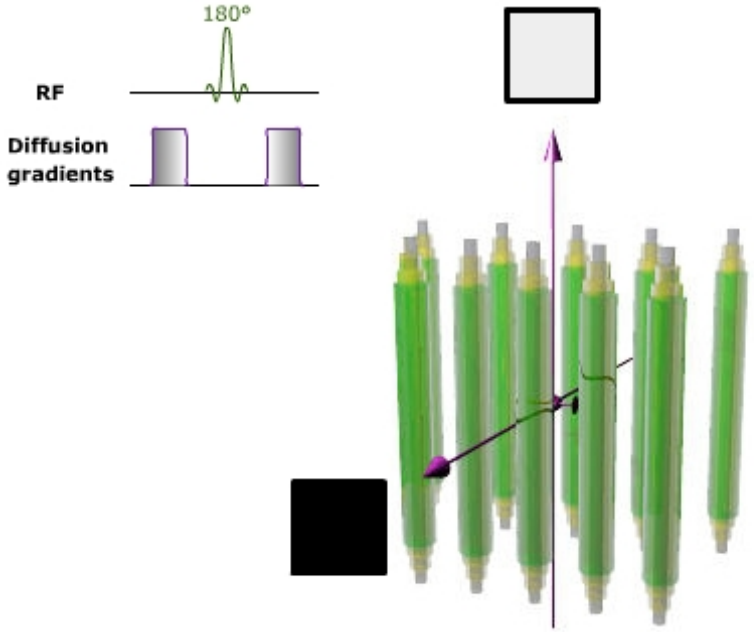


Hagmann P., et al. Radiographics (2006)

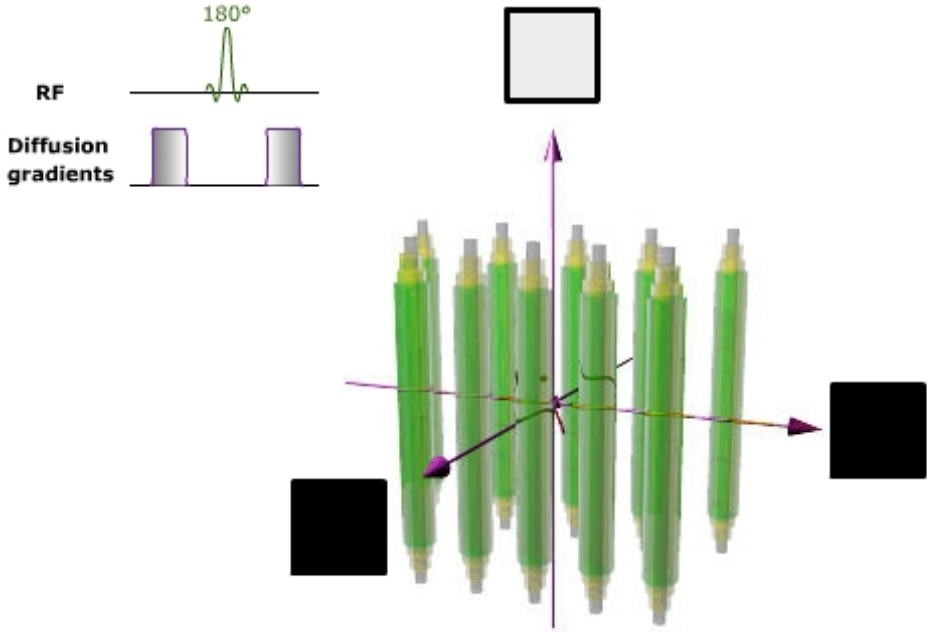
DTI Sequence



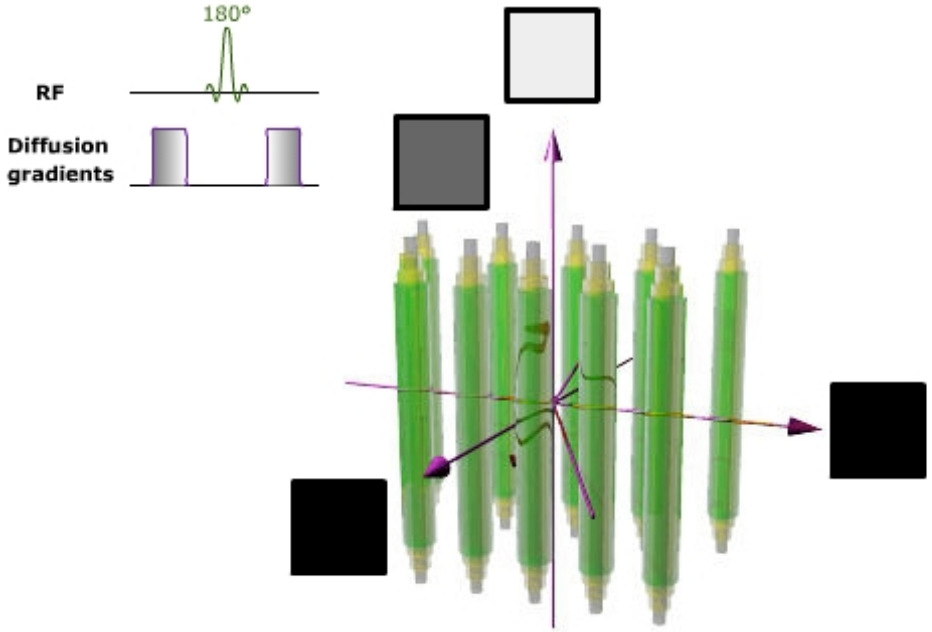
DTI Sequence



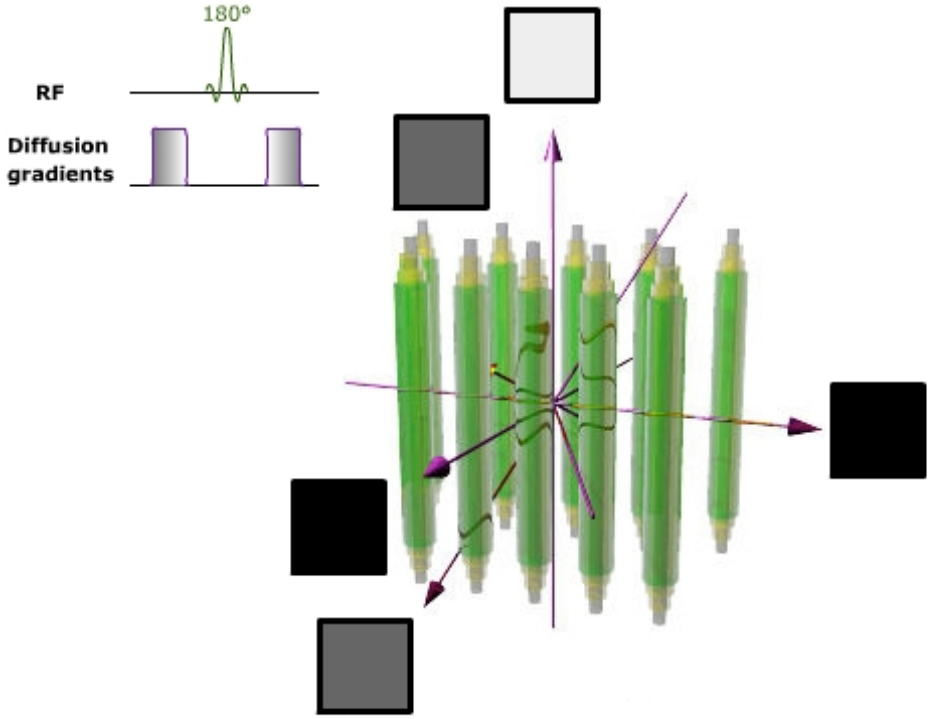
DTI Sequence



DTI Sequence



DTI Sequence



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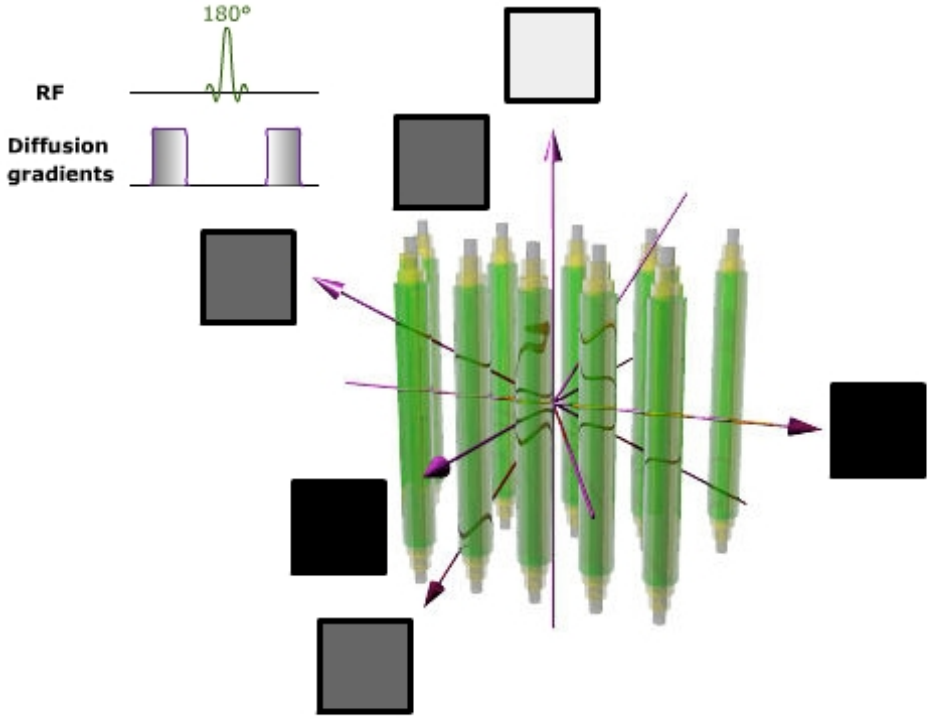
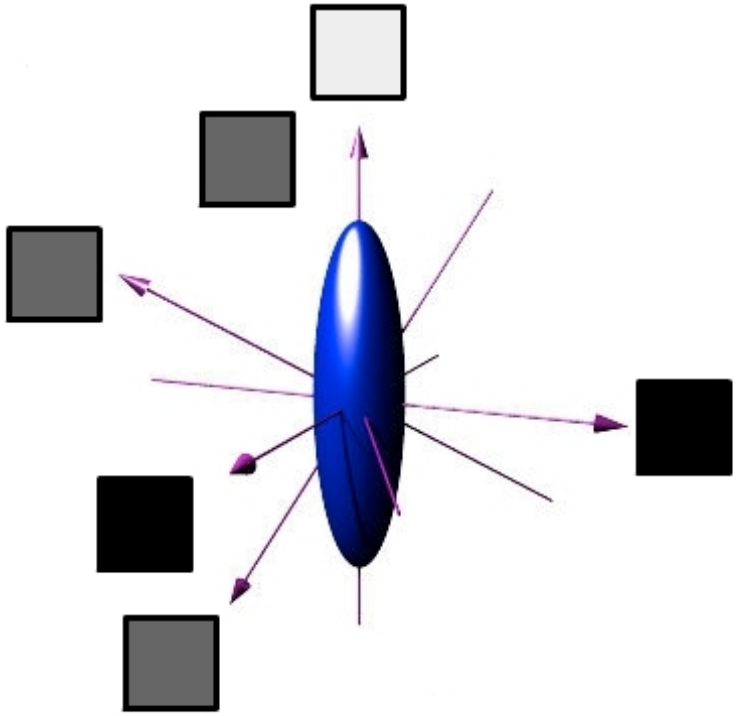
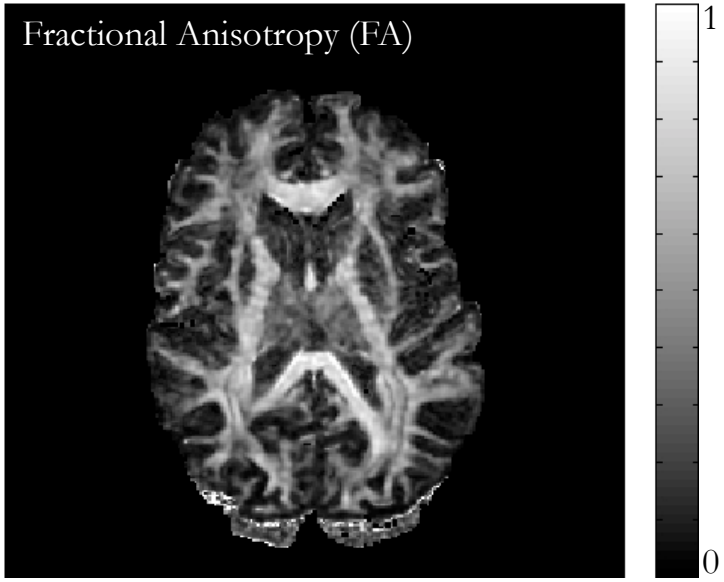
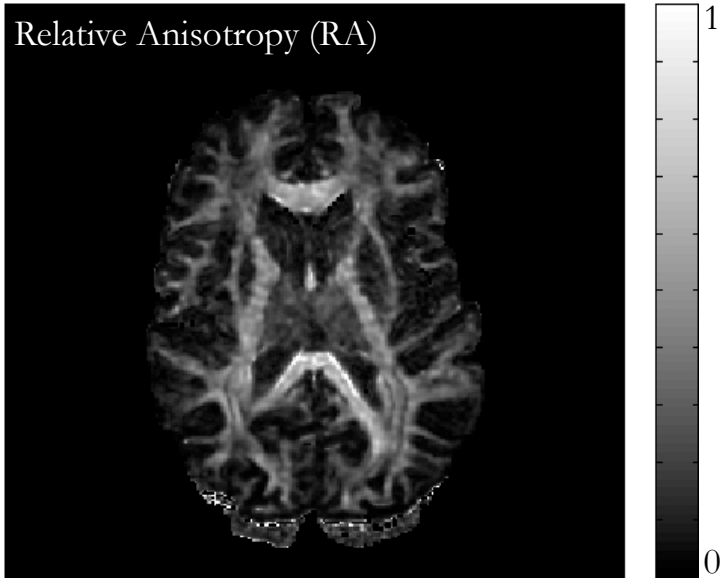


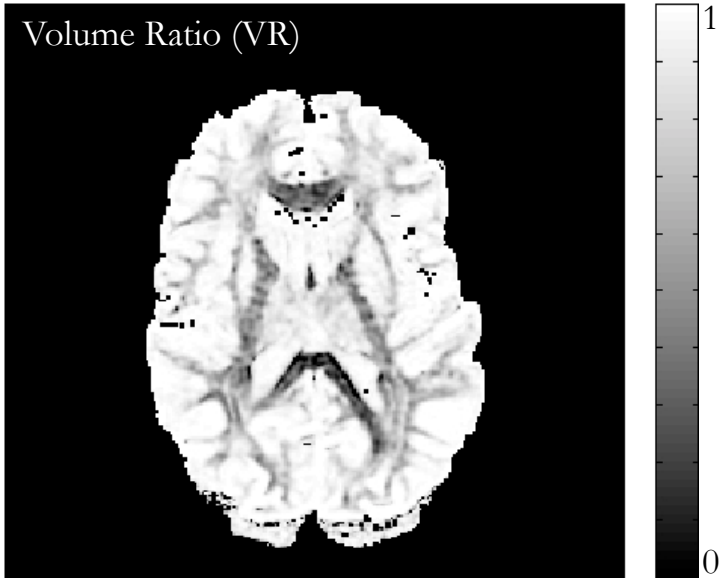
DTI Sequence

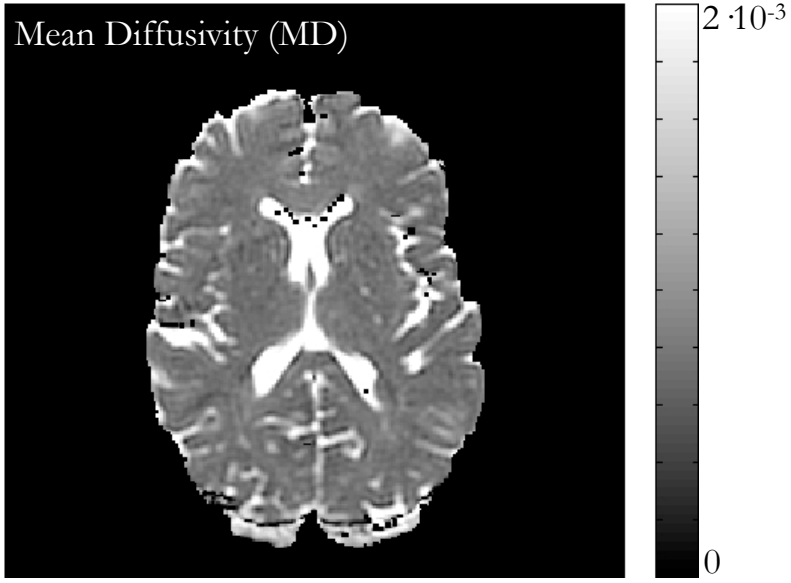


DTI - Measures

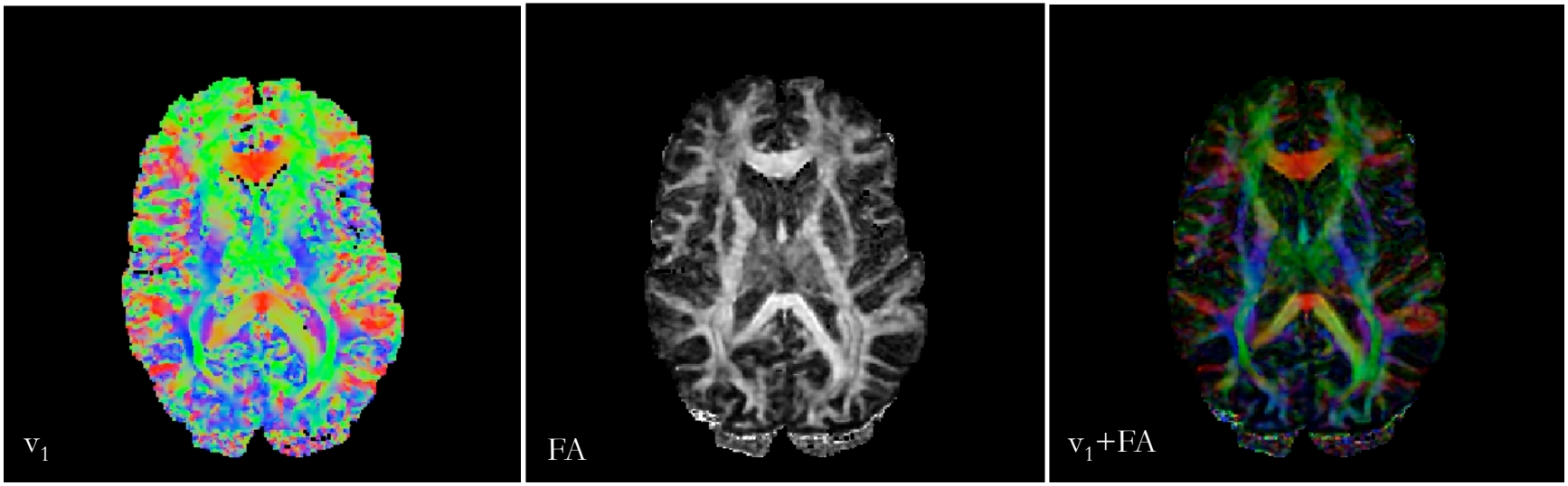








DTI - Visualization



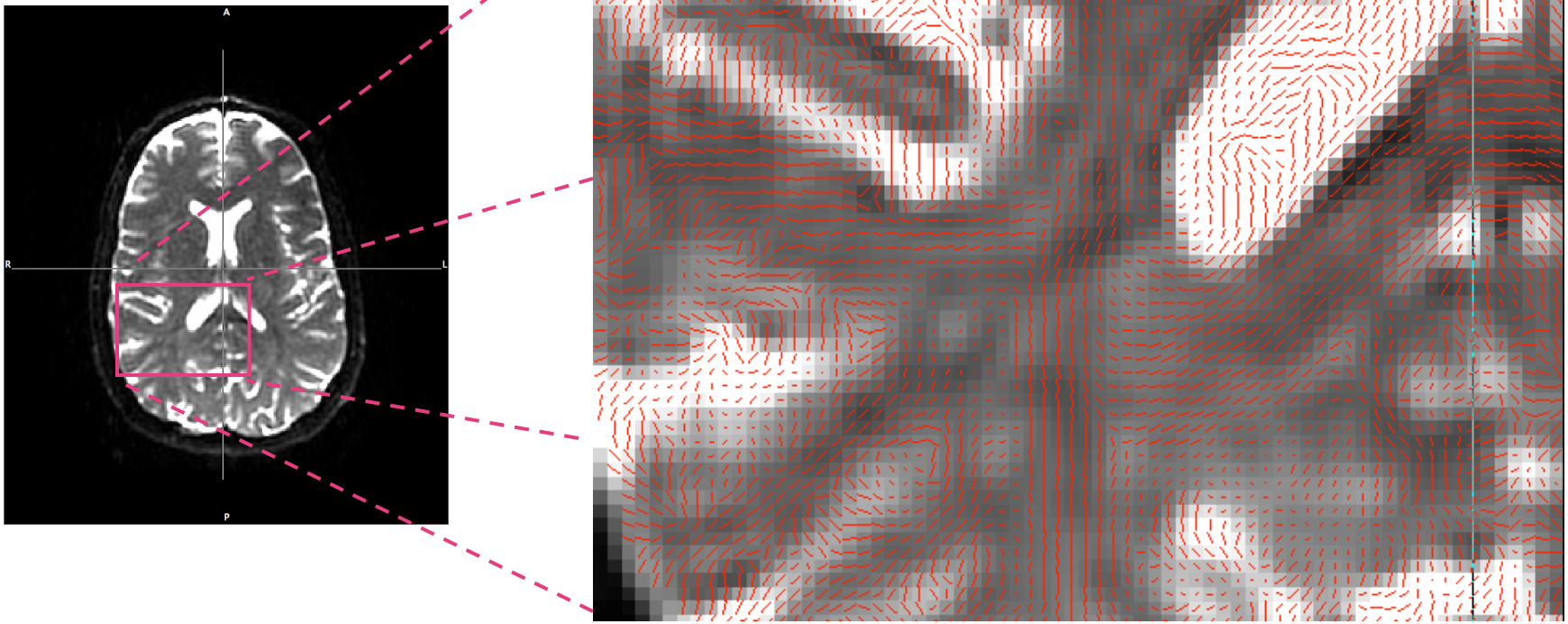
RGB code (— red | green • blue)

- The eigenvectors carry information about the diffusion tensor orientation.
- The first eigenvector (v_1) is usually used to represent the main fiber's orientation.

DTI - Visualization

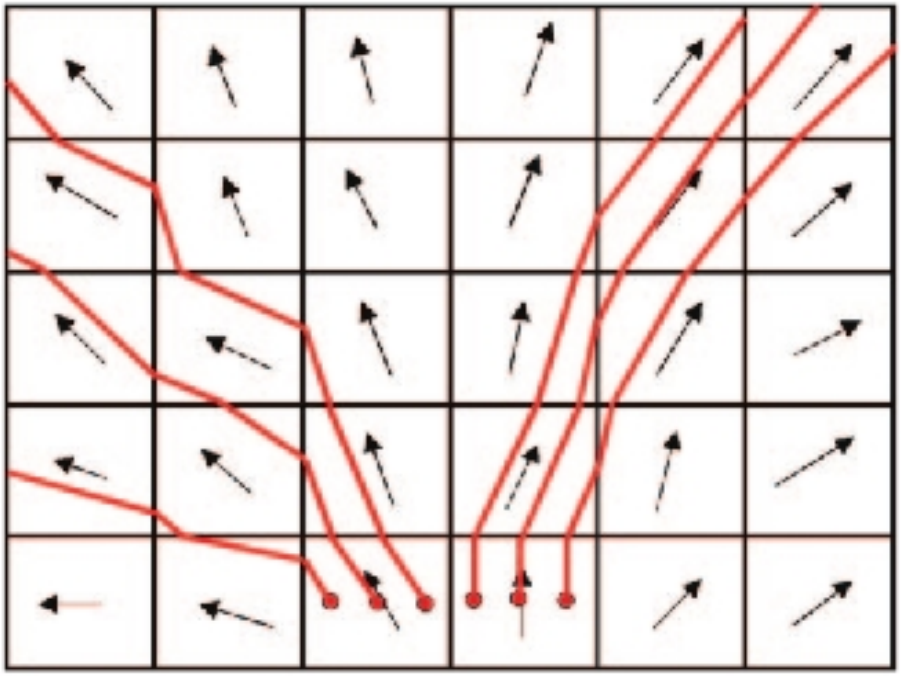
Hagmann, P. et al., Radiographics (2006)

DTI - Visualization



v_1 can also be superimposed on the anatomical image

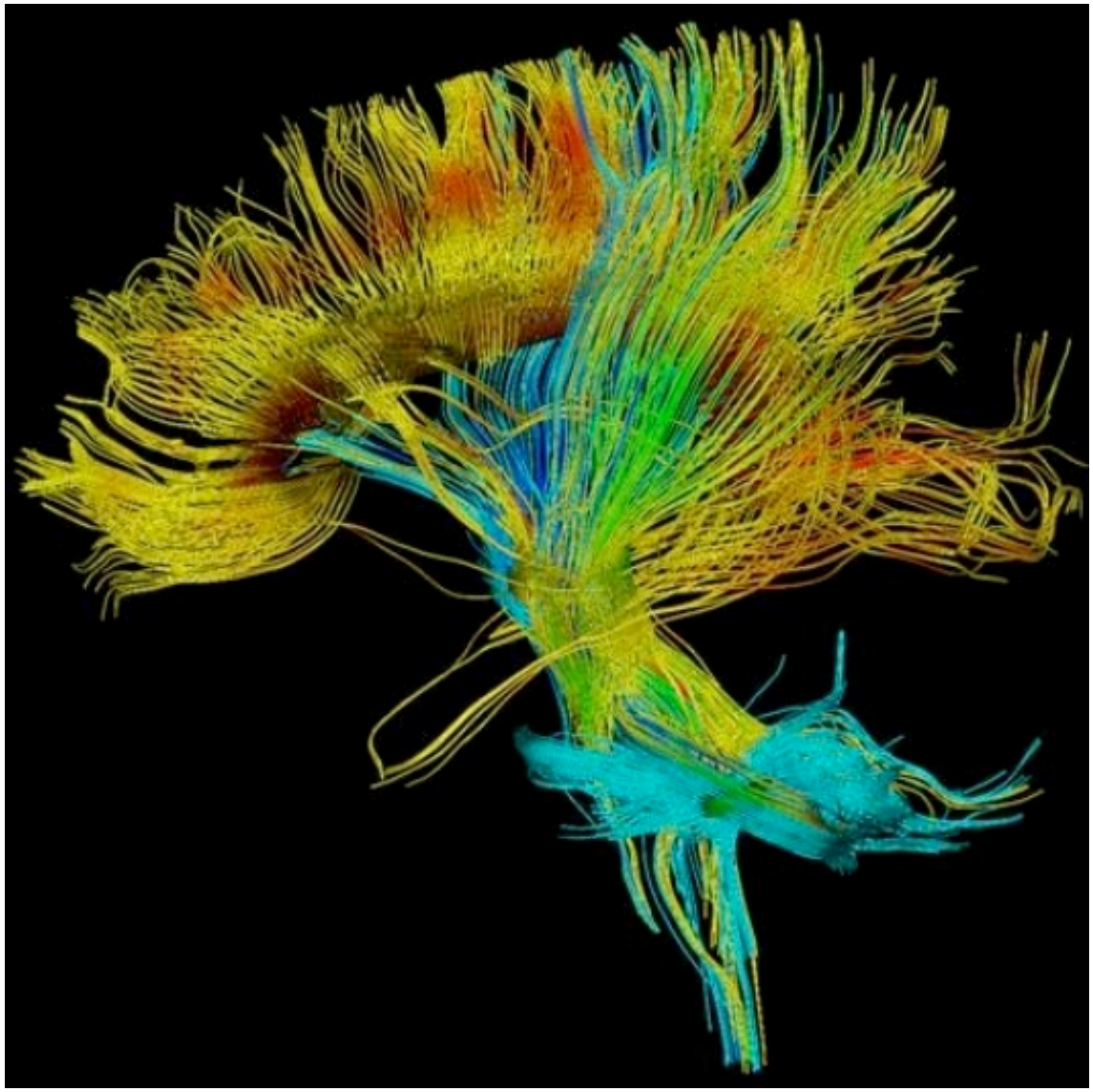
Diffusion Tractography



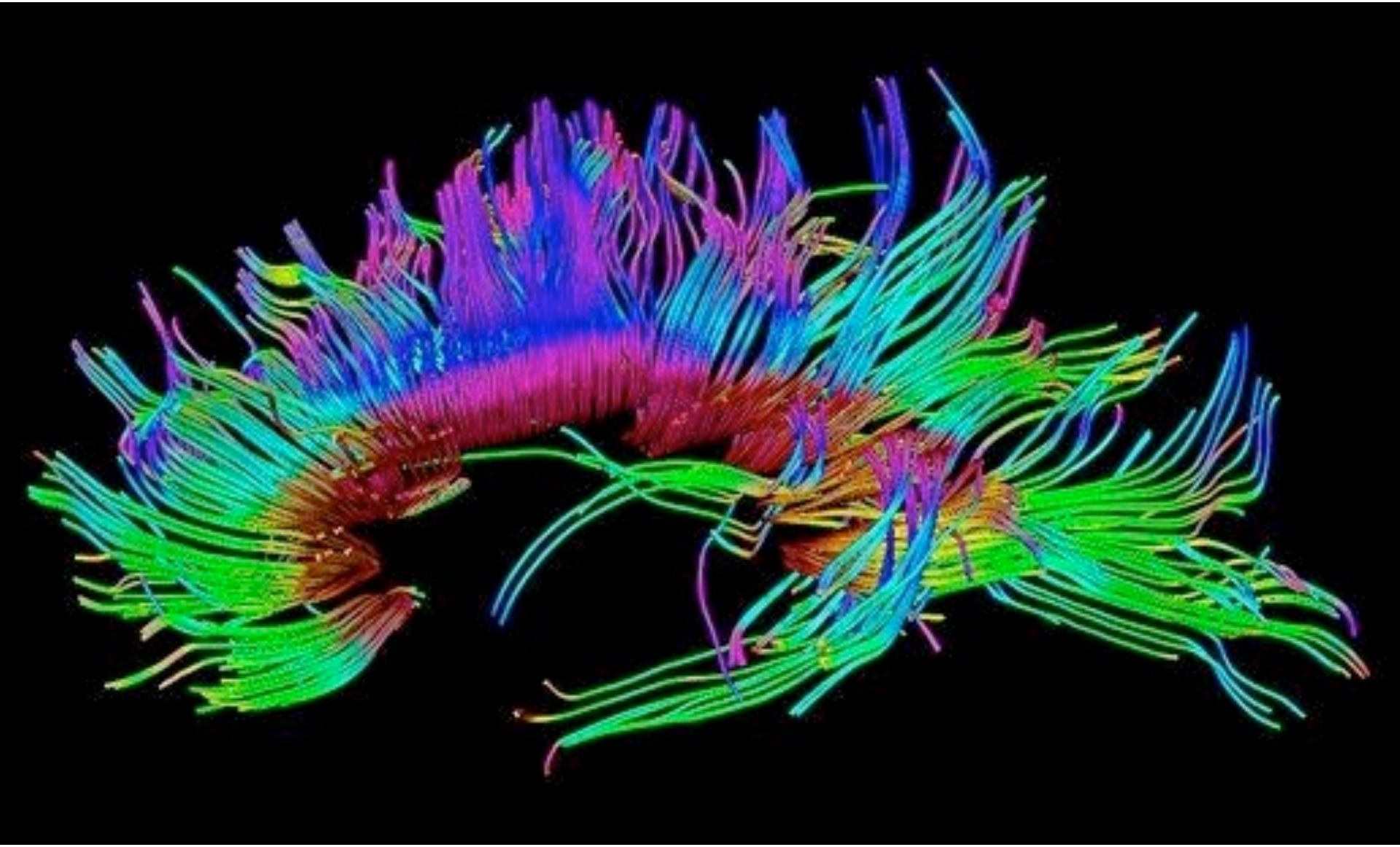
Mukherjee et al., AJNR (2008)

- Draw multiple streamlines from a given region (seed)
- Each voxel's fiber trajectory is taken to be the main tensor direction
- Stopping criteria:
  - maximum turning angle
  - minimum FA
  - region

Diffusion Tractography

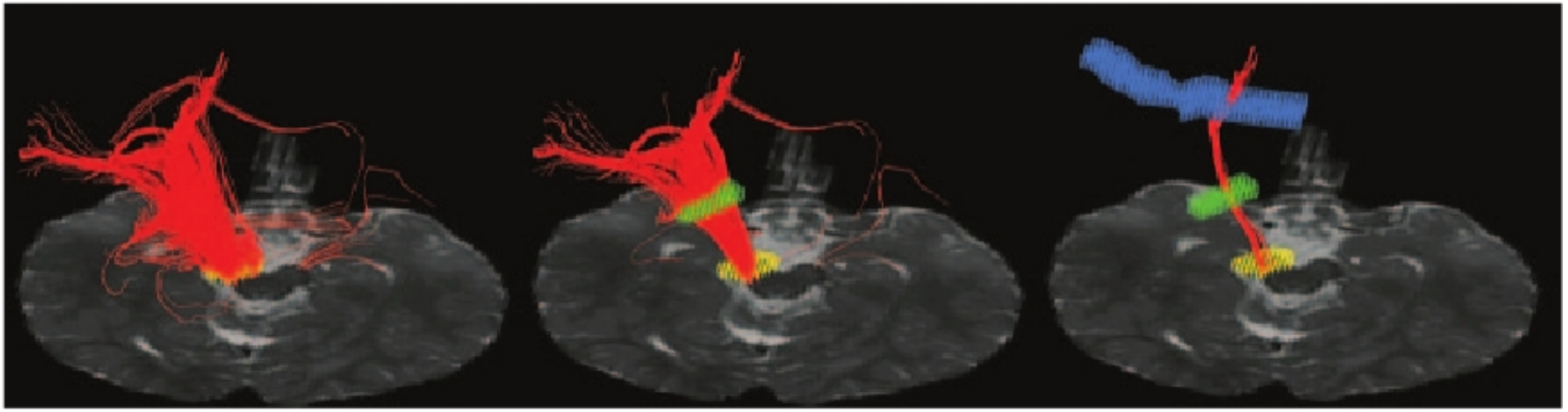


Diffusion Tractography



Wiegall et al., 2003, Kirby

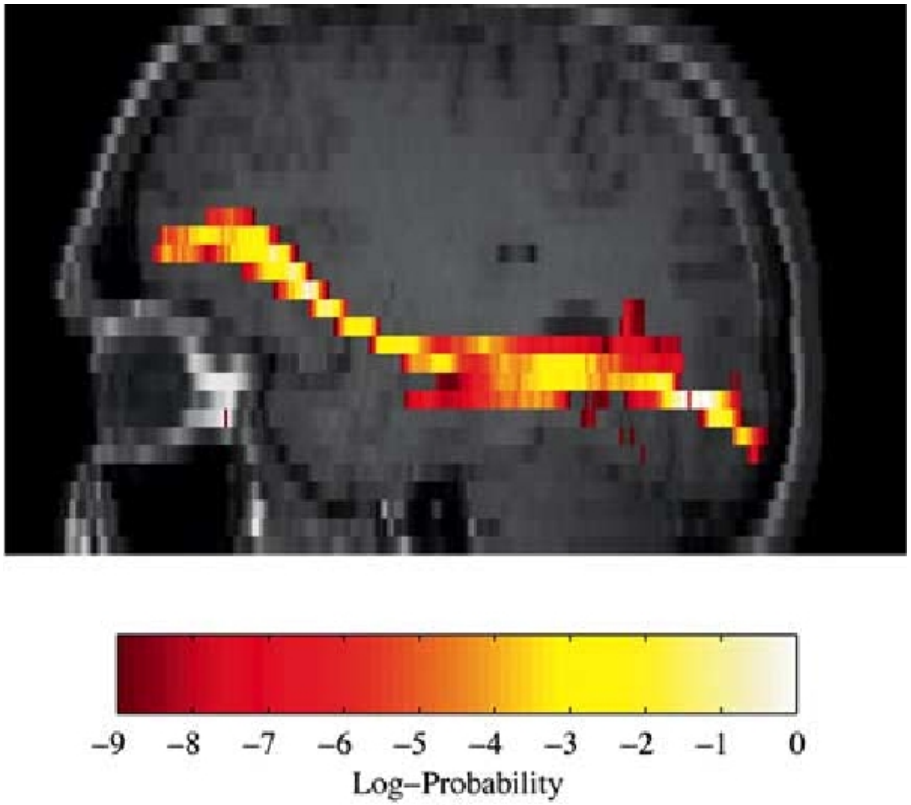
Diffusion Tractography



Mukherjee et al., AJNR (2008)

User-defined regions, based on prior anatomic knowledge, can be used to restrict fiber tracts.

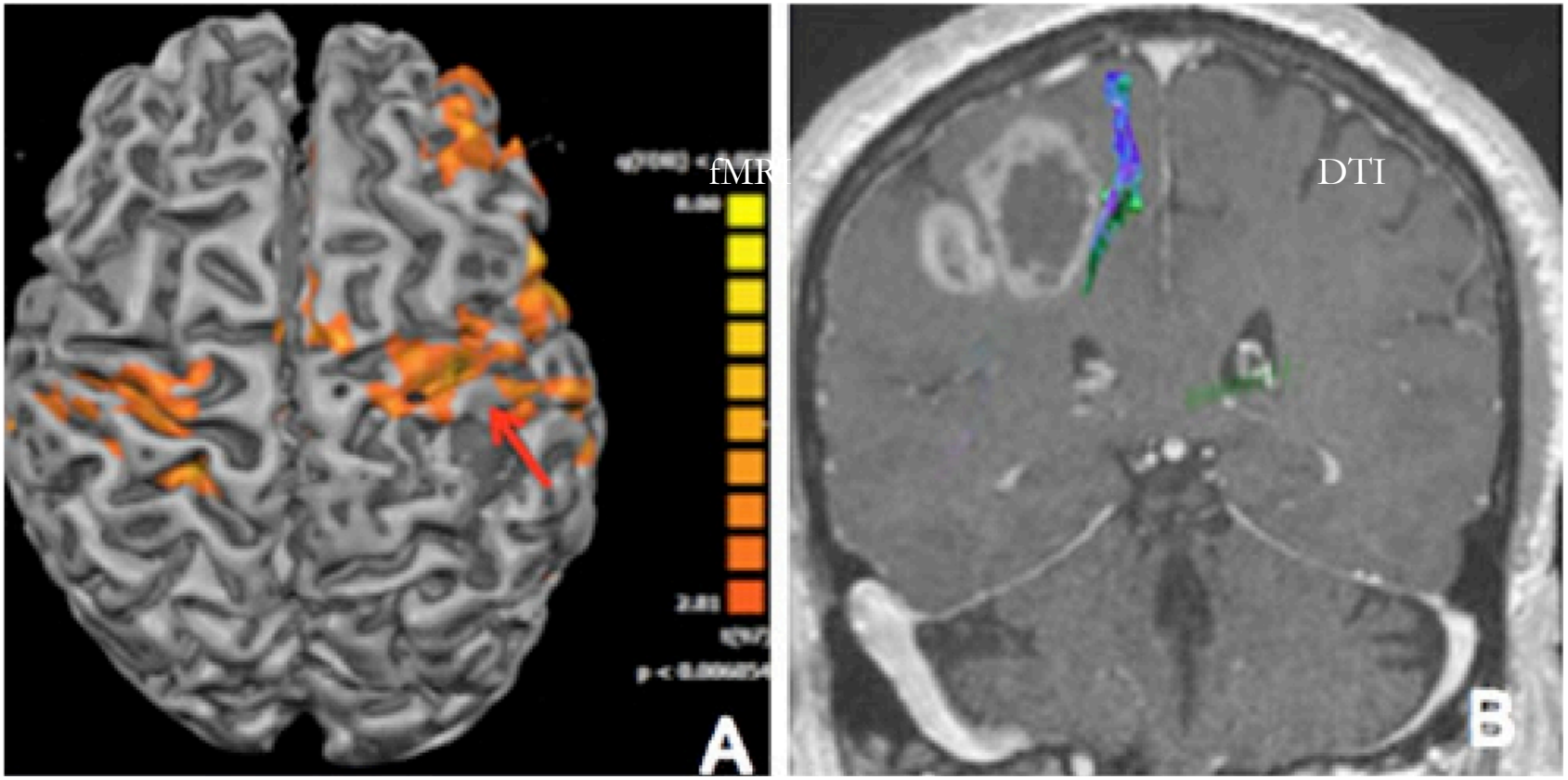
Diffusion Tractography



Friman O., et al. IEEE Trans. (2006)

Probabilistic tractography gives the probability of fiber directions for each voxel.

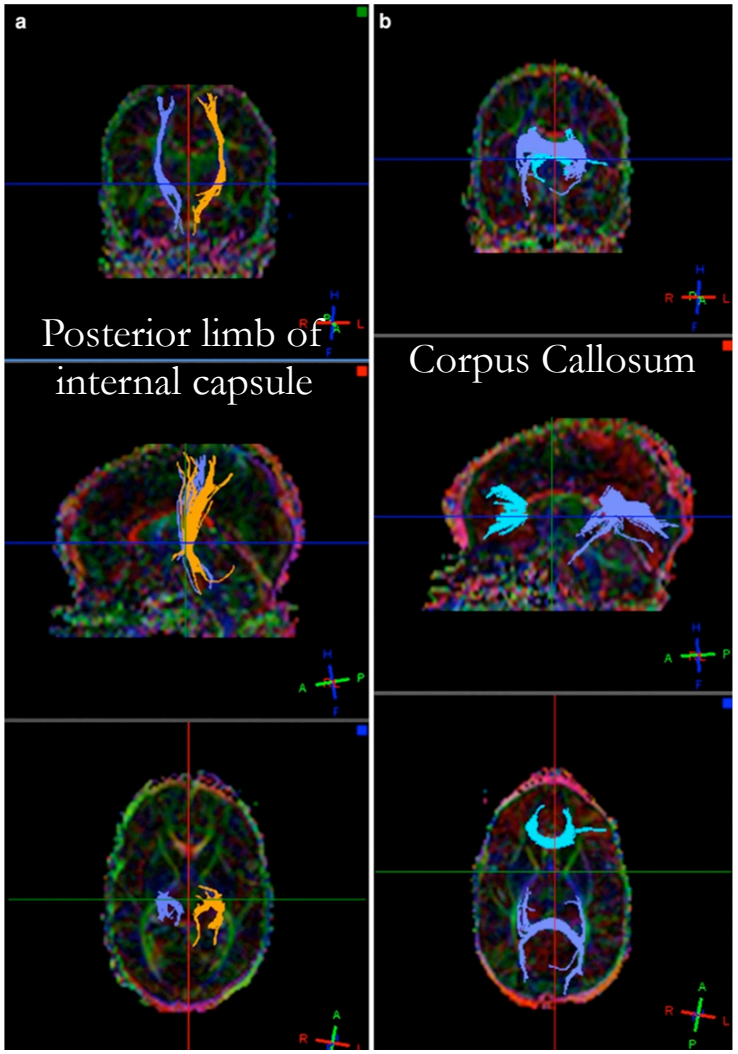
DTI Application



Spena G., et al. Acta Neurochir (2010)

Preoperative fMRI and DTI studies to circumscribe a resection area

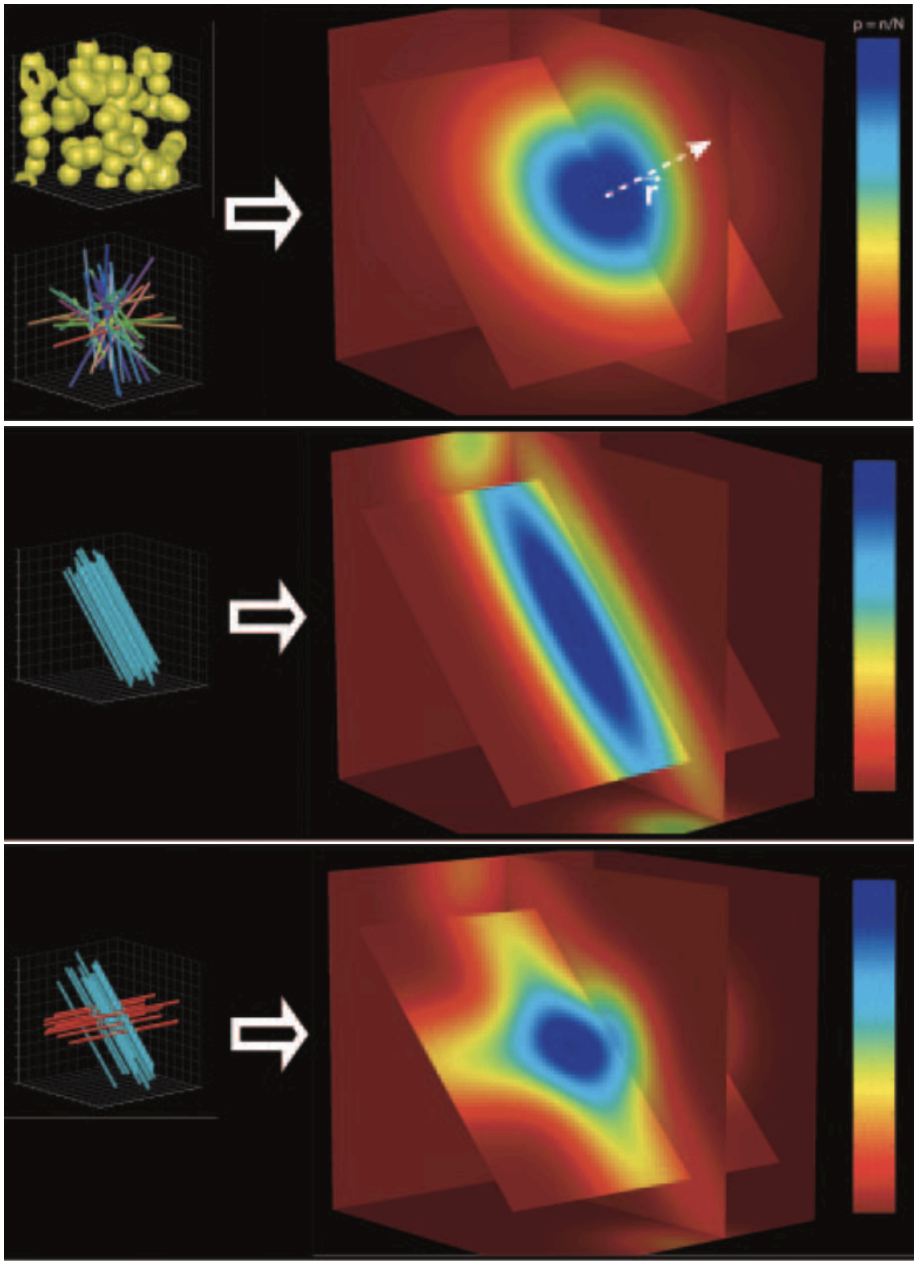
DTI Application



de Bruïne FT., et al. Eur Radiol (2010)

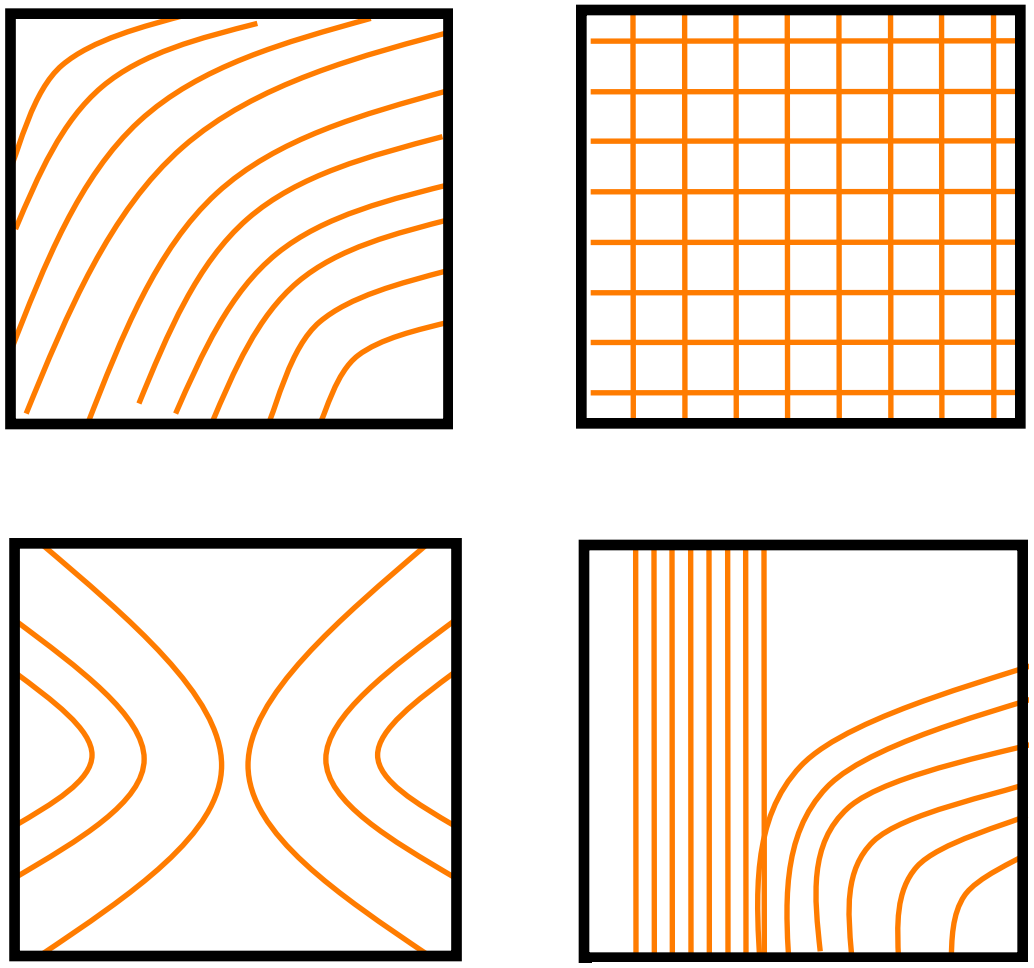
Development of a 41-week-old preterm infant

DTI Limitations



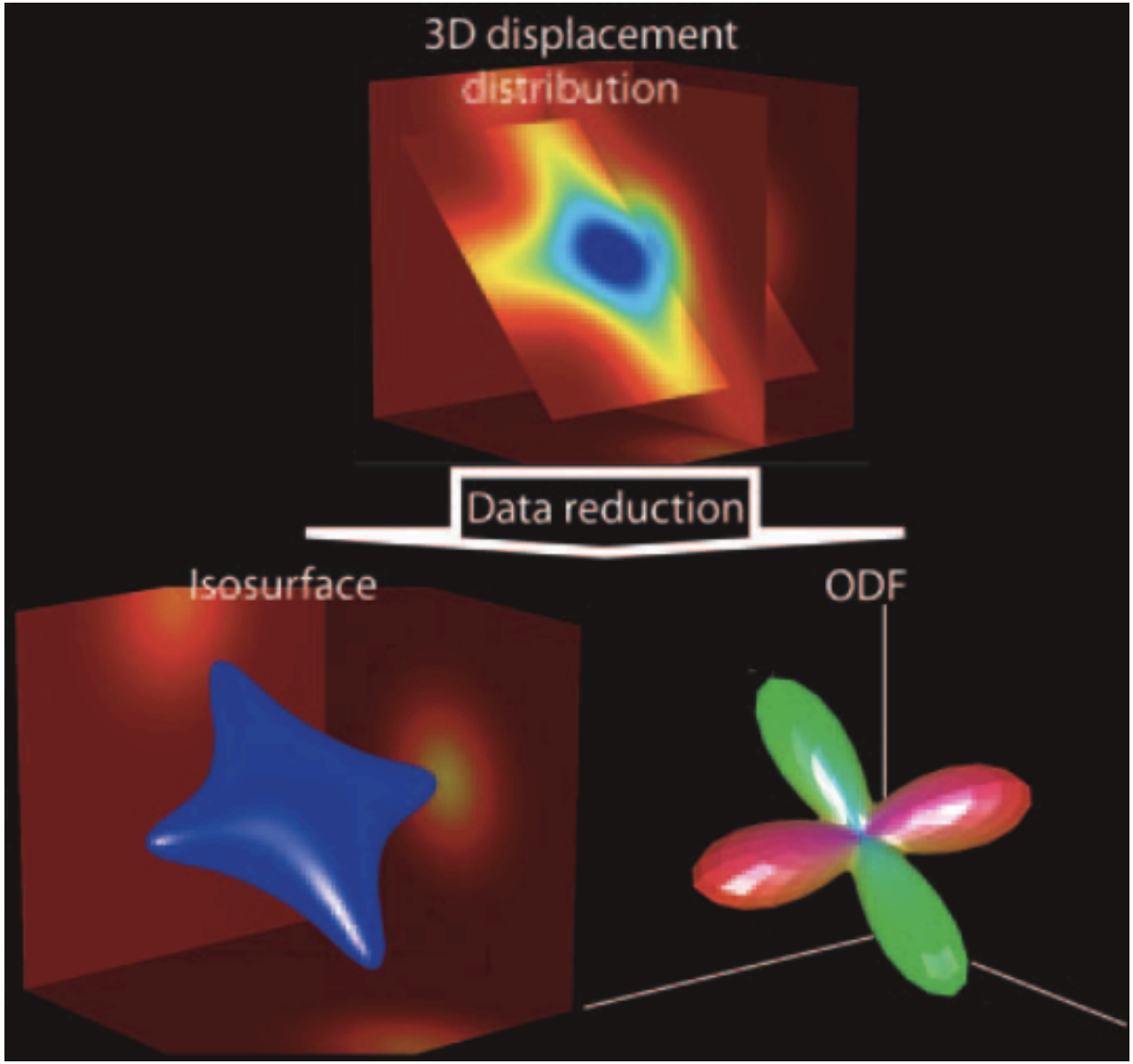
Hagmann P., et al. Radiographics (2006)

DTI Limitations



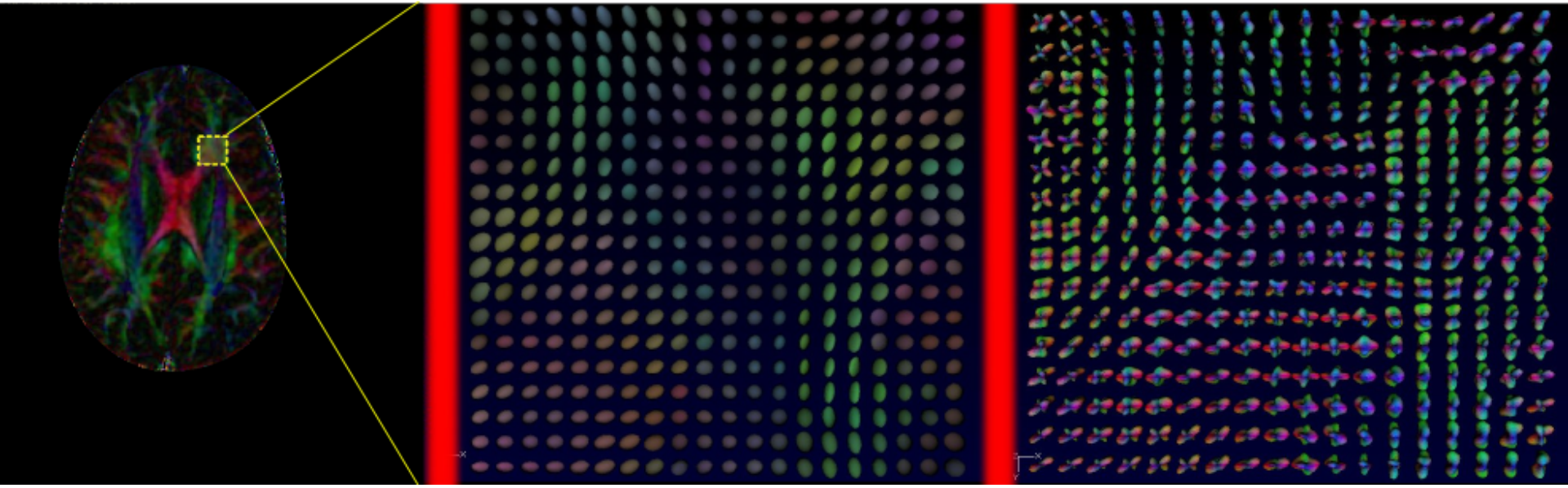
Fiber geometry

Anisotropy



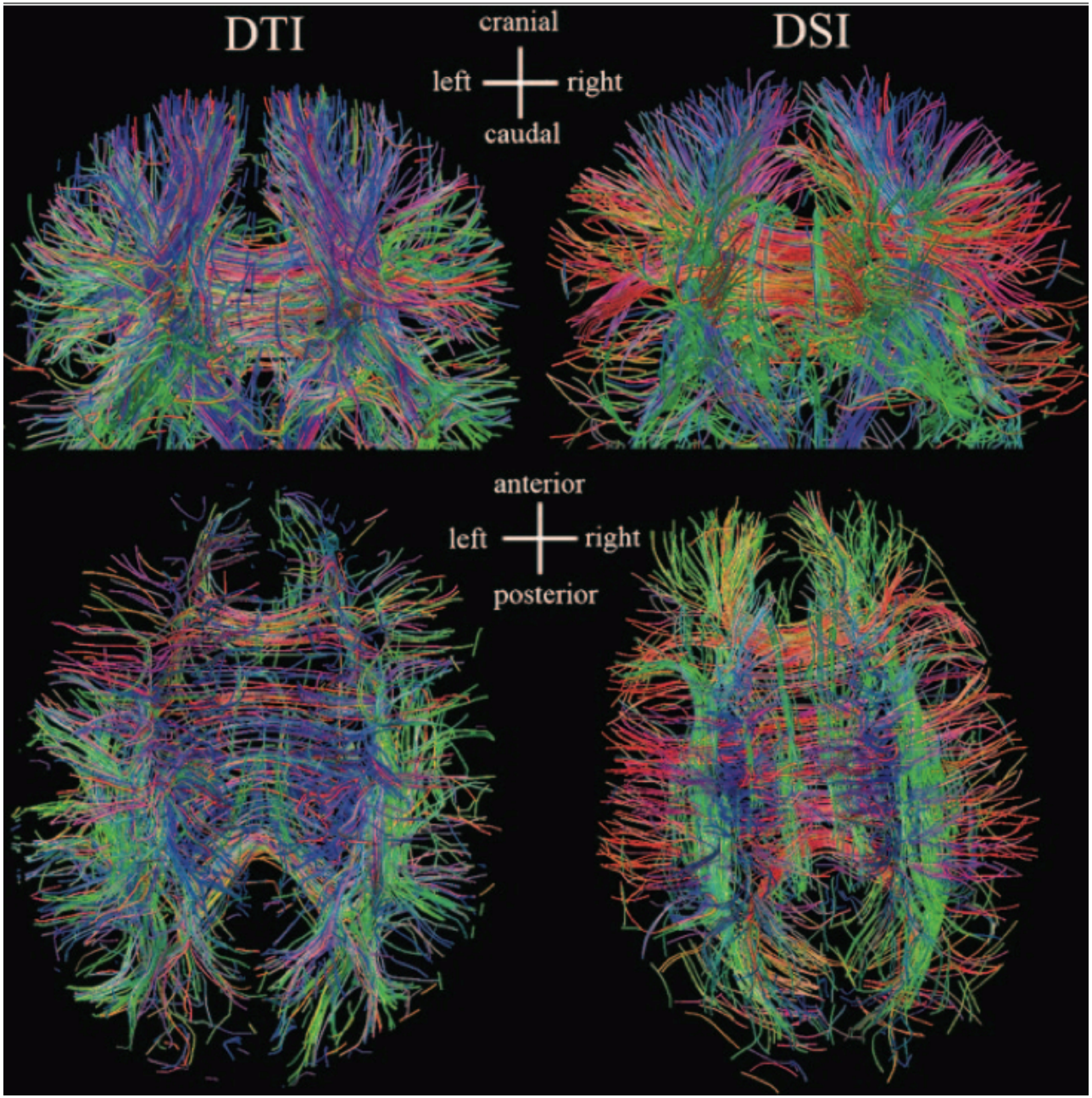
Hagmann P., et al. Radiographics (2006)

DTI vs DSI (Diffusion Spectrum Imaging)



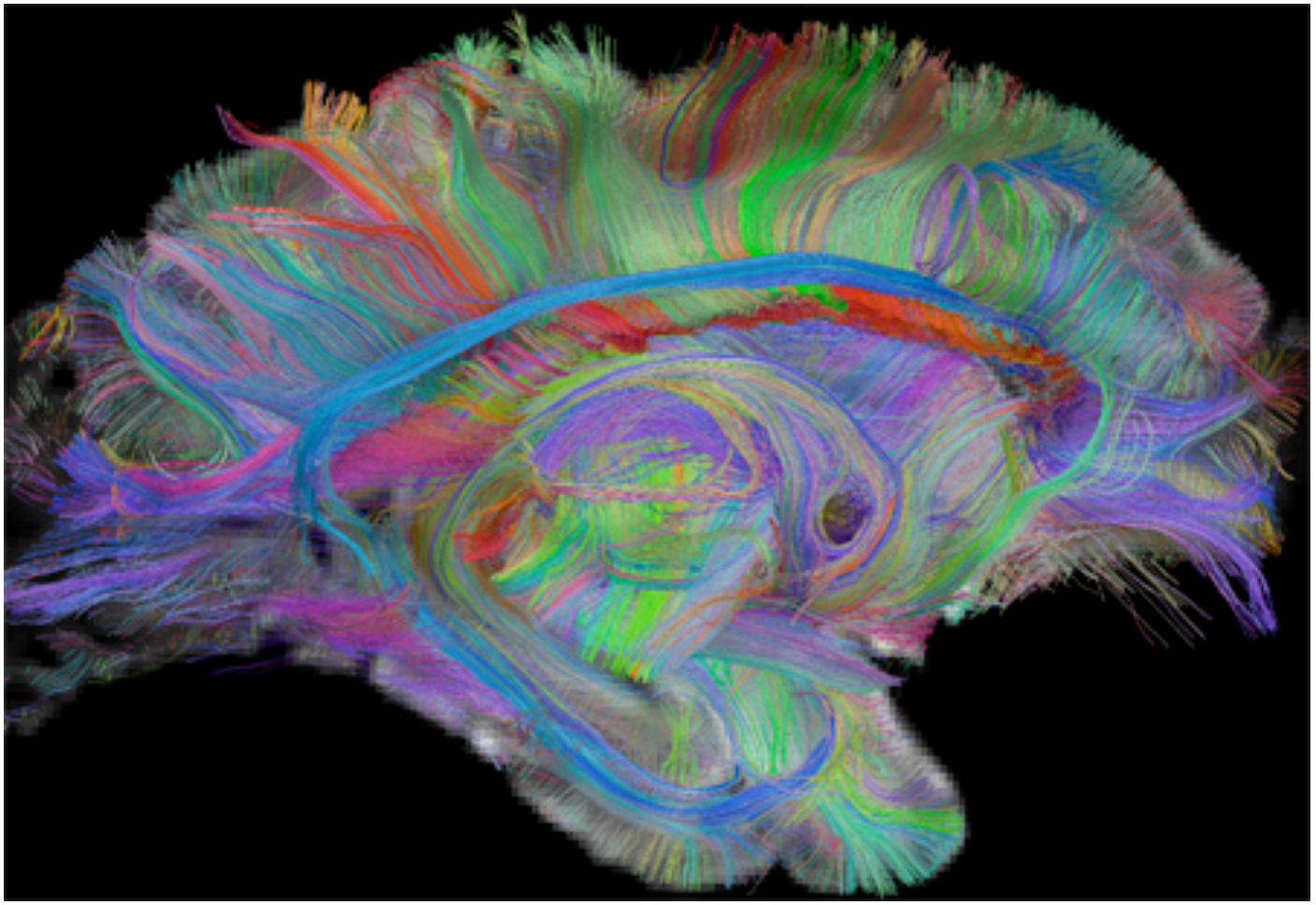
http://www.cim.mcgill.ca/~assemlal/spip.php?article2

DTI vs DSI (Diffusion Spectrum Imaging)



Hagmann P., et al. Radiographics (2006)

Diffusion Spectrum Imaging

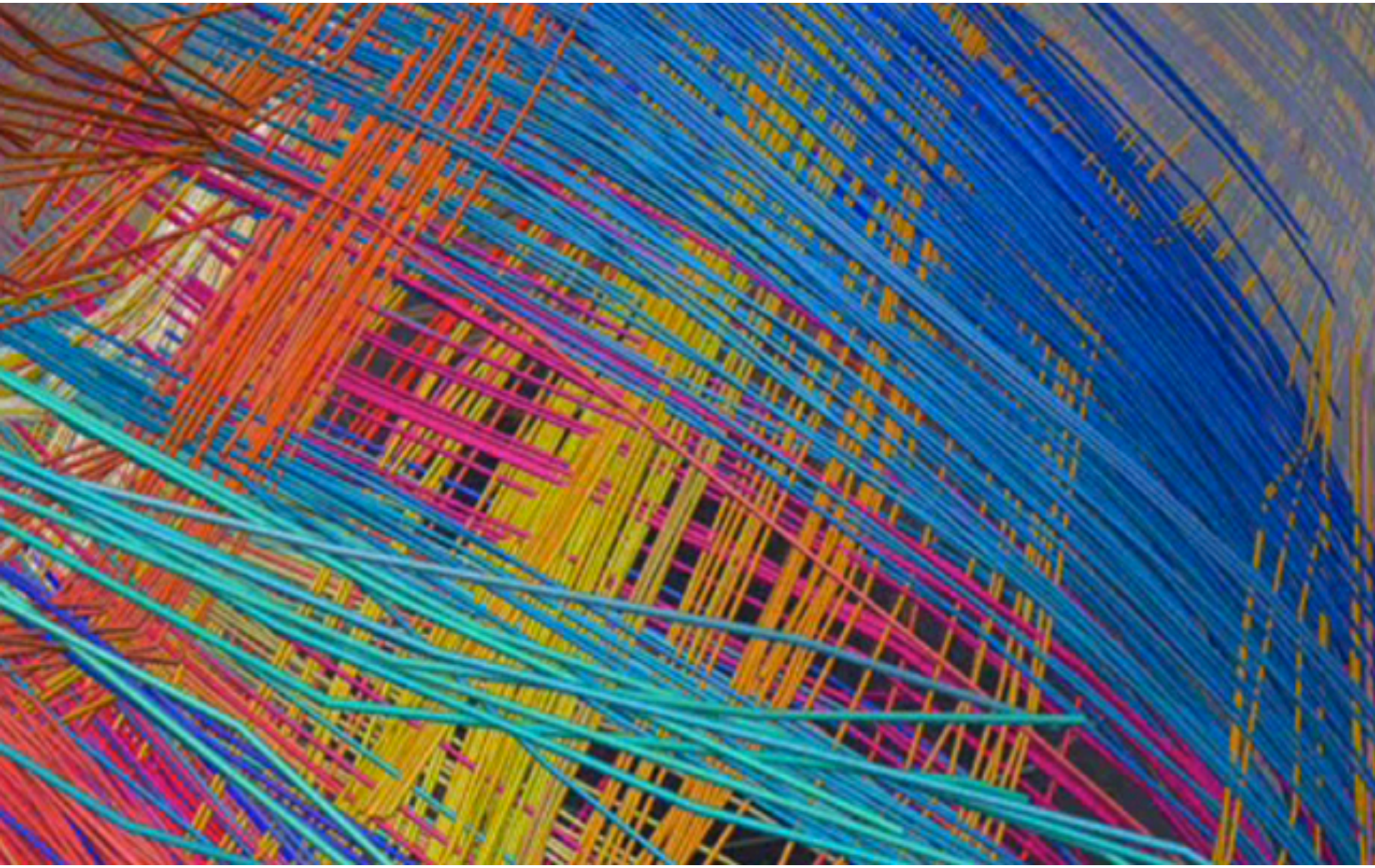


- 515 gradient directions
- Multiple b-values [0-12 000 sec/mm^2]
- Fourier transformation is applied to each voxel

Diffusion Spectrum Imaging

Van Wedeen (2012)

Architecture



Van Wedeen (2012)