Challenges in Medical Imaging

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- **TÜBITAK 112E320 (2013-2016):** New computational mathematical methods in pre-and postoperative brainstem white matter pathways analysis with Diffusion Tensor Imaging
- **TÜBITAK 108E162 (2009-2012):** Assessment of Fluid Tissue Interaction Using Multi-Modal Image Fusion for Characterization and Progression of Coronary Atherosclerosis
  - **Supporting Organizations**: Tubitak-BMBF, TUBITAK- GERMAN BMBF Intense Cooperation Grant

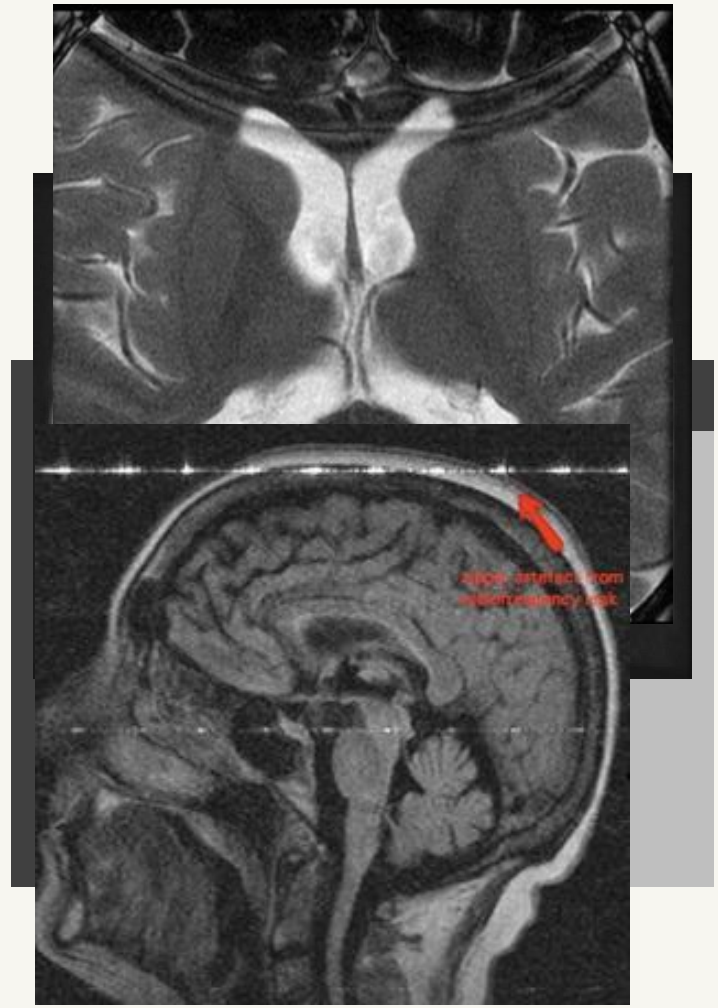
  References:
  - Cetin et al., "Vessel tractography using an intensity based tensor model with branch detection," *IEEE Trans Med. Imaging. 2013,* Impact Factor: 4.268.
  - Cetin et al., “Automatic detection of coronary artery stenosis in CTA based on vessel intensity and geometric features“ , MICCAI'12, 3D Cardiovascular Imaging Segmentation Challenge, Nice, 2012.
- **TÜBITAK 108E126 (2009-2012):** Novel Medical Image Analysis Methods for Cancer Treatment Monitoring
- **etc**.

Outline

- Challenges in Neuroimaging
  - Artifacts
    - Types
    - Removing Artifacts
      - Direct Problem : denoising
      - Inverse Problem : deblurring
  - Diffusion Tensor Imaging (DTI) vs Constrained Spherical Deconvolution (CSD)

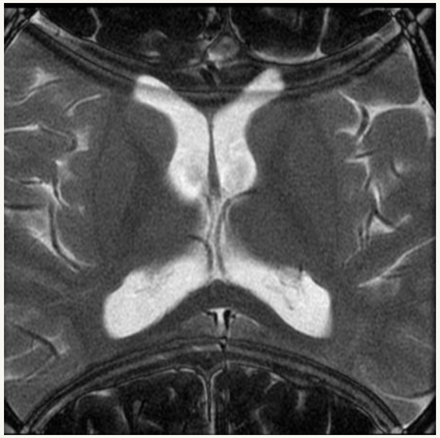
Imaging Artifacts

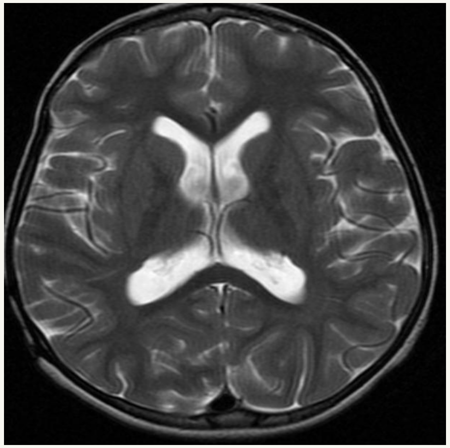
- Aliasing or “Wrap-around” artifact
- Motion artifact
- Ringing artifact
- Zipper artifact
- etc.



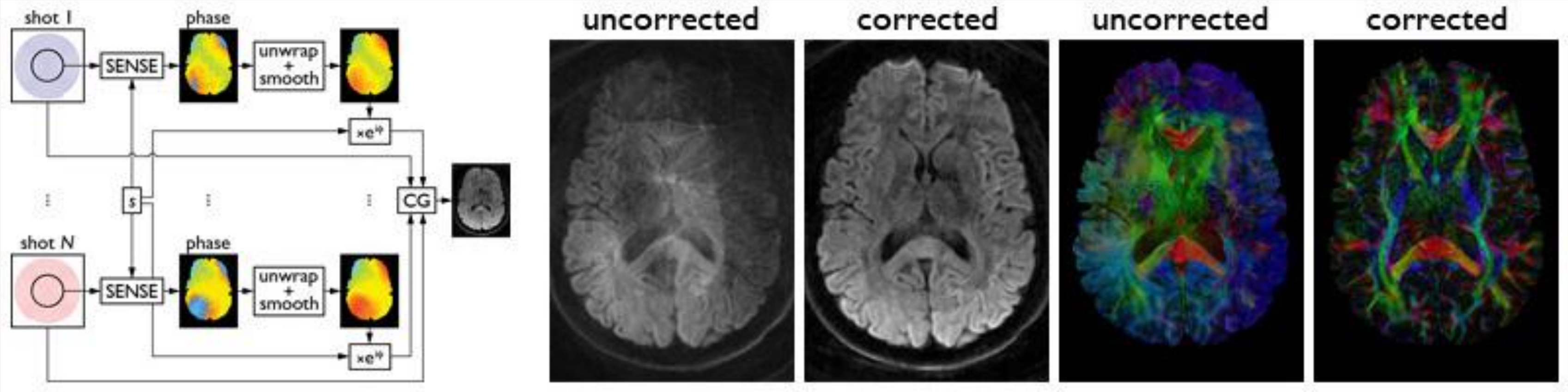
Aliasing Artifact

- Cause: FOV too small for body part
- Appearance: Body part extends beyond one edge of image and is projected at the opposite side
- Correction: Sample data sufficient for a larger FOV





Aliasing Artifact

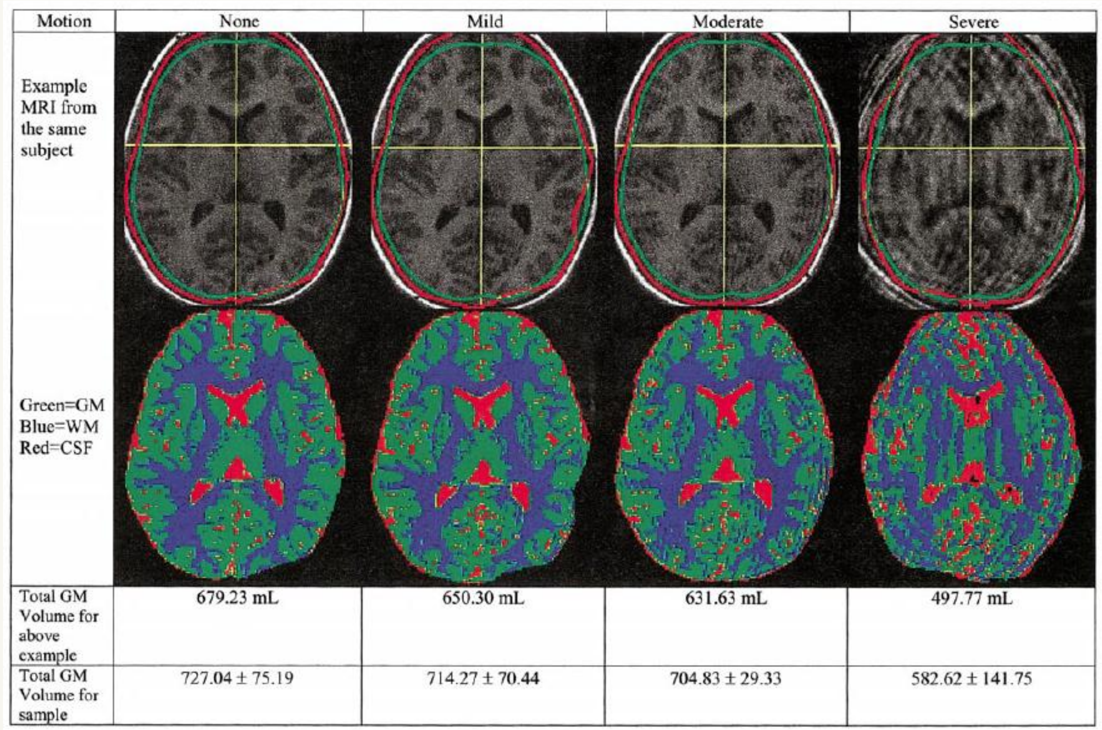


Truong TK, Guidon A , *High-resolution multishot spiral diffusion tensor imaging with inherent correction of motion-induced phase errors* Magn Reson Med., 2013.

Motion Artifact

- Cause:
  - Motion causes phases changes during signal sampling
  - Or intensity changes b/w signals, both resulting in phase encoding errors
- Appearance:
  - Repetitive patterned noise that resembles the source structure
  - Repeated at regular intervals along phase encoding axis
- Correction:
  - Average multiple signals
  - Complete image acquisition rapidly

Motion Artifact - fMRI



Motion	None	Mild	Moderate	Severe
Example MRI from the same subject				
Green=GM Blue=WM Red=CSF				
Total GM Volume for above example	679.23 mL	650.30 mL	631.63 mL	497.77 mL
Total GM Volume for sample	727.04 ± 75.19	714.27 ± 70.44	704.83 ± 29.33	582.62 ± 141.75

Jonathan D. Blumenthal, Alex Zijdenbos, Elizabeth Molloy, and Jay N. Giedd , *Motion Artifact in Magnetic Resonance Imaging: Implications for Automated Analysis*, NeuroImage 16, 89–92 (2002)

Image Denoising

- Removing noise from data
- Method: Filtering image with kernel
  - Gaussian filter: blurring effect on white noise
  - Non-local means filter: blurring effect on rician noise
  - Perona-malik filter: while blurring noise, preserves structures edges

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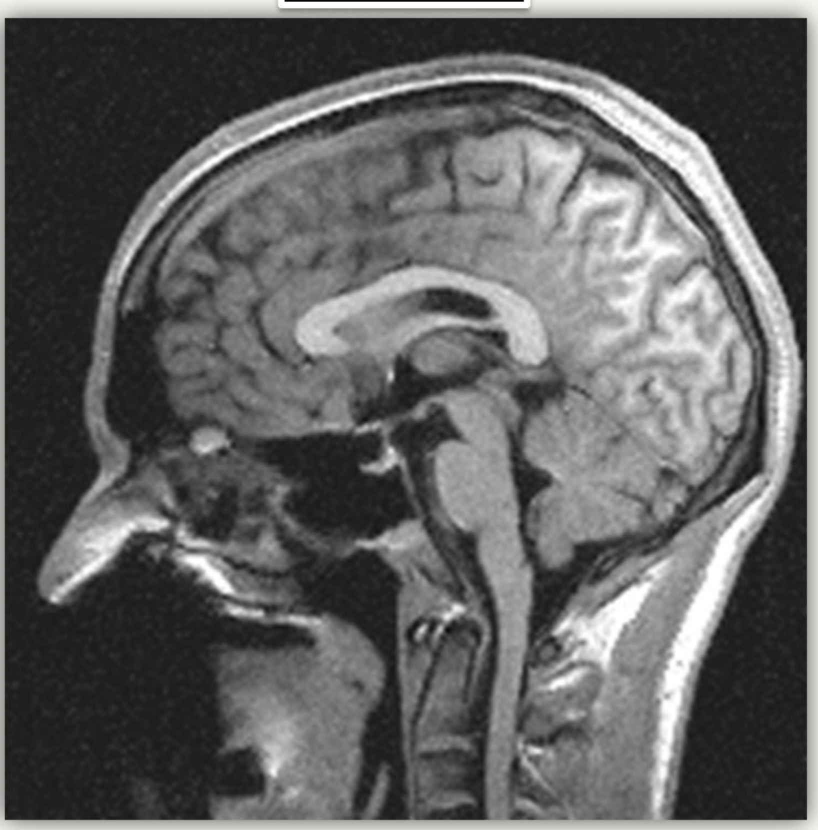
Image Denoising

noisy

denoised



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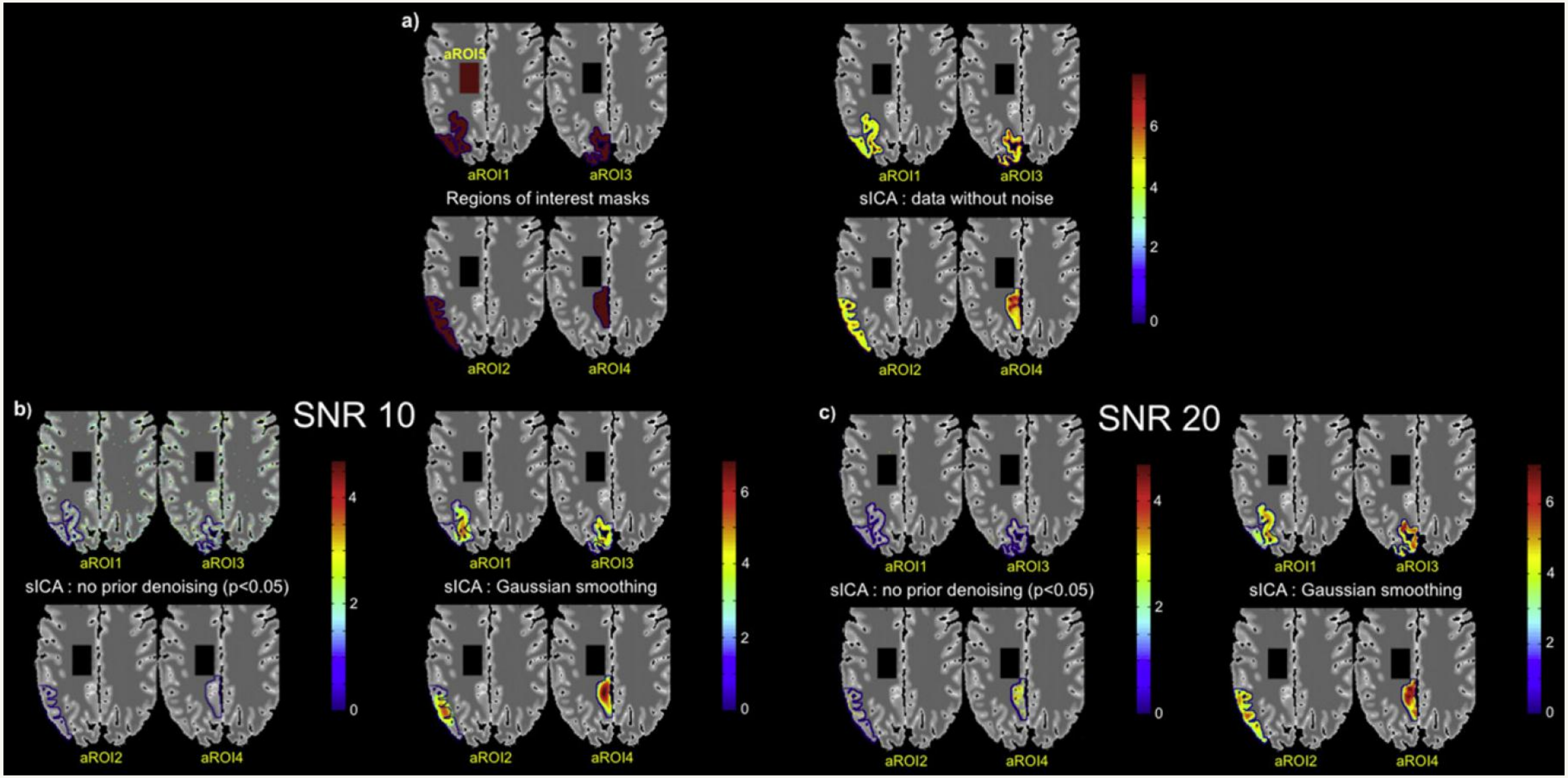
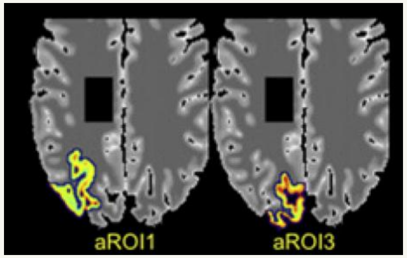
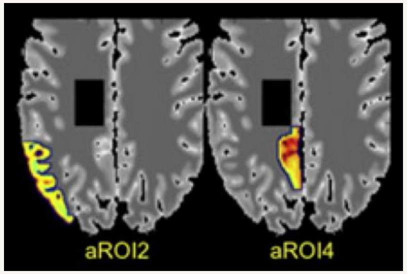


Jean Michel Pignat, Oleksiy Koval, Dimitri Van De Ville, Sviatoslav Voloshynovskiy, Christoph Michel, Thierry Pun, *The impact of denoising on independent component analysis of functional magnetic resonance imaging data*, Journal of Neuroscience Methods, Volume 213, Issue 1, 15 February 2013, Pages 105-122.





Sensitivity = TP/(TP+FN)	No smoothing	After Gaussian Smoothing
ROI1	< 0.1	0.51
ROI2	< 0.1	0.53
ROI3	< 0.1	0.65
ROI4	< 0.1	0.90

Image Deblurring

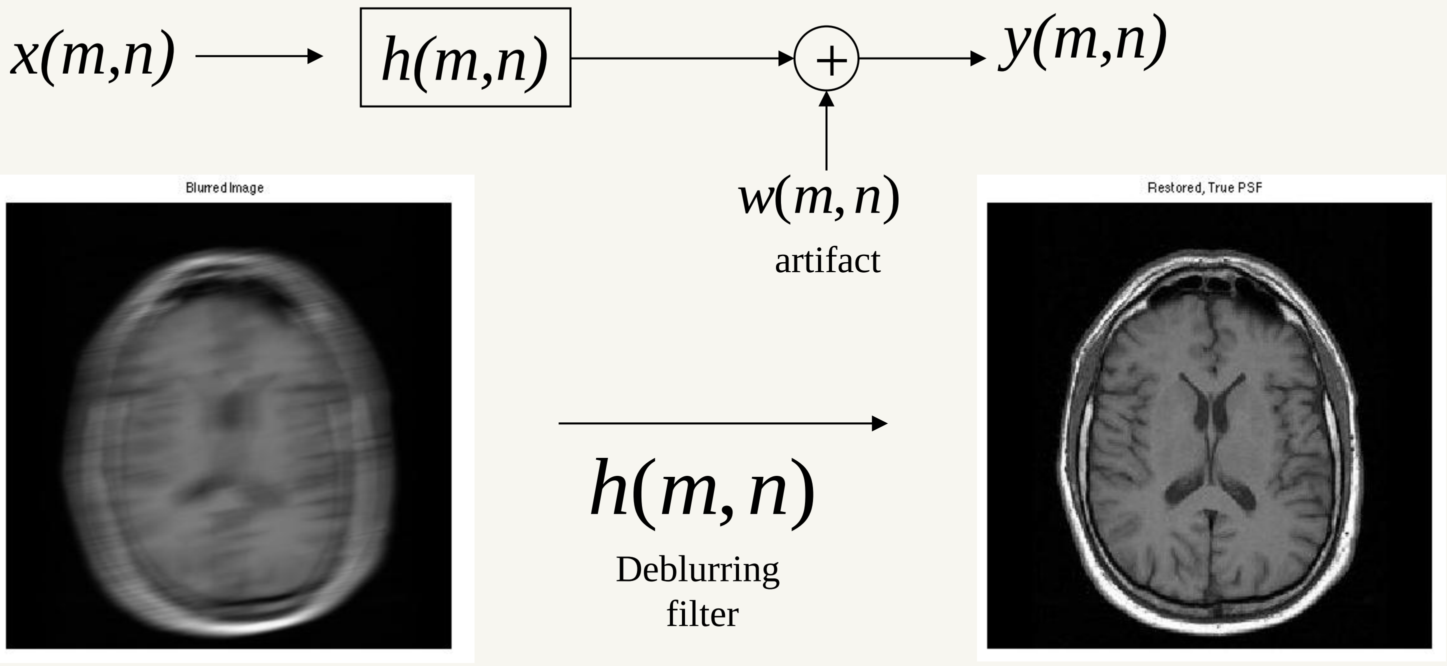
- How to restore original data ?

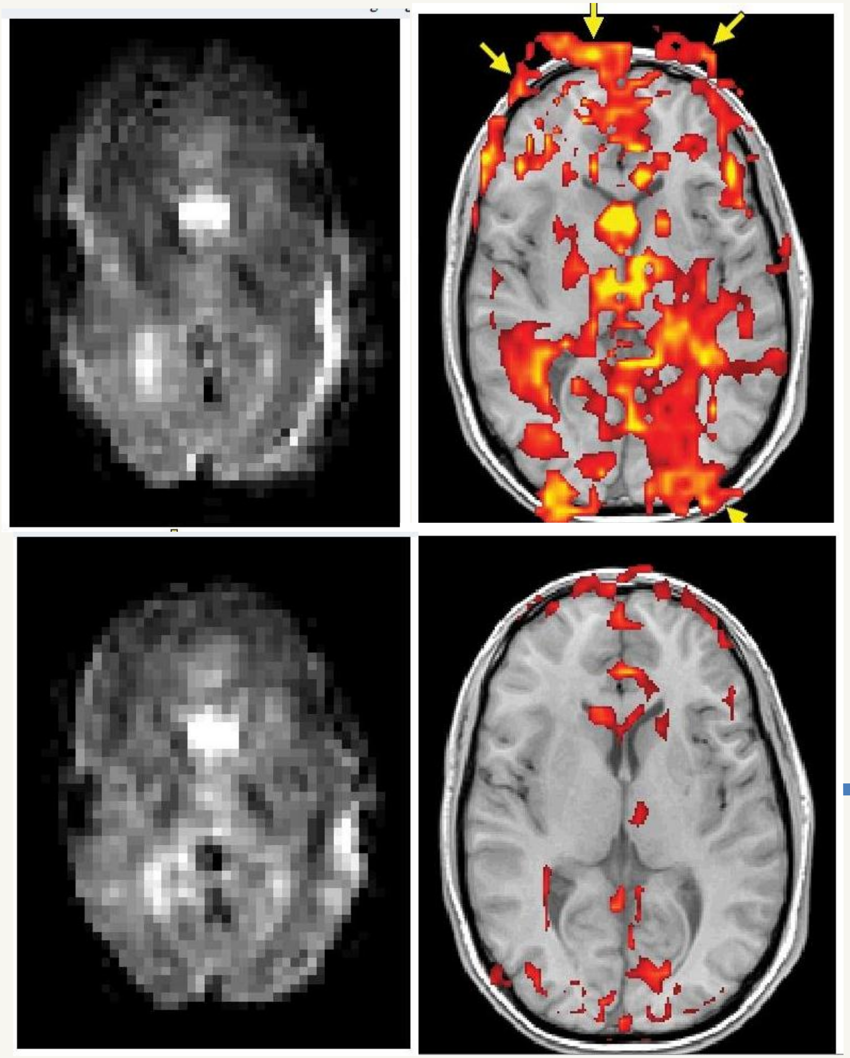
Before the repair

After the repair

Modeling Blurring Process – Inverse Problem

- Linear degradation model

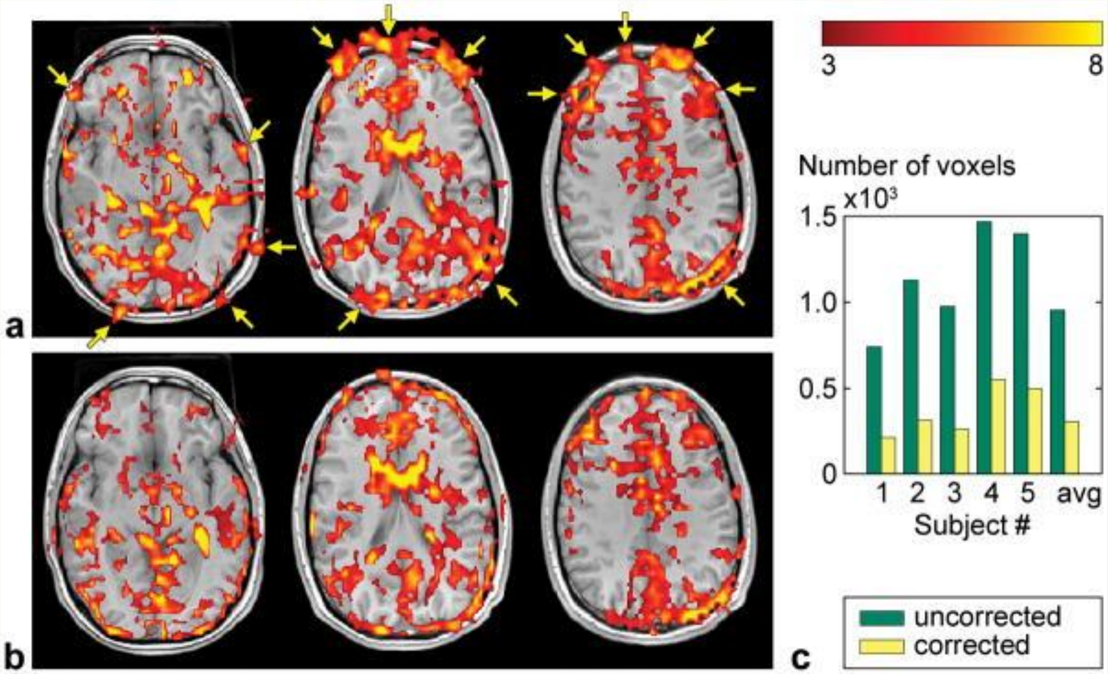




Before deblurring

After deblurring

Truong TK, Chen NK, Song AW., *Application of k-space energy spectrum analysis for inherent and dynamic B0 mapping and deblurring in spiral imaging*, Magn Reson Med. 2010 Oct;64(4):1121-7. doi: 10.1002/mrm.22485.

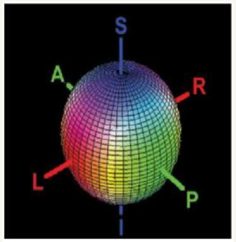


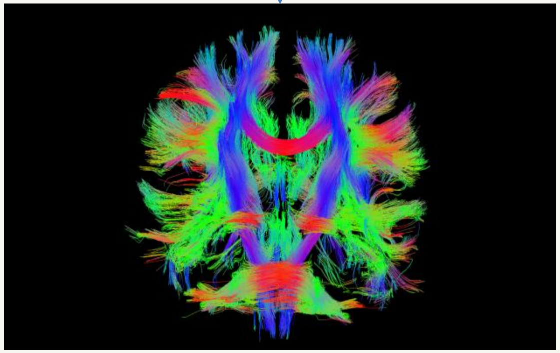
Activation maps uncorrected (**a**) and corrected (**b**) in three different slices.
c: Number of activated voxels outside the brain across all slices for each subject and averaged across subjects.

Diffusion Tensor Imaging

- Diffusion Tensor Imaging is a method used for imaging white matter.

STEP 1: DWI data acqusition → **STEP 2:** Estimation of fiber orientations → **STEP 3:** Application of tractography algorithm





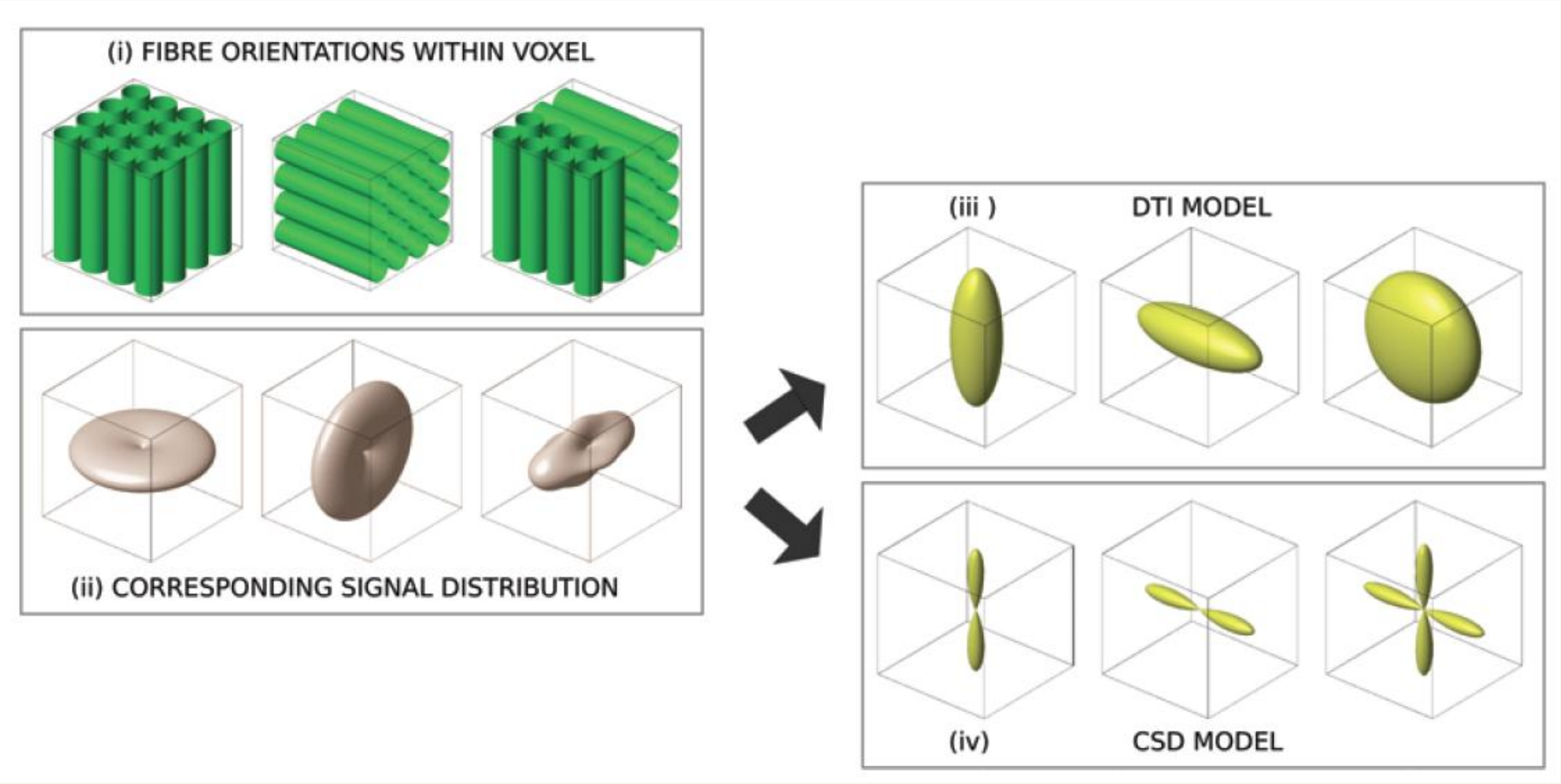
Diffusion Tensor imaging in bipolar disorder

Diffusion tensor imaging studies in bipolar disorder.

Study	BD Sample, age at scan (SD)	Comparison Sample, age at scan (SD)	Methods	Results (BD group compared to controls unless otherwise specified)
Adler et al. (2004)	- 9 BD I, 32 (8)	- 9 matched controls, 31 (7)	- ROIs placed 15, 20, 25, and 30 mm above the AC - Analysis of FA and ADC - Mean FA and ADC in each ROI were combined bilaterally - 5 mm contiguous coronal slices, 25 directions	- Lower FA in the ROIs 25 and 20 mm above the AC - No differences in ADC
Beyer et al. (2005)	- 14 male BD, 44.0 (17.6)	- 21 matched controls, 44.6 (13.5)	- ROIs placed in bilateral OFC, SFG, MFG - FA and ADC measured - 5 mm axial slices, 2.5 mm gap, 6 directions	- Higher ADC in bilateral OFC - No differences in FA
Haznedar et al. (2005)	- 40 BD (17 BD I, 7 BD II, 16 cyclothymia), 42.2 (10.8)	- 36 matched controls, 40.7 (11.6)	- Manual ROIs placed in caudate, putamen, thalamus - Relative anisotropy (RA) measured -5 mm contiguous axial slices, 6 directions	BD spectrum group compared to controls: - Lower RA in internal capsule WM - Higher anisotropy in right anterior frontal WM, most pronounced BD I subgroup
Adler et al. (2006a)	- 11 adolescent first episode manic BD (total sample age = 14 (2))	- 17 matched controls	- 12 ROIs placed from 2 mm below the AC-PC to 28 mm above it anteriorly and posteriorly. - FA and ADC measured - 5 mm contiguous axial slices, 25 directions	- Lower FA in superior frontal ROIs, especially in L hemisphere
Regenold et al. (2006)	- 8 BD, 58.4 (12.9)	- 8 neurologic controls, 54.5 (12.8)	- 40 ROIs placed on 8–10 consecutive slices rostral to the midbrain in each lobe - ADC measured - 5 mm axial slices, 1 mm gap, 3 directions	- Higher combined average ADC over all ROIs - Trend toward higher ADC in frontal ROIs
Frazier et al. (2007)	- 10 pediatric BD, 9.2 (3.0)	- 8 matched controls, 9.2 (2.4)	- ROIs placed along SLF I and in CG-PAC WM	- Lower FA in SLF I and CG-PAC WM

Katie Mahon et al., *A role for white matter abnormalities in the pathophysiology of bipolar disorder,* Neuroscience and Biobehavioral Reviews 34 (2010) 533–554

White matter fiber tractography: why we need to move beyond DTI



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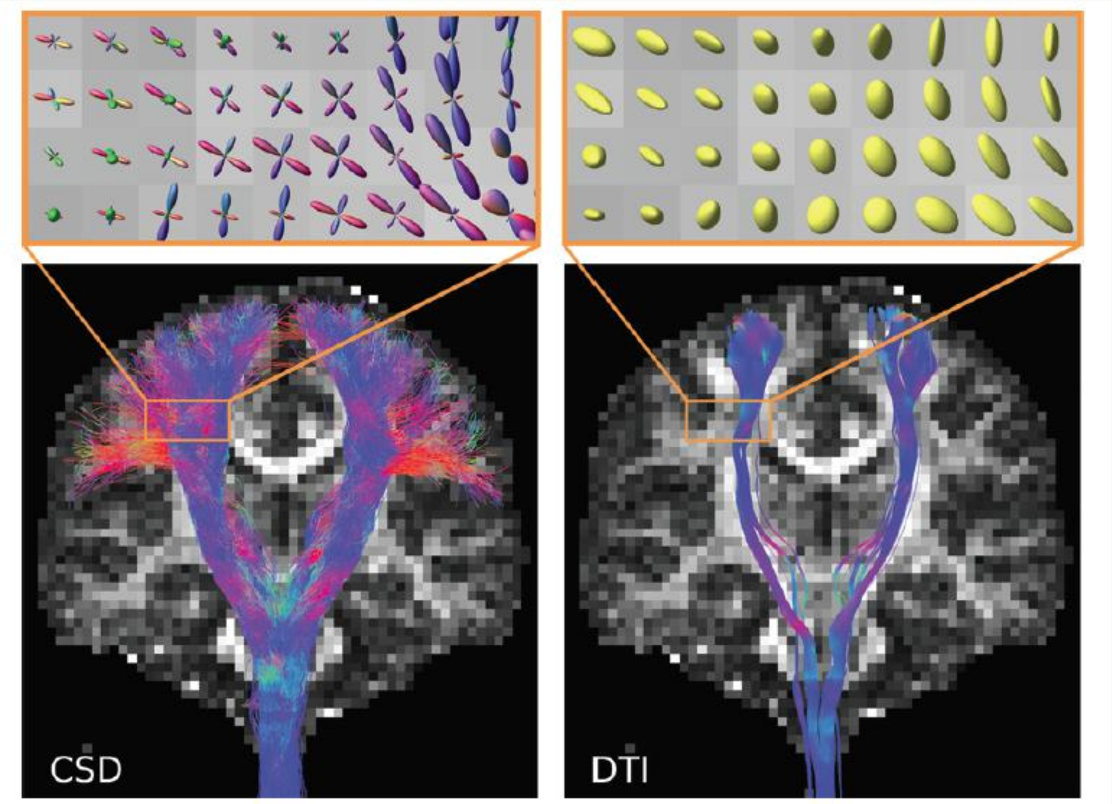
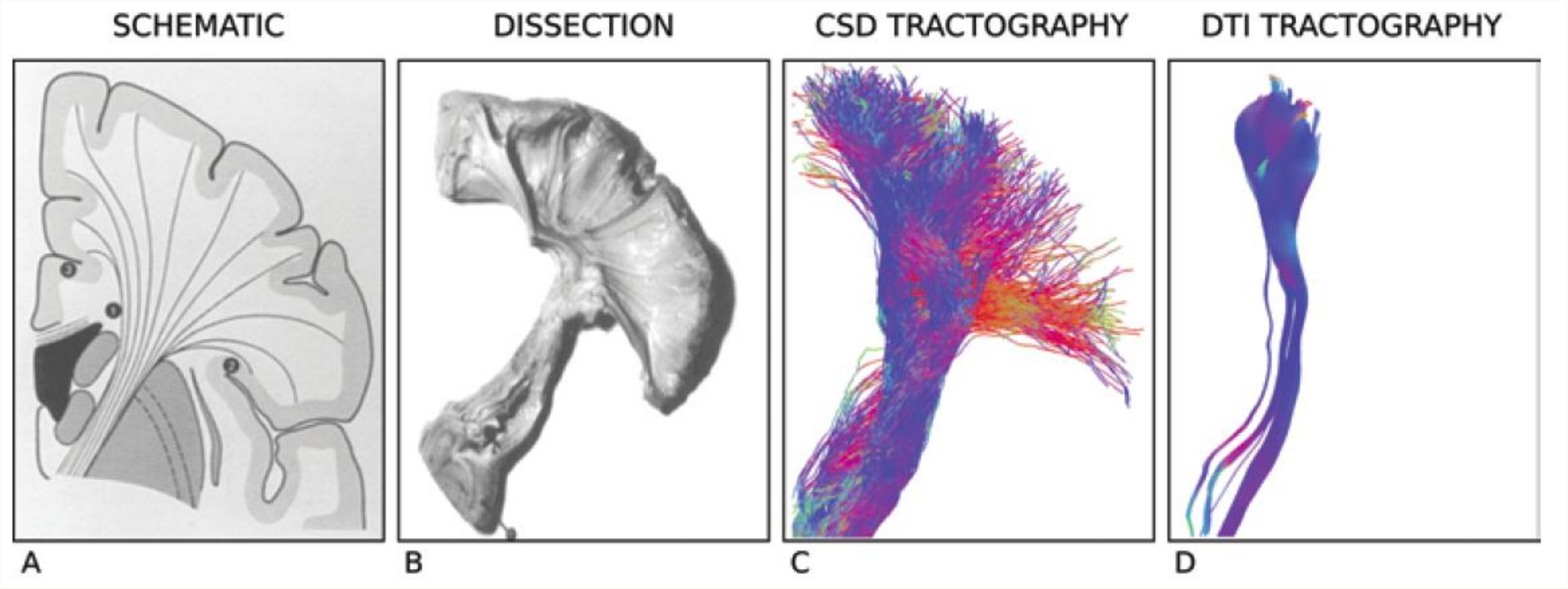


Fernando Calamante et al., *White matter fiber tractography: why we need to move beyond DTI,* J Neurosurg 118:1367–1377, 2013

White matter fiber tractography: why we need to move beyond DTI



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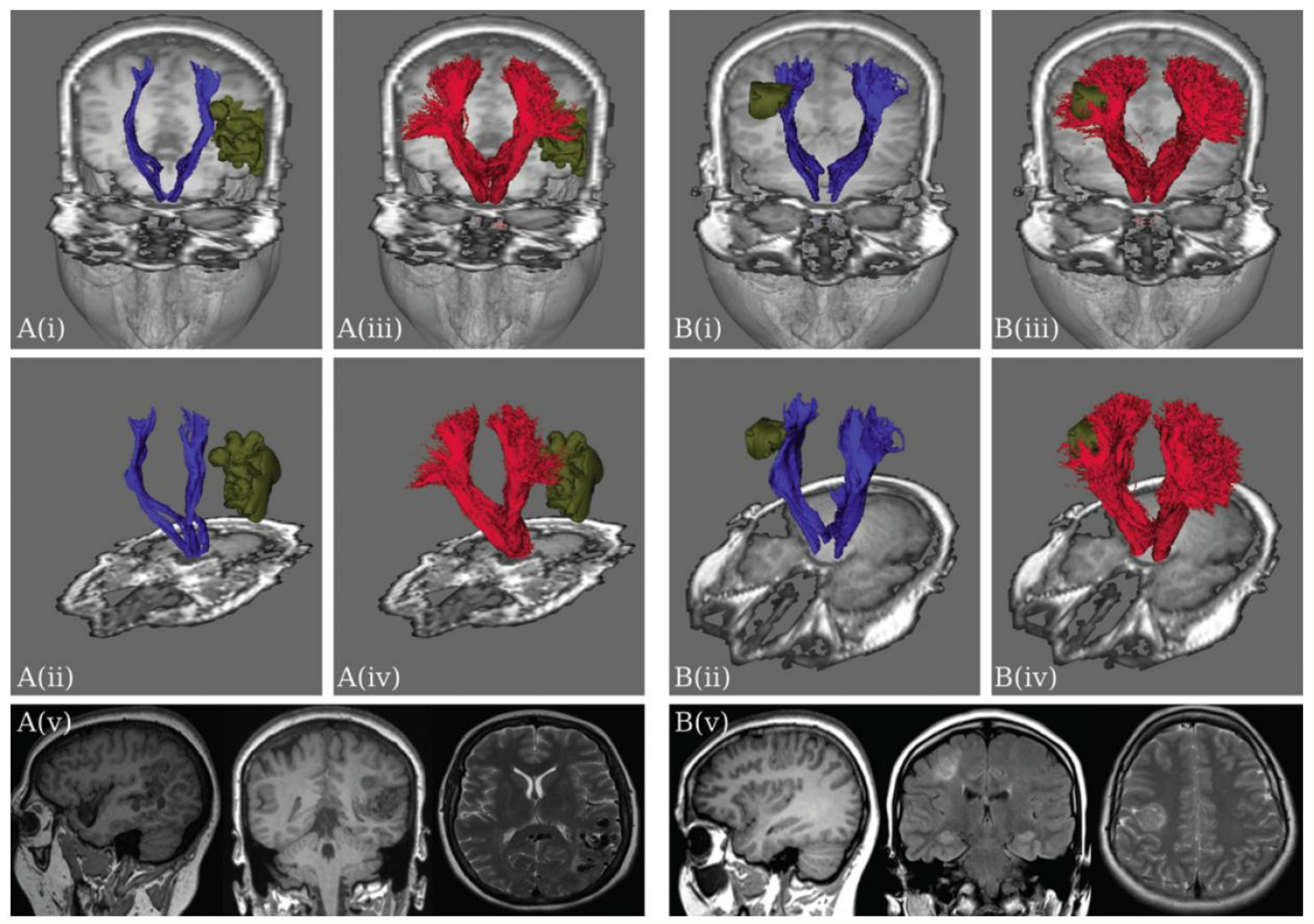
DTI vs CSD



Fernando Calamante et. al, *White matter fiber tractography: why we need to move beyond DTI,* J Neurosurg 118:1367–1377, 2013

Conclusions

- Imaging causes artifacts
- Image deblurring/denoising operations must be performed before classification
- Spatial normalization and registration to an atlas, e.g. Talairach atlas, may also increase accuracy
- CSD method is a better way for white matter tractography

THANKS FOR LISTENING ☺

ANY QUESTIONS ?

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