

PreQual v1.0.8 (dtiQA v7 Multi)
Creation Date: August 27, 2022

Authors:
- Leon Cai (leon.y.cai@vanderbilt.edu)
- Qi Yang (qi.yang@vanderbilt.edu)

Run Date: 2023-07-03 13:52:58.446924

Project: proj
Subject: subj
Session: sess

Parameters:
- B-Value Threshold: 50
- Shells: Auto
- Run Denoise: True
- Run Degibbs: False
- Run Rician: False
- Run Prenormalize: True
- Topup B0s: First
- Try Synb0-DisCo: True
- Extra Topup Args:
- Eddy Mask: True
- Eddy B-Value Scale: 1.0
- Extra Eddy Args:
- Run Postnormalize: False
- Run N4 Bias Field Correction: False
- Mask Improbable Voxels: False
- Glyph Visualization Type: tensor
- Atlas Registration Type: FA
- Split Outputs: False
- Keep Intermediates: False

Preprocessing: Topup (Synb0) + Eddy
Inputs (w/ PE direction and readout time):
- sub-4594_ses-adni2year2_dwi (j+, 0.05)
- t1 (raw)

Warnings (See "PreQual User Guide" at github.com/MASILab/PreQual for more information):

- All input volumes must have the same phase encoding axis, as input into this pipeline and as reflected above. Please see the PE Direction page of this PDF for more information.
- Both the sform and qform codes for sub-4594_ses-adni2year2_dwi were non-zero. The NIFTI file was resaved with the sform affine overriding the qform.
- Both the sform and qform codes for t1 were non-zero. The NIFTI file was resaved with the sform affine overriding the qform.

Methods Summary:

The diffusion data were preprocessed and quality-checked with the following pipeline built around the MRTrax3 [1], FSL [2], and ANTs [3] software packages. First, any volumes with a corresponding b value less than 50 were treated as b0 volume for the remainder of the pipeline. The diffusion data were denoised with the provided dwidenoise (MP-PCA) function included with MRTrax3 [4][5][6]. The images were then intensity-normalized to the first image and concatenated for further processing. No reverse phase encoded images were acquired, but corresponding T1 images of the subjects were available. Thus, a T1 image was used to generate a synthetic susceptibility-corrected b0 volume using SYNBO-DISCO, a deep learning framework by Schilling et al. [7]. This synthetic b0 image was used in conjunction with FSL's topup to correct for susceptibility-induced artifacts in the diffusion data. FSL's eddy algorithm was then used to correct for motion artifacts and eddy currents and to remove outlier slices [8][9][10][11]. Lastly, the preprocessed data were fitted with a tensor model using the dwi2tensor function included with MRTrax3 using an iterative reweighted least squares estimator [12]. The quality of this preprocessing pipeline was then assessed qualitatively for gross errors and quantitatively analyzed using a three-step approach. In the first step, the preprocessed data were analyzed in accordance with the method outlined by Lauzon et al. [13]. The brain parenchyma without CSF were masked in a restrictive manner by using an eroded brain mask generated on the average b0 image using the bet2 function included with FSL [14]. Then, the tensor fits of the masked data were backpropagated through the diffusion model to reconstruct the original diffusion signal. The goodness-of-fit for the tensor model was then assessed using a modified pixel chi-squared value per slice per volume. In the second step, the tensor fit was converted to a fractional anisotropy (FA) image [15][16]. The ICBM FA MNI atlas with 48 white matter tract labels provided with FSL were then non-rigidly registered to the subject's FA image with the ANTs software package [17][18][19][20]. The average FA for each tract was then quantified and assessed for physiologic congruence. Lastly, the gradient orientations were visualized and checked using the dwgradcheck script included with MRTrax [21].

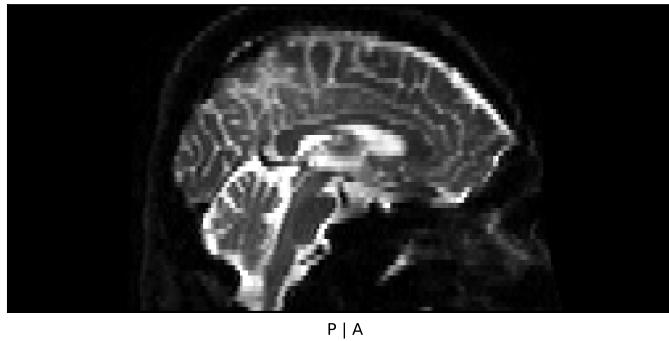
References:

- [1] Tournier, J. D. et al. (2019). MRtrix3: A fast, flexible and open software framework for medical image processing and visualisation. *NeuroImage*, 116137.
- [2] Jenkinson, M. et al. (2012). Fsl. *NeuroImage*, 62(2), 782-790.
- [3] Tustison, N. J. et al. (2014). Large-scale evaluation of ANTs and FreeSurfer cortical thickness measurements. *NeuroImage*, 99, 166-179.
- [4] Veraart, J. et al. (2016). Denoising of diffusion MRI using random matrix theory. *NeuroImage*, 142, 394-406.
- [5] Veraart, J. et al. (2016). Diffusion MRI noise mapping using random matrix theory. *Magnetic resonance in medicine*, 76(5), 1582-1593.
- [6] Cordero-Grande, L. et al. (2019). Complex diffusion-weighted image estimation via matrix recovery under general noise models. *NeuroImage*, 200, 391-404.
- [7] Schilling, K. G. et al. (2019). Synthesized b0 for diffusion distortion correction (Synb0-DisCo). *Magnetic resonance imaging*, 64, 62-70.
- [8] Andersson, J. L. et al. (2003). How to correct susceptibility distortions in spin-echo echo-planar images: application to diffusion tensor imaging. *NeuroImage*, 20(2), 870-888.
- [9] Smith, S. M. et al. (2004). Advances in functional and structural MR image analysis and implementation as FSL. *NeuroImage*, 23, S208-S219.
- [10] Andersson, J. L. et al. (2016). An integrated approach to correction for off-resonance effects and subject movement in diffusion MR imaging. *NeuroImage*, 125, 1063-1078.
- [11] Andersson, J. L. et al. (2016). Incorporating outlier detection and replacement into a non-parametric framework for movement and distortion correction of diffusion MR images. *NeuroImage*, 141, 556-572.
- [12] Veraart, J. et al. (2013). Weighted linear least squares estimation of diffusion MRI parameters: strengths, limitations, and pitfalls. *NeuroImage*, 81, 335-346.
- [13] Lauzon, C. B. et al. (2013). Simultaneous analysis and quality assurance for diffusion tensor imaging. *PloS one*, 8(4).
- [14] Smith, S. M. (2002). Fast robust automated brain extraction. *Human brain mapping*, 17(3), 143-155.
- [15] Bassier, P. J. et al. (1994). MR diffusion tensor spectroscopy and imaging. *Biophysical journal*, 66(1), 259-267.
- [16] Westin, C. F. (1997). Geometrical diffusion measures for MRI from tensor basis analysis. *Proc. ISMRM'97*.
- [17] Mori, S. et al. (2005). MRI atlas of human white matter. Elsevier.
- [18] Wakana, S. et al. (2007). Reproducibility of quantitative tractography methods applied to cerebral white matter. *NeuroImage*, 36(3), 630-644.
- [19] Hua, K. et al. (2008). Tract probability maps in stereotaxic spaces: analyses of white matter anatomy and tract-specific quantification. *NeuroImage*, 39(1), 336-347.
- [20] Avants, B. B. et al. (2008). Symmetric diffeomorphic image registration with cross-correlation: evaluating automated labeling of elderly and neurodegenerative brain. *Medical image analysis*, 12(1), 26-41.
- [21] Jeurissen, B. et al. (2014). Automated correction of improperly rotated diffusion gradient orientations in diffusion weighted MRI. *Medical image analysis*, 18(7), 953-962.

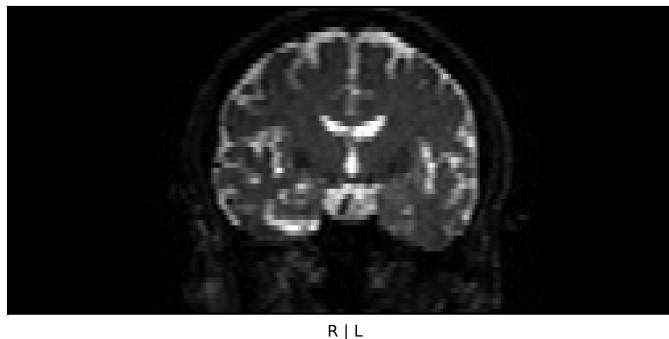
PE Direction

1

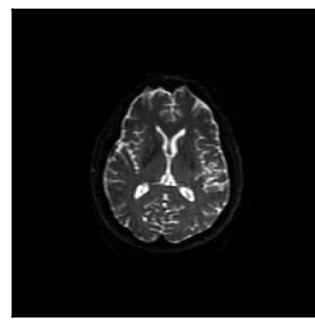
Sagittal



Coronal



Axial

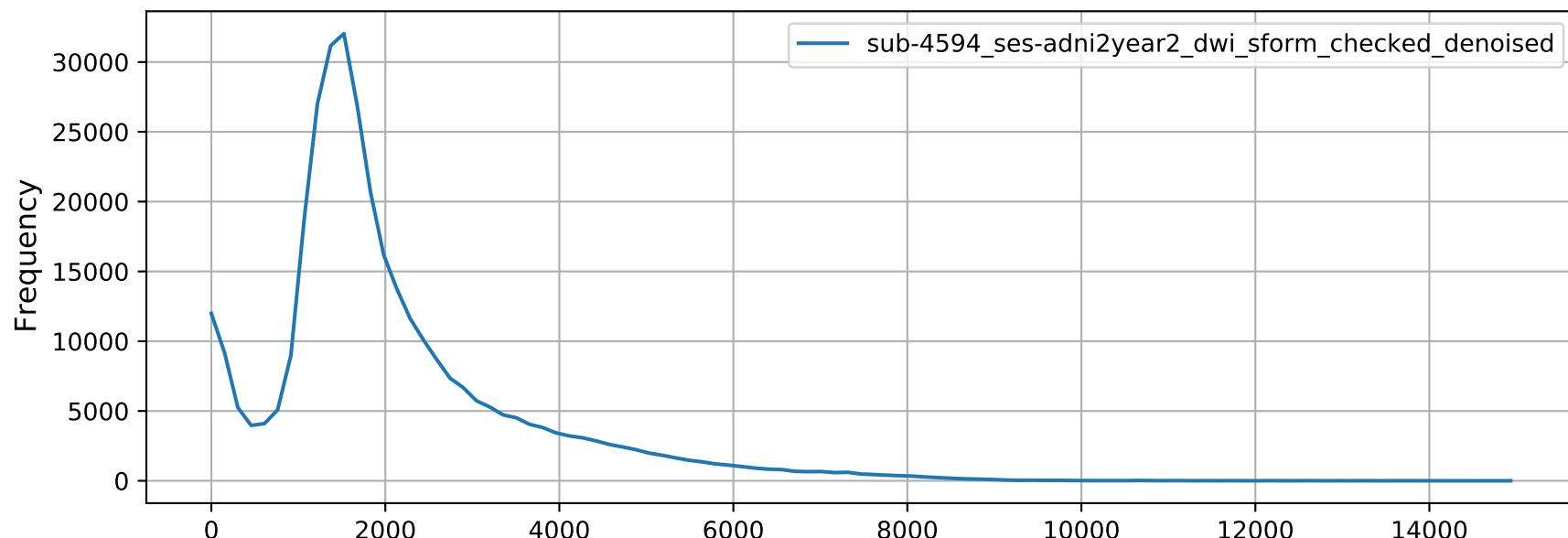


1) sub-4594_ses-adni2year2_dwi_sform_checked (To A)

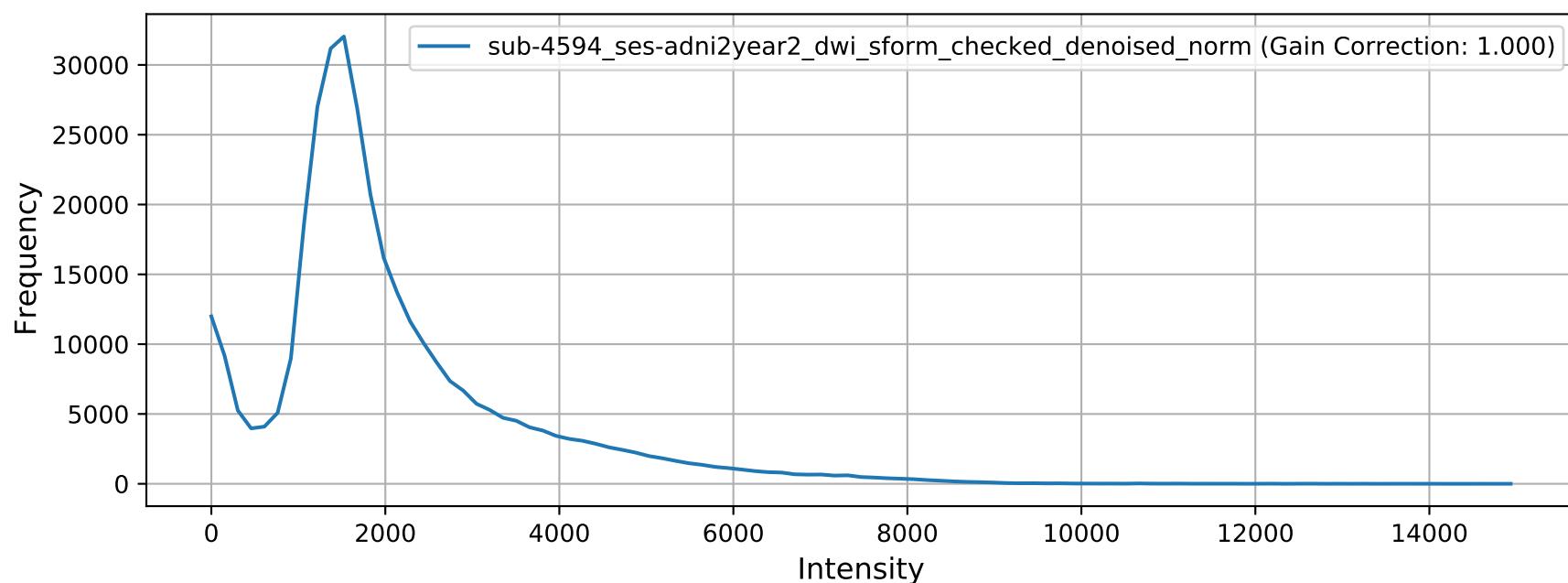
The supplied phase encoding direction for the input images was "j". Thus, the best interpreted anatomical axes for these images based on their affines are described to the left. Please ensure that these axes (direction agnostic) are interpreted to be the same and are visually distorted above for all images. It is an underlying assumption of this pipeline that all images be phase encoded on the same axis with varying direction as appropriate.

Prenormalization:
Average b0 Intensity Distributions By Scan Within Approximate Masks

Before

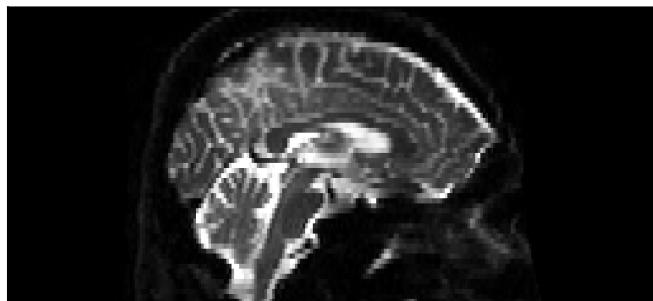


After

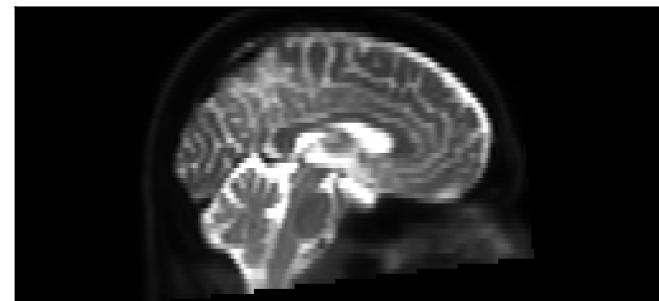


Synb0-DisCo
T1

Distorted b0



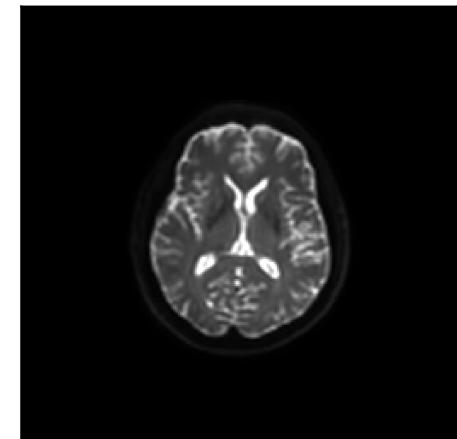
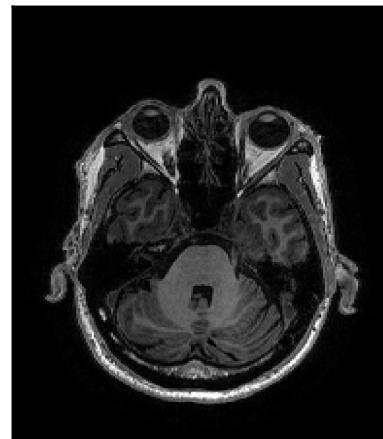
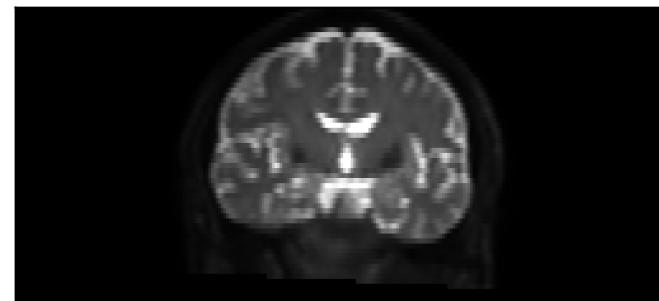
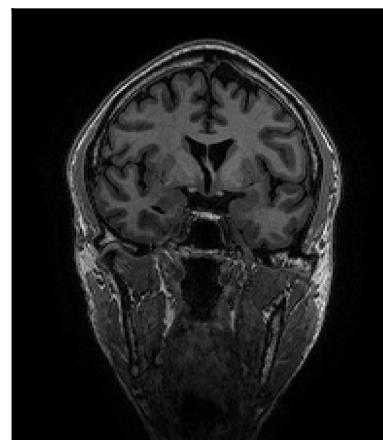
Synthetic b0



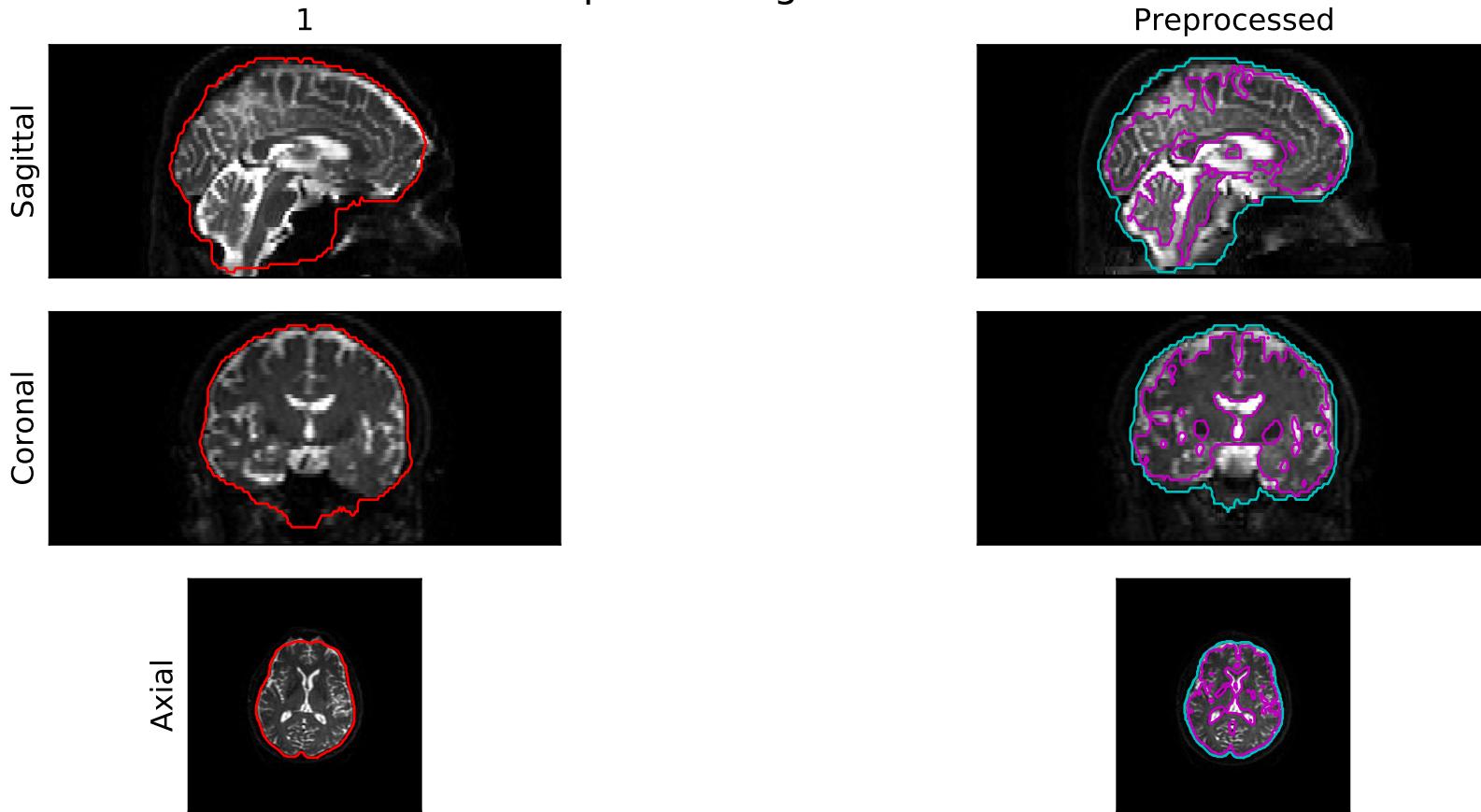
Sagittal

Coronal

Axial



Preprocessing and Masks

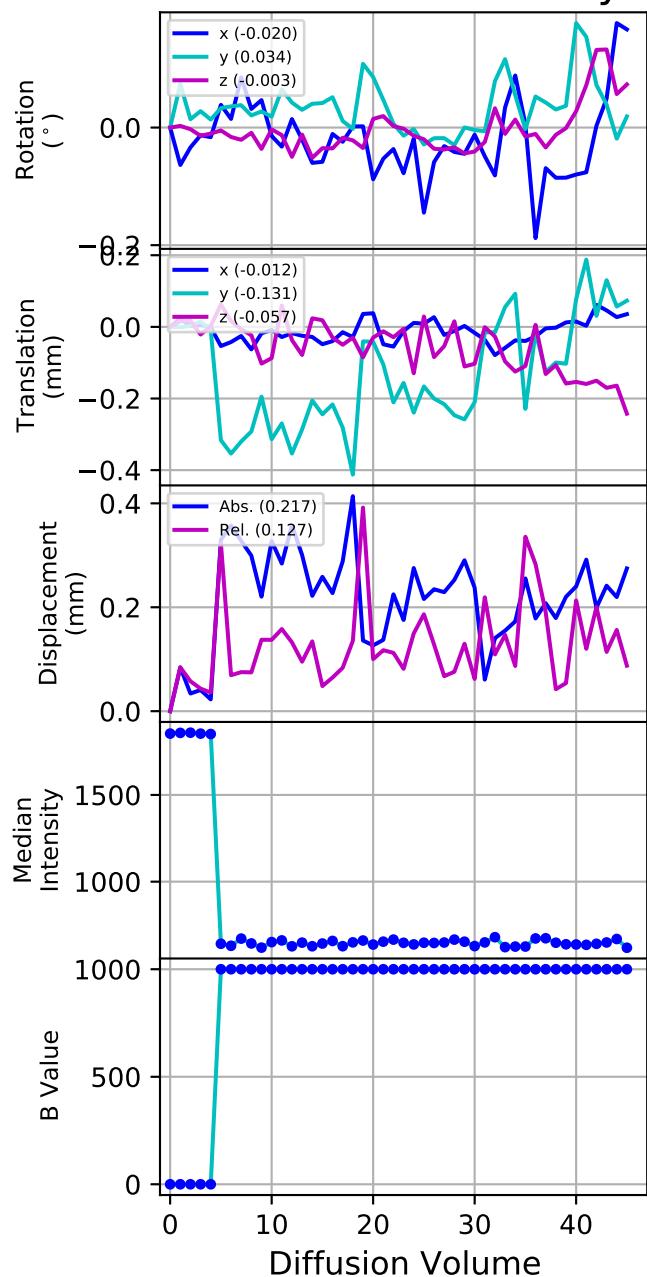


- Eddy Mask
- Preprocessed Mask (0.79% Voxels Improbable)
- χ^2 Mask

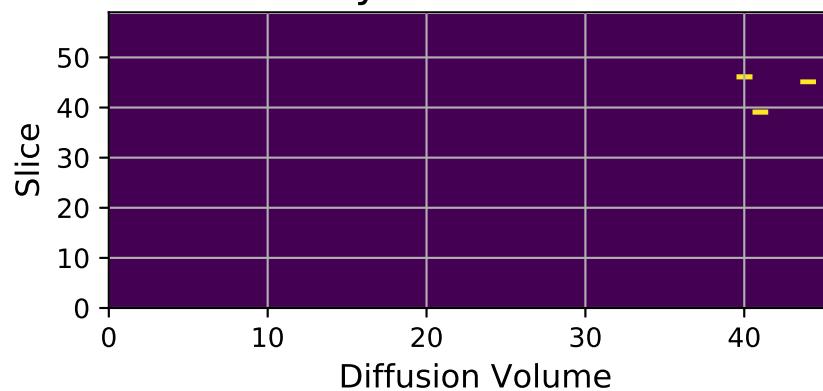
1) sub-4594_ses-adni2year2_dwi_sform_checked

- Eddy Mask: If `--eddy_mask` is "on" (default), this is calculated on the averaged raw b0s if `topup` is not run and on the averaged topped-up b0s if it is. If `--eddy_mask` is "off", this mask is not applied and eddy is performed on the entire volume. This mask need only be approximate and is used for motion and eddy-current correction.
- Preprocessed Mask: This is calculated on the preprocessed averaged b0s. It is used for tensor visualization and other analyses (i.e. SNR and CNR calculations, gradient table checks, etc.) and is the basis for the chi-squared mask.
- Chi-Squared Mask: This is calculated from the preprocessed mask by subtracting the CSF and eroding the result. It is used to determine the voxels in which to perform the chi-squared analysis.

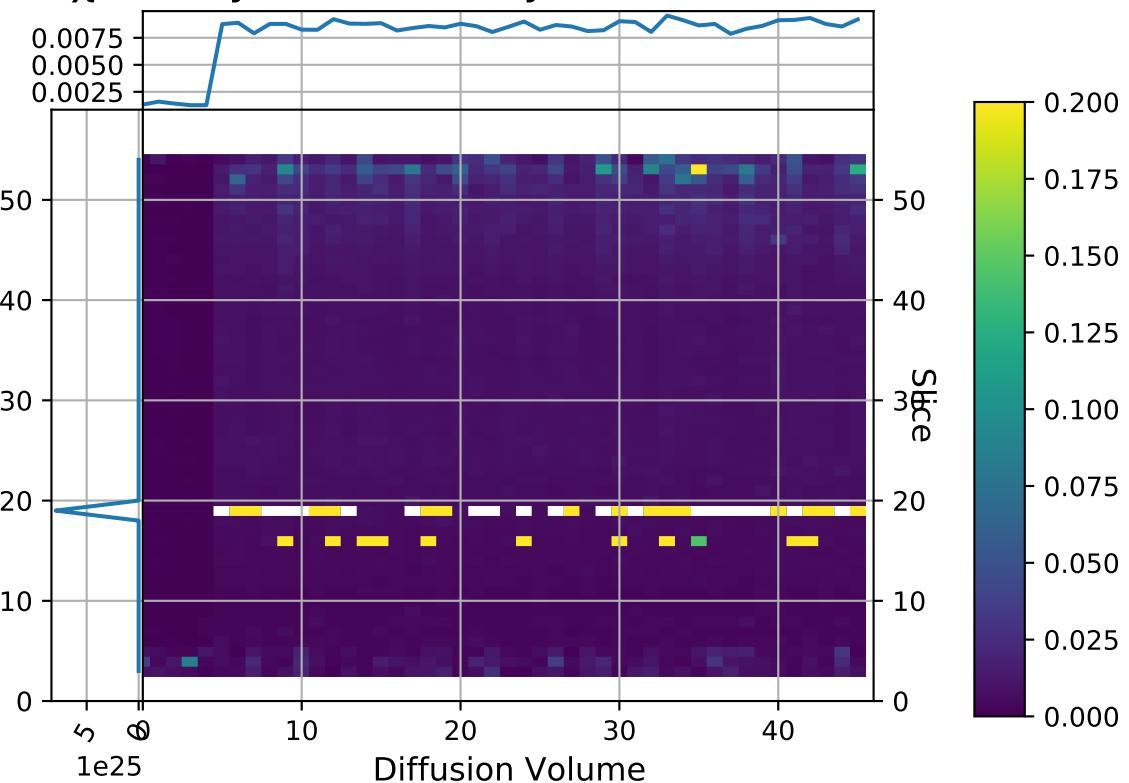
Motion and Intensity



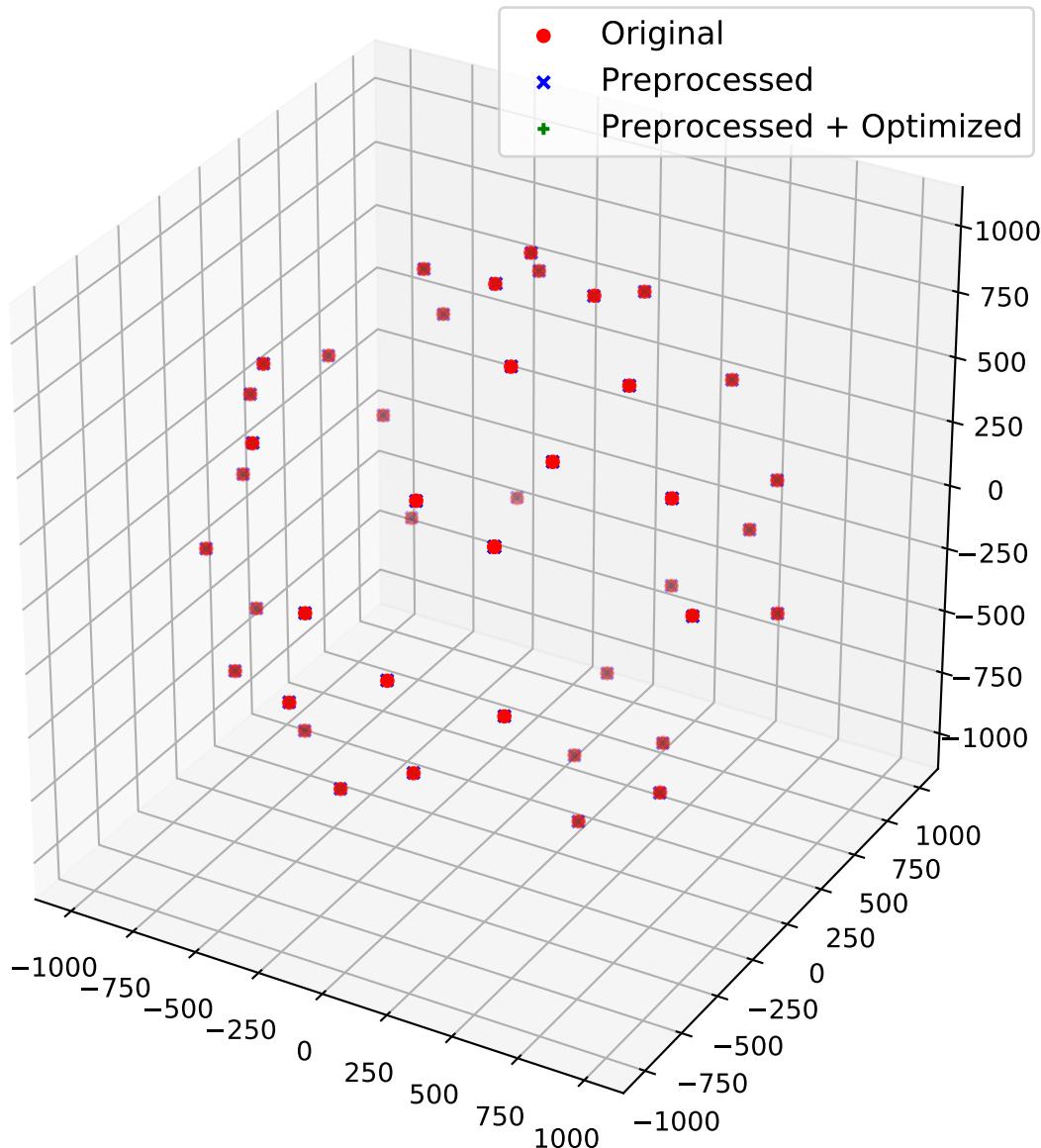
Eddy Outlier Slices



χ^2 Analysis After Eddy Outlier Correction



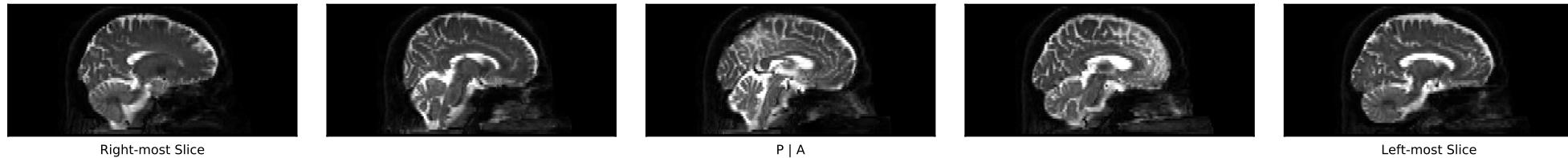
Gradient Check



- Original: Raw gradients (b-vectors scaled by b-value) given as input.
- Preprocessed: Gradients output and rotated by eddy. Often slightly different than the original gradients.
- Preprocessed + Optimized: Preprocessed gradients that have been sign and order permuted to produce the optimal tract length as determined by dwigradcheck in MRTrix3. Ideally identical to the preprocessed gradients. If not, this suggests an incorrect sign or axis permutation in the b-vectors. Tensor or vector glyph visualization in this PDF can help support this.

Preprocessed $b = 0.0$, 5 scan average, SNR = 23.490

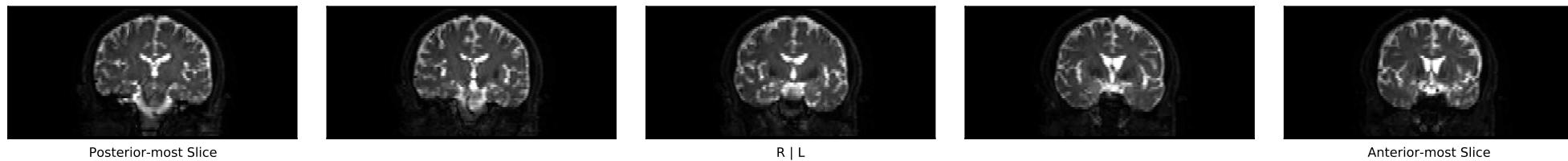
Sagittal



Right-most Slice

Left-most Slice

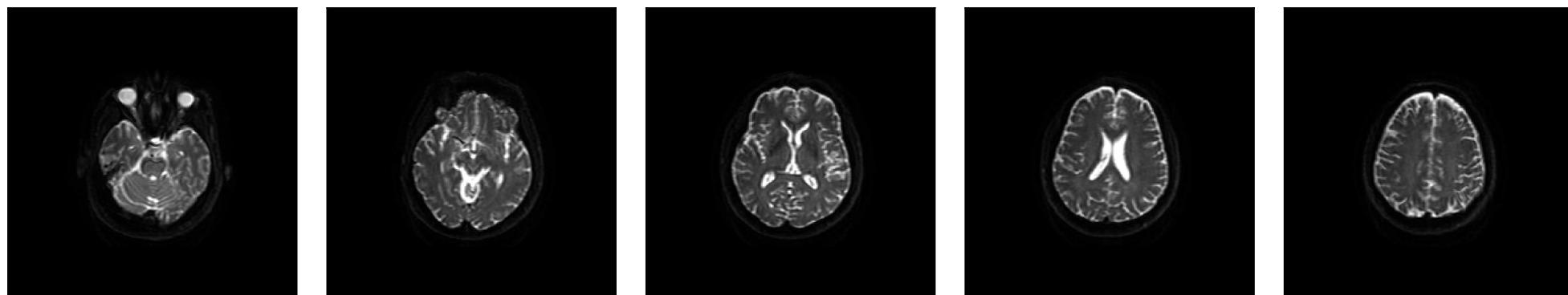
Coronal



Posterior-most Slice

Anterior-most Slice

Axial

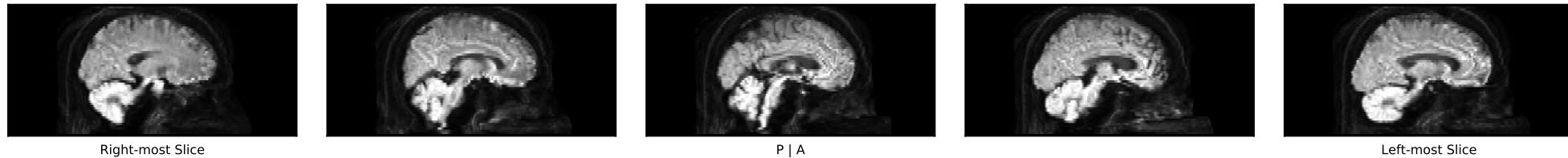


Inferior-most Slice

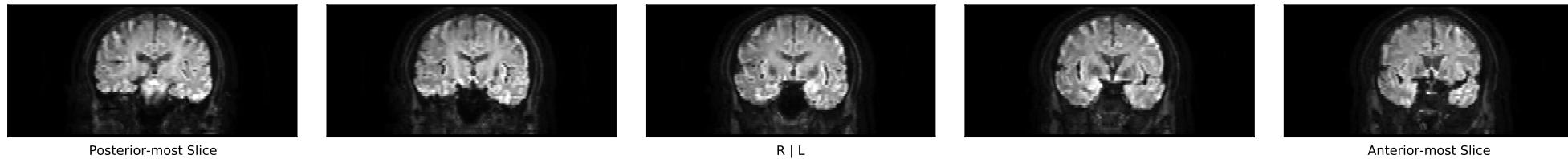
Superior-most Slice

Preprocessed $b = 1000.0$, 41 scan average, CNR = 1.254

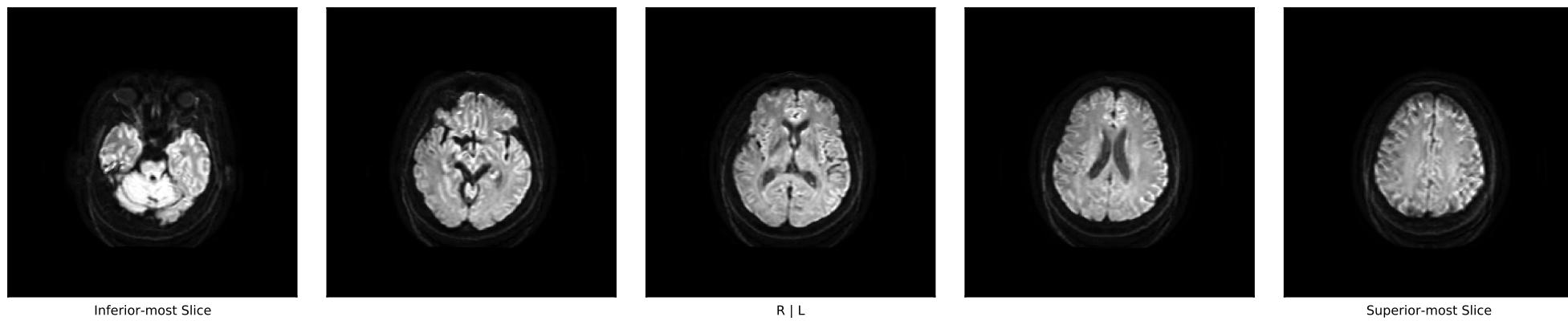
Sagittal



Coronal

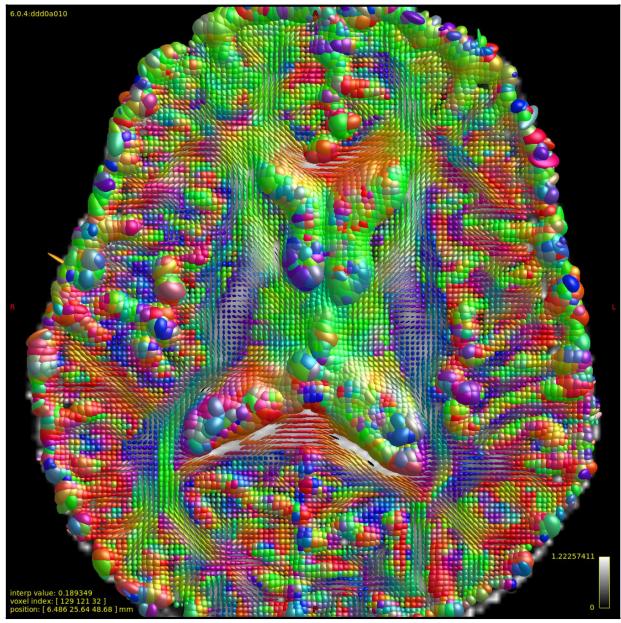
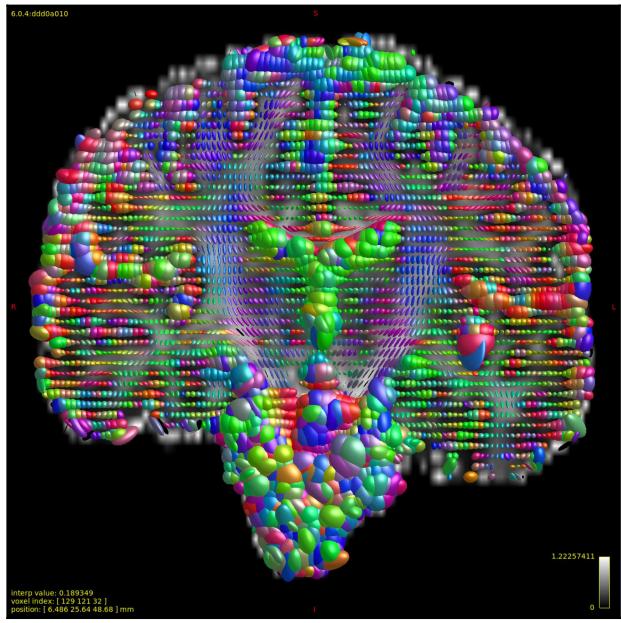
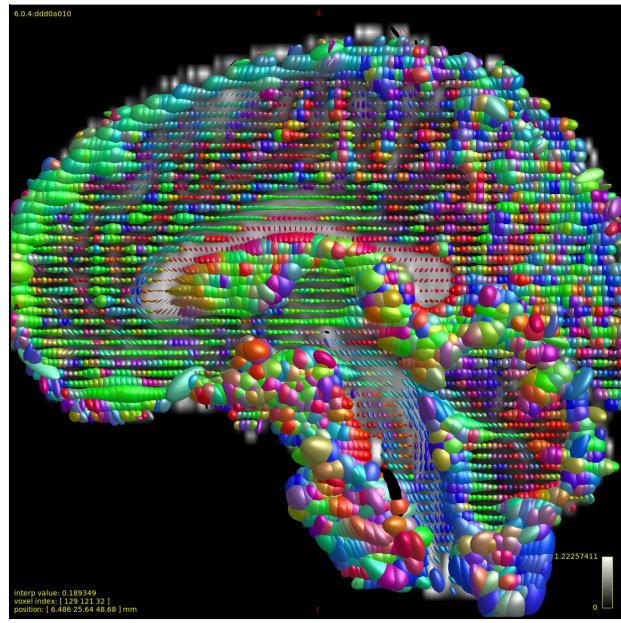


Axial

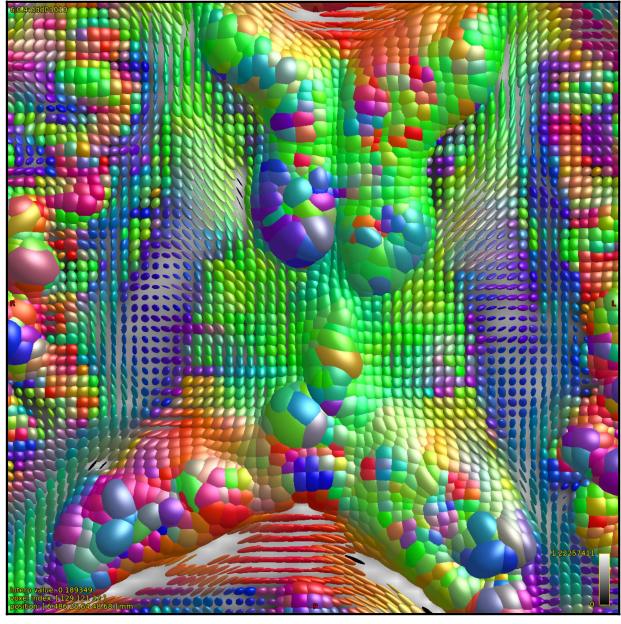
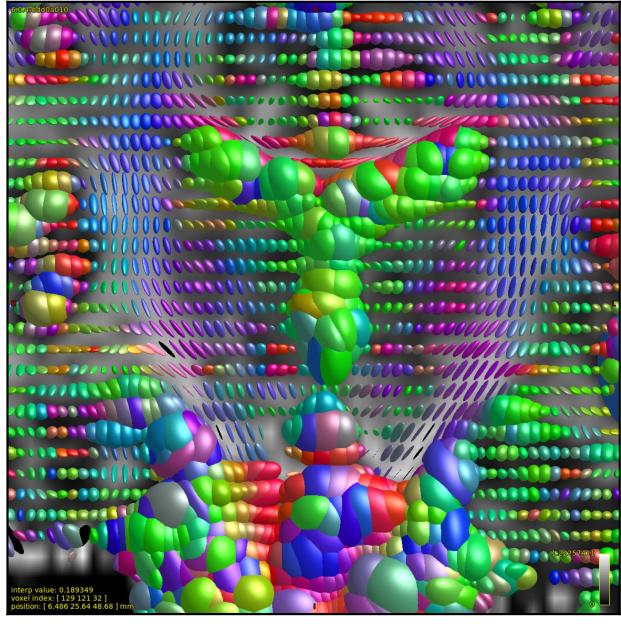
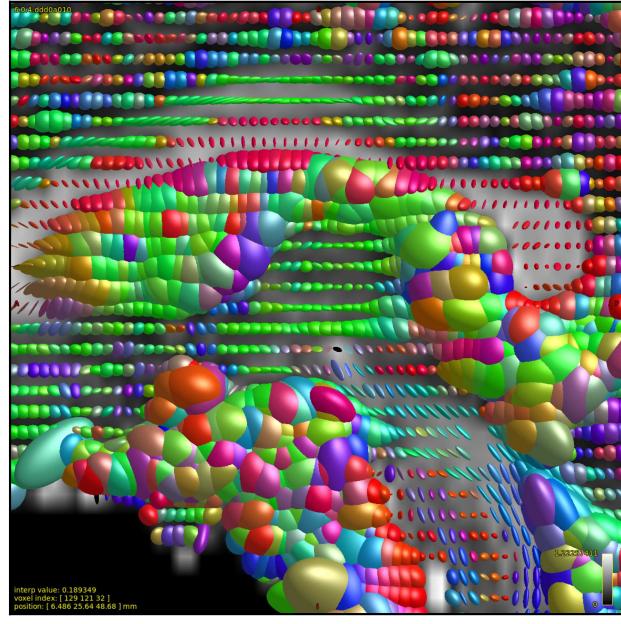


Tensors (Non-physiologic Eigenvalues Omitted)

160 mm FOV



80 mm FOV



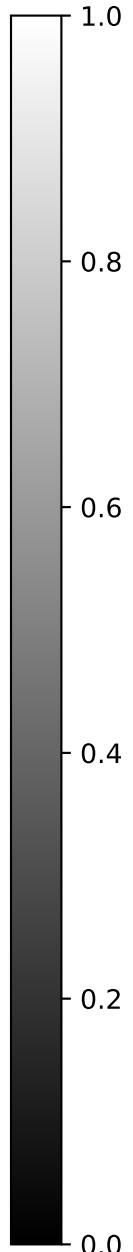
Sagittal

Coronal

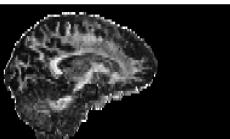
Axial

FA

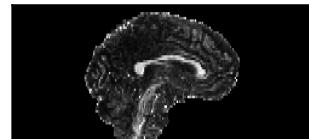
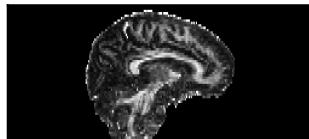
(White matter should be bright)



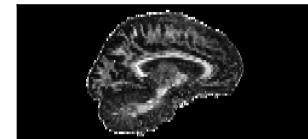
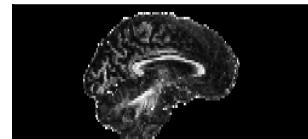
Sagittal



Right-most Slice

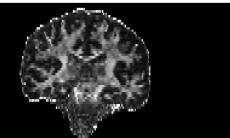


P | A

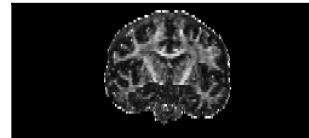
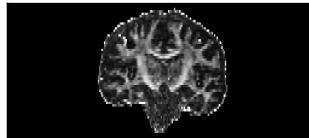


Left-most Slice

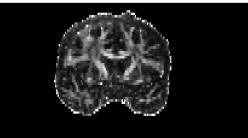
Coronal



Posterior-most Slice

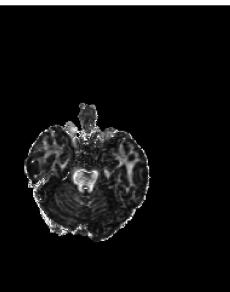


R | L

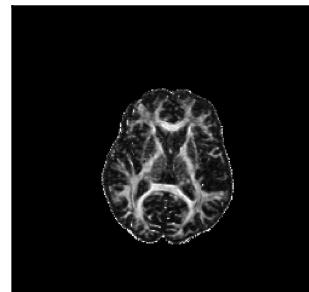
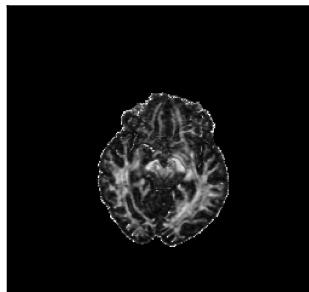


Anterior-most Slice

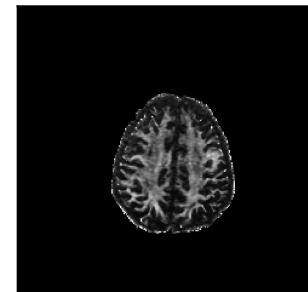
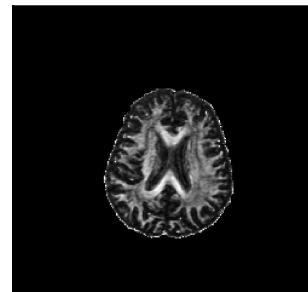
Axial



Inferior-most Slice

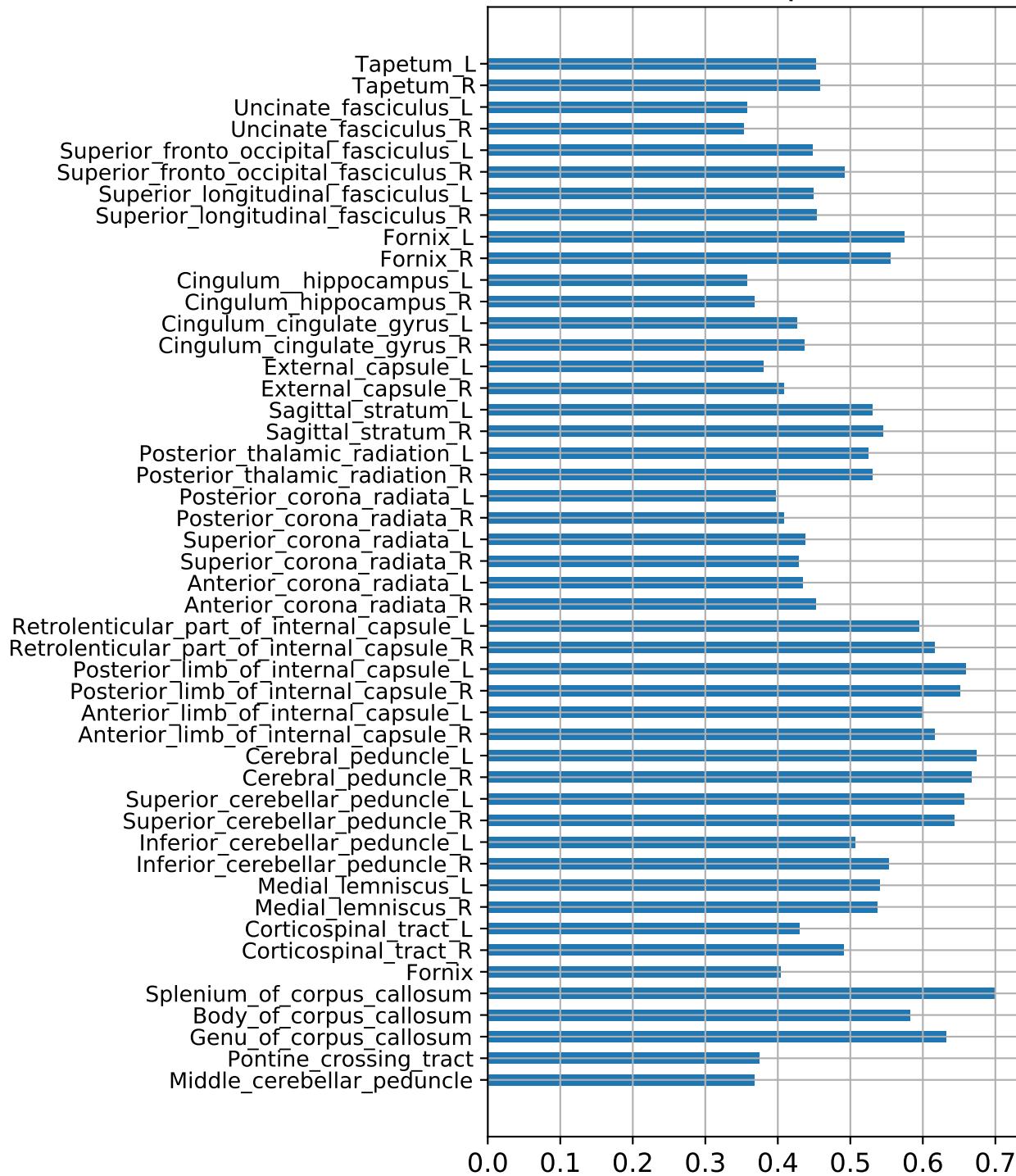


R | L



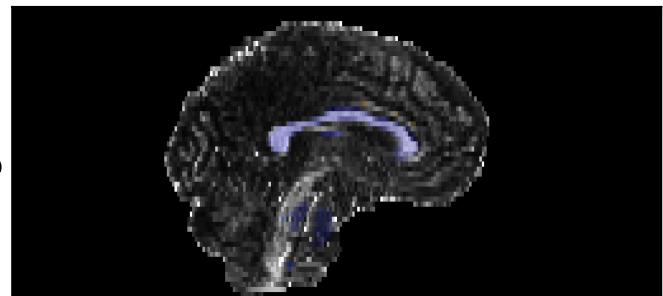
Superior-most Slice

Median FA per ROI

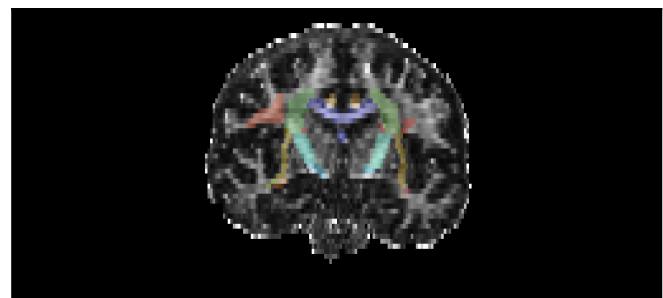


FA ROI Alignment

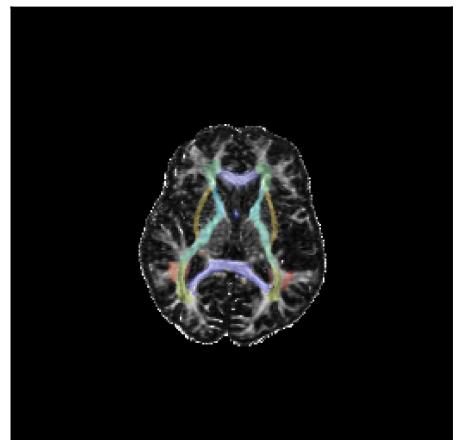
Sagittal



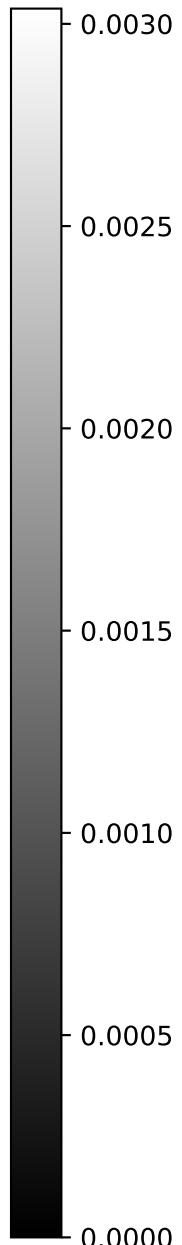
Coronal



Axial



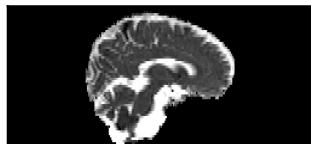
MD
(CSF should be bright)



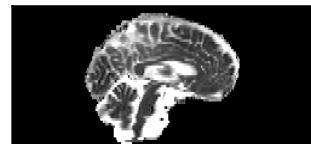
Sagittal



Right-most Slice

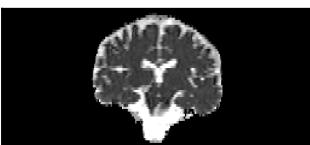


P | A

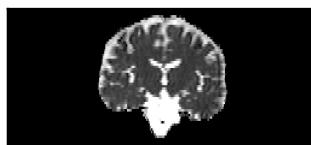


Left-most Slice

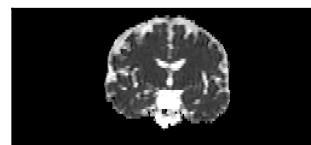
Coronal



Posterior-most Slice

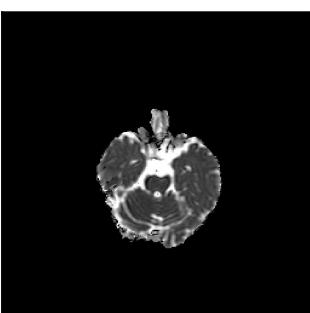


R | L

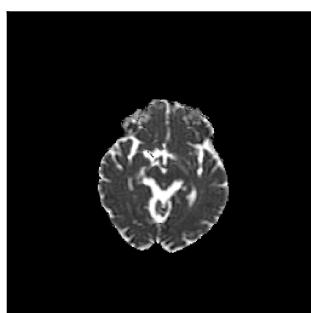


Anterior-most Slice

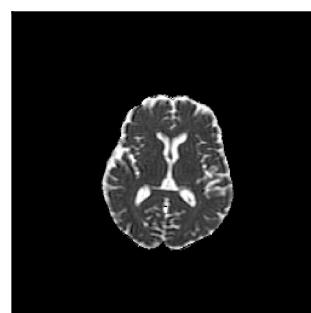
Axial



Inferior-most Slice



R | L



Superior-most Slice